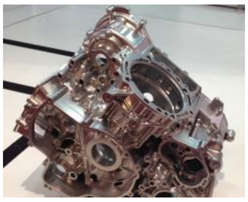
WORLD FOUNDRY ORGANIZATION

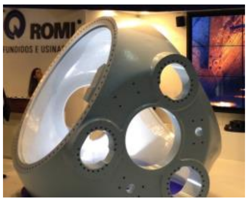
The reference point for the global metal casting industry

WFO GLOBAL FOUNDRY REPORT

2020

ACTUAL SITUATION OF THE WORLDWIDE CASTING INDUSTRY






October 2020

The World Foundry Organization

WFO GLOBAL FOUNDRY REPORT 2020

Actual situation of the worldwide casting industry

October 2020

Editorial and contents coordination

The World Foundry Organization Ltd.
Winton House, Lyonshall, Kington HR5 3JP United Kingdom
+ 44 1544 340332 andrew@thewfo.com

Acknowledgments

The World Foundry Organization is comprised of National foundry organisations or associations representing foundries, suppliers and academia from around the world.

This documentation has been collected and prepared by The World Foundry Organization with the information gathered by the next WFO National Representatives:

American Foundry Society
Association of Finnish Foundry Industry
Association of Foundrymen and Metallurgists of the Belarus Republic
Association of Hungarian Foundries
Association Technique de Fonderie
Assofond
Australian Foundry Institute
Czech Foundrymen Society
Egyptian Foundrymen Society
Foundry Institute of the Clausthal University of Technology
Foundry Institution of Chinese Mechanical Engineering Society
ICME – Institute of Cast Metals Engineers
Indonesian Foundry Industries Association - Growth Steel
Institute of Indian Foundrymen
Japan Foundry Engineering Society
Korea Foundry Society
National Foundry Technology Network
Norwegian Foundry Technical Association
Polish Foundrymen’s Association
Romanian Technical Foundry Association
Slovenian Foundrymen Society
Sociedad Mexicana de Fundidores
Swedish Foundry Association
Swiss Foundry Association
Tabira Foundry Institute
Tüdöksad – The Turkish Foundry Association

This documentation has also counted with the active cooperation of next organizations:

Cast Metals Federation
Fachverband Metalltechnische Industrie
Fundación Azterlan
Hungarian Mining and Metallurgical Society
RISE Swecast AB

Dear foundry colleagues,

It continues to give us great pleasure to introduce this new edition of the ***WFO Global Foundry Report***, which this year is the 5th time we have prepared it. The report has grown both in its content and reputation and has now become a valuable tool for this industry and helps to cement the WFO as the focal point and conduit for information for our industry.

Obviously 2020 has been a very strange and difficult year for our industry and the global manufacturing sector too, Covid 19 has placed many obstacles in the progression planning of both Countries, Industries and Populations and these will, we suspect, have long terms effects on life around the world. With this in mind the demand for accurate and informative details on the trends and changes in the industry becomes more important and we feel the WFO is uniquely placed to assist with this.

This report is aimed at providing this high value information about the global casting industry, including key areas of change within each country (output trends, market strengths and current issues, whether these are environmental, energy or customer focused…), providing updated information from most of the main players in the global casting scenario.

This 2020 edition presents also several exclusive interviews with globally recognized leaders from the metalcasting industry, helping so shaping some of the challenges for our sector.

This initiative is part of the new 2020 to 2023 WFO Strategic Plan that includes further activities to be set in place for the benefit of its members and the support to the global foundry industry. It has been a disappointing year with the need to cancel both the World Foundry Congress and World Foundry Summit, but please be assured these are ready and waiting to be held as soon as the global restrictions make it possible, good luck and stay safe.

Yours sincerely,

Umur Denizci

President of the WFO
Owner at Denizciler Dokumculuk iron foundry

Eur Ing Andrew Turner

General Secretary of the WFO

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GLOBAL FOUNDRY PERSPECTIVES

The World Foundry Organization is an extraordinary working frame to interact within an international network that represents companies, technicians, stakeholders and organizations linked to the foundry technology all over the world. This includes the exchange of updated information on the status of the foundry industry from each member country, information available every year through the Global Foundry Report.

In addition to this, next you can also access some exclusive interviews with innovative companies and industry leaders in the metalcasting sector, which help visualizing some of the challenges for this industry.

Automotive disruption and its effects in Foundry

Interview with…

Paul Eichenberg

Managing Director
PAUL EICHENBERG STRATEGIC CONSULTING
United States

The actual coronavirus pandemic has supposed a big disruption also in Automotive industry, with actual drops in the demand and expected changes in the market shares. In your opinion, could this new scenario impact somehow the roadmap and milestones for the electric vehicle revolution?

COVID-19 is impacting the adoption of EV in a significant manner. With dozens of companies expected to file for bankruptcy this summer due to the shutdowns, I predict that only the biggest and/or most prepared businesses are going to survive the new reality imposed by the pandemic. Their success will have already been set in motion long before the shutdowns hit; essentially, I think the competition for future stakes in the EV landscape will be thinned considerably.

For more insight into this topic from a different angle, I recommend reading Peter Murphy's article entitled “Governments Tie Automotive Stimulus Packages To Clean Mobility.” As we move into this new era, businesses who evolve into the electric landscape will be increasingly rewarded. There really is no turning back to the pre-COVID reality.

There is a common concern in the foundry industry about the future of its supply chain, especially in sectors like Automotive where this is complex and not so resilient. Which can be the new drivers for its evolution or transformation in the post Covid19 era?

COVID-19 and technical disruption is transforming the automotive industry. The evolution is focused heavily on electrified-autonomous systems. Examples include:

- Last-mile commercial delivery vehicle demand is expected to grow due to COVID-19 induced e-commerce and touchless autonomous drones and rovers.

- Demand for Robotaxi technology likely rising as touchless personal mobility becomes a personal priority.

With all forecasts announcing drastic reductions of the castings consumed in e-cars, it is very likely that the rise of Electric Vehicles will disrupt the metalcasting industry. Which can be the most affected component markets and some of the opportunities in this redesign of the industry?

The products that will fade away are those that are tied solely to the internal combustion engine, such as engine blocks, cylinder heads, cam phasers, front covers, oil pan and pump housings – not to mention components like transmission housings and pump housings. This is, on average, about $650 of content per vehicle; in a pre-COVID-19 world, we’re talking about a $60 billion market.

As far as new opportunities are concerned, the motor/gear boxes of electric vehicles have similar castings to ICEs, but the per-vehicle content is significant lower. In addition, power electronics systems, inverters, converters, and on-board chargers will all still require metal castings. This currently represents $125-150 in vehicle content.

There could be additional opportunities for metal castings around the EV skateboard and battery pack, but these opportunities require significant engineering, market development, and consideration of competing technologies like stampings and injection molding.

The first logical approach of foundry managers can be a thorough review of their portfolio in comparison with the new buyer requirements for e-cars. How do you think they could complement this necessary aspect with a more complex business model review to thrive and survive in the new scenario?

There many items for foundries to consider as they approach this disruption. The first thing everyone should do is recognize and accept that there will be a $40+ billion decline in automotive and that this decline will have a significant impact across the entire industry. The available capacity will need to go somewhere. As automotive companies look to diversify for survival, non-automotive applications will face increasing competitive intensity and unprecedented margin pressure.

As far as automotive suppliers, I suggest the following actions as they reconsider their strategic approach moving forward.:

- Review the overall portfolio mix to identify reliance on the internal on internal combustion engine to clarify the challenge.
- Assess the existing processes, products and competencies that can be leveraged for new opportunities.
- Identify the diversification and the transformational opportunities.
- Designate priorities based on available capital, resources and risk tolerance.

Automotive suppliers concerned by the impact of this disruption in their businesses have already started their own transformation. Which are the strategic options these companies are adopting that can serve as an example and show possible roadmaps to the foundry industry?

If we study the automotive industry – particularly larger, more aggressive companies – we see four basic strategies being deployed. They include:

Divestiture, in which a group removes assets from its business portfolio. Divestitures can take several forms, such as sell-offs, spin-offs, or equity carve-out. Delphi, Continental, and GKN are high profile examples of this;

Business transformation, in which a change management strategy to closely align people, process and technology initiatives with a new strategic vision is employed (examples include the BWA acquisition of Delphi, ZF and TRW);

Diversification, in which a company enters a new segment or industry in which they don't already operate. Expansion of an existing product line is an example of diversification;

Consolidation, or the merging of two or more organizations. The primary goals are to create financial synergy, a competitive edge, and leverage in shrinking markets. Current examples include American Axle and Tenneco.

Paul Eichenberg is the founder and managing director of a strategic consulting firm dedicated to helping automotive businesses navigate radical change. Prior to launching his own firm, Paul accumulated 20 years of hands-on experience as a strategic leader for Fortune500 companies in Asia, Europe and the US. He spearheaded Magna's pivot towards optimization of internal combustion engine, electric vehicles, and hybrid technologies.

Innovation as a driver for foundry companies

Interview with...

Kazutoshi Kimura

President
KIMURA FOUNDRY Co., LTD.
Japan

Kimura Foundry Group is well known worldwide for its leadership in innovation and commitment to research and development in materials, processes and technology. Which are the keys for your Group's continuous generation of high added value to the product and development of new business models?

The key has been the effort to improve and innovate the technology of Full Mold Casting (FMC) Process which is the most important mission to Kimura Foundry.

Focusing this, we have overcome and will continuously try to overcome many challenges to apply the technology to the other fields. Sharing value and virtue with all the employees to tackle with every challenge and obstacle is what I engage myself every day.

Setting FMC as our business domain is also the key to enhance our activities.

3D Printing for molds and cores is a big and successful reality in the Kimura Group's activity. Which do you think are the next challenges for 3D Printing in foundry industry?

Kimura Foundry has developed Direct Molding Process (DMP) where we utilize sand 3D printers which normally are used for aluminum castings but we successfully apply for cast and steel iron.

The challenge we will face is how we apply this technology to larger castings instead of current small ones. Even apart from FMC or conventional wooden pattern process, developing a casting technology without molding is getting more critical.

In words of the International Federation of Robotics, the post-Covid19 economy will impulse the automation. Being also Japan the world biggest producer of robots, do you think that investment in Robotics and Automation will be increased as a driver in Asian foundries in the near future?

Kimura has already installed and utilizing robots in finishing process. This movement will become a rocket boost to casting industry not only in Asian region but worldwide.

As foundry business being categorized as so called "3D industry (Dangerous, Dirty, and Demeaning)", Kimura will continue to focus on introducing FA and AI to improve working environment and productivity.

One of the reactions of your company to the decline in production caused by 2008 crisis was an increase towards sectors such as machine tools, which supposed a successful strategy. Do you believe this new crisis can make Asian foundries look for diversification in new products or client markets?

Kimura Foundry has explored new industries such as machine tool sector and industrial component business around the time of the crisis in 2008. We have also developed DMP and reverse engineering technology applying from the existing casting related technology.

From now on, "market in" concept is getting more crucial as there is more concerns about social environment. EV or Pb-less idea is an example of them. How we reply to those demand with high quality at lower price is the key.

Kimura Foundry America was successfully established in Indiana, United States, in 2018, with the objective of becoming the 'world's number one clean foundry' and being this the first time for your company to offer a business outside Japan. How do you evaluate the present evolution and the future of this part of your business?

Kimura Foundry Co., Ltas launched its first oversea subsidiary in 2018, Kimura Foundry America Inc (KFA). KFA utilize DMP and focus on producing rapid proto castings.

The new foundry is slower than expected due to the COVID issue, but I am sure that the demand in US for those speedy castings are existing more than in Japan.

Especially, as foundry related companies get specialized in US, such as pattern manufacturers, molding companies, foundries or machining shops, our KFA which has all the capability as one stop service will be well acknowledged and accepted.

Kazutoshi Kimura was born in 1969, Shizuoka, Japan. Graduated from Nihon University and worked for several years in one of the major trading company in Japan, joined Kimura Foundry Co., Ltd. Since February 2011, acting as President of Kimura, and currently also as Director of Japan Foundry Society, Inc.

A new context for the foundry industry

Interview with…

Patricio Gil

CEO
MAPPSA
Mexico

Discussions around the necessity of a change in the supply chains have also been raised in our industry following the impact of the Covid19, with voices asking for shorter ones. Do you think this could be an opportunity for foundry producers like Mexico to become an alternative for some of these supplies?

I believe Mexico offers great opportunities for the foundry industry mainly to supply the North American market and mainly for these reasons:

- The opportunity to replace volume currently imported from Asia to reduce the supply chains.
- The opportunity to replace volume currently imported from China to USA which is affected by tariffs imposed by the US Government.
- Since Mexico is becoming an important manufacturing place and more manufacturing in moving from USA and Canada to Mexico there are new opportunities coming to México.
- Mexico has availability of labor at very competitive cost.

The forecasts warn auto sales in US to see a drop for 2020, with a new share in markets to be consolidated in response to this drop in demand. The evolution of E-mobility is also an impacting factor in the industry. In this context, how do you see the future for this big driver for metalcasting in America?

The automotive industry is the main consumer of metal castings so after the volume drop and the emerging of e-mobility we should review our product portfolio and our business model because the market is demanding more flexibility, reduction in delivery dates and more variety of grades of metals. We should be able to question our traditional methods of producing castings and adapt to the new ones. Additionally, the emerging of additive manufacturing is changing the market rules for prototyping and low production runs.

Foundry companies need now to be creative to take advantage of the changes in the new context, with many managers reporting they have been asked to think out-of-the-box when planning new strategies. Based in your wide experience, which can be some leadership keys for foundry management in this new road ahead?

It is very important to be near the customers and understand the new requirements. As I mentioned before the new trend is flexibility and rapid response time. We should see the evolution of manufacturing technology especially on predictive maintenance, process control and product development such as simulation tools.

One big challenge is to attract, develop and retain people we should be also willing to try new working ways of collaboration. The combination of talent between the foundries, the foundry suppliers and research center is a key factor to continue building competitive advantages.

It has been highlighted that those foundries working for different industries and segments have been more resilient in this actual pandemic crisis. Do you think diversification can be a must for the foundry industry in the future? Could this be more focused in bigger portfolios for different industries or in an increase in exportations to new geographic markets?

Yes. Diversification is always beneficial for the business cycles.

If we may combine different markets with different geographic regions is very good for the business. What is important also is to be aware of threats such as material replacement or obsolescence of the end products we are making parts to.

Foundries have also faced complicated restrictions regarding social distance and travelling, which led the way to the use of remote working tools for administration, sales, learning or networking. In which way do you think these tools have come to stay and to help digitalizing our industry?

Foundries as well as other industries are facing complicated times. These pandemic restrictions help us review our management processes and it is a great opportunity to review our business practices trying to be leaner and more efficient. I believe some of the new business practices such as virtual meetings, flexible working schedule, home office and less travel are here to stay. In some way the new business practices and the new generation of foundry technicians and executives is a new great combination to make the foundry industry more competitive.

How do you perceive the impact for the North American foundry industry with the new Free Trade Agreement signed between the USA, Canada and México (T-MEC)?

The new Free Trade Agreement will be beneficial especially on the automotive sector because it increases the limits of regional content for the vehicles so the OEM´s have an incentive to buy the castings regionally. Additionally, the commercial discussions and tariffs imposed between the USA and China makes more attractive to buy locally and reduce the import of castings from China.

Patricio Gil has more than 35 years of experience in the foundry industry. Former CEO of Blackhawk Foundry. Past President of the Ductile Iron Society, Past President of the Mexican Foundry Society and Past President of the American Foundry Society. Frequent speaker in foundry congresses around the world. Currently managing its own machining company.

Cooperation as a core value for our sector

Interview with…

Juan José Leceta

WFO Jozef Suchy Medal 2019 award-winning
Owner
J.J. LECETA & ASSOC., *España*

Mr. Leceta, you were recently awarded with the first Jozef Suchy Medal, a recognition of the WFO to the professionals that have had a significant contribution to this organization. After a long dedication to the WFO Executive and being also one of its Past Presidents, how did you live this moment?

It was very emotional to receive the Joseph Suchy Award at the beautiful city of Portoroz, Slovenia in 2019. I accepted this award on behalf of my dear preceding colleagues. Especially those members of the WFO with which I worked more closely and left us along the latest years such as George Booth (USA), Joseph Suchy (Poland), Robert Jordan (U.K.), Itsuo Ohnaka (Japan) and Leonid Koslov (Russia). WFO (founded as CIATF in 1926) is one of the most veteran Professional Associations on International level. It will soon reach the first century of existence. Of course, this does not happen by chance, but as a result of enthusiastic work during all these years of our predecessors.

Foundry is a mature industry with a long and rich past, which has seen several crises affecting its companies in its history. In your wide experience, which are the lessons from previous crises that you think can be also valuable for foundry managers now?

The statement "foundry is a mature industry" is something I have heard since I started sixty-three years ago. It is true that foundry is a long existence industry, and when we see cast components produced thousands of years ago in places like China and Mesopotamia, we can realize the important contribution of Foundry Industry and Foundrymen to the Worldwide Industrial Development. What has allowed the foundry industry to have such a long history and such a relevant contribution has been the constant spirit of innovation providing the right solutions to specific demands and even anticipating in creating the demand with new ideas, materials or processes. I have been able to witness and in a modest way participate in this spirit of innovation during the last 50/60 years.

In the industry as in life nothing is permanent, everything changes. Crisis arrives and also passes. The present one is not the first and will not be the last. Constant innovation, team building, everybody rowing in the same direction; Talking openly with customers, suppliers and partners with the aim to find solutions for common interests; Leadership, determination and quick reaction. Maintaining this attitude both in good times and in difficult situations could be my humble advice for Foundry Managers.

You have strong bonds with foundry markets not only in Europe, but also in Asia and America. In a crisis with a global big drop in demand and probable new share markets for all the foundry players, which do you think can be some keys for EU companies to compete with the rest of the producing regions?

Covid19 pandemic's consequences and big demand drop may change the way of doing business and purchasing strategies. In my opinion, close and transparent cooperation with customers in all respects; flexibility in adapting designs to new demands; quick reaction to schedule alterations; prompt deliveries; fruitful close communication, will be differential factors to which customers will give more value than ever before. Basically, doing your best to be the best alternative for your customers.

This is a technologically intensive industry, where innovation and new developments have a crucial role for its future. In your opinion, which can be some of the most relevant future developments or new technologies for advancing foundry industry?

The areas I foresee more innovations to come are in digitalisation of the full online manufacturing process to assure that the simulation and procedures established are achieved. Full company digitalization will be a must to be competitive. New processes like 3D moulding, added manufacturing and new ones that will arrive will request more multidisciplinary teams working together, being in permanent contact with Technical Centers, Universities and the World Foundry Community. Close, open and constant communication with partners and customers, and as much as possible inhouse R+D+I are necessary requirements for keeping our companies sustainable and projecting to the future, and this is valid for any foundry size. A decided bet for investment in R+D+I is essential, either in house or in collaboration with technological centers.

Participating at the WFO and its Member Associations in each country is a good way to maintain the company technological antenna and will help companies to be actors of their future and not merely spectators.

Cooperation is being remarked as one of the keys for the industrial recovery. Being global collaboration one of the core values of the WFO, which do you think can be the renewed role from a global body like the World Foundry Organization in the post-Covid19 era?

When I was in England for training in the middle of the last century, I discovered, among many other good institutions, the existence of all kinds of associations such as BCIRA (British Cast Iron Research Association), SCRATA (British Steel Castings Research & Trade Association, IBF (Institute of British Foundrymen). At these institutions I had the privilege to meet magnificent technicians and generous people who shared openly with me their knowledge, for what I will be always thankful. They were excellent and extremely useful to the foundry industry. After this experience I realized how useful these Associations are for the Foundry Industry and I decided that I would do my best to participate in them, what I have done at The Spanish Technical Association, CAEF (Committee of European Foundry Associations and WFO.

Now, due to Covid19 pandemic we are seeing the intensive interchange of information and co-operation among scientific institutions from all over the world. This cooperation will save many lives by reducing dramatically the time for the availability of a vaccine and useful treatments.

WFO will continue working on the encouragement, dynamization and coordination of technical information exchange among the global scientific & technical foundry community as it has been doing for the last 100 years.

Juan Jose Leceta started working in a foundry in 1957, moving in 1961 to a manufacturing and supplying company. After 12 years in UK he returned to work in several foundries assuming executive responsibilities. From 1992 and up to now he has developed an activity as a consultant working for companies in Europe, North Africa, North America, Asia and Middle East.

WORLD FOUNDRY INDUSTRY 2019-20

TOP FIVE WORLD PRODUCERS

Alphabetical order

FOUNDRY PRODUCTION IN CHINA

National representation in the WFO:
FOUNDRY INSTITUTION OF CHINESE MECHANICAL ENGINEERING SOCIETY
WWW.FOUNDRYNATIONS.COM

Investigation and Analysis on Chinese Foundry Industry under COVID-19 Pandemic65

Data from the National Bureau of Statistics, China shows a sharp decline of industrial growth rate during the first two months of 2020. Industrial enterprises above designated size have created only RMB 410.7 billion profit, with a year-on-year decrease of 38.3%. The revenue, operation cost, and profit of foundry industry (under the category "metal products") have declined by 25.2%, 25.3% and 49.0%, respectively, on a year-on-year basis.

In March, with the epidemic in China is gradually being under controlled, the stable recovery of production has brought a rebound of Chinese PMI after a sharp decline in February. The manufacturing PMI rose to 52.0%, non-manufacturing PMI 52.3%, and comprehensive PMI output index 53.0%, with 16.3%, 22.7% and 24.1% higher than previous month, respectively. By March 25, 96.6% of large and medium-sized foundry companies have resumed production according to national survey of purchasing executives. Export-oriented foundry enterprises, however, will be challenged much by global spread of COVID-19 and economic recession.

2020 will be a year with the greatest adversely affect for Chinese foundry industry since 2008. Based on current control measures and initial results in China, we believe the impact on the industry is temporary, and the market tends to be stable and has a good prospect in a long run. It is still too early to estimate the degree that the global market has been impacted because it is largely dependent upon overseas prevention and control situation. The pandemic causes tremendous impact in short term.

The future and further success in the battle with pandemic will enable the recovery of depressed investment and consumption, and releases huge economic potential and power in a gradual way. In addition, the expanding of continuous investment in key areas such as "new infrastructure" (5G, ultra-high voltage, intercity traffic, charging station, big data center, artificial intelligence, industrial network, etc.) by Chinese government will also bring great opportunities to foundry industry.

Total output of various types of castings in China

According to the data released by the China Foundry Association, the total output of castings in China in 2019 is 48.75 million tons, showing a slight year-on-year decline of 1.2% (Figure 1). The following data is based on the 2018 data and statistical analysis on the key enterprises' casting output in 2019 and the China Customs import and export data, with reference to the development trend of the downstream OEMs, aiming to reflect the changing trend of China's casting output in terms of materials and downstream sub-sectors.

Figure 1. *2003-2019 China's casting production (10,000 tons) and growth rate*

1. Output of castings in different downstream industries

It can be seen from Table 1 that automotive industry continually declined (4.1%), and the castings of machine tools showed a sharply year-on-year decline of 10%. Castings in areas of ship and internal combustion engine and agricultural machinery also declined for 5.4% and 5.5%, respectively. Engineering machinery and mining and metallurgy machinery are the two fields with the greatest growth, but only 3.5% and 2.2%, respectively.

Industries	Autom.	Internal combustion engine and agricultural machinery	Engineering machinery	Mining and metallurgy machinery	Pipes and fittings	Machine tools	Rail transp.	Power equip.	Ship	Others	Total
2014	1260	640	360	530	630	285	240	240	50	385	4620
2015	1250	635	315	480	695	260	210	240	45	430	4560
2016	1410	615	330	440	760	250	175	250	40	450	4720
2017	1510	620	380	450	770	260	200	240	40	470	4940
2018	1480	545	425	450	825	250	218	215	37	490	4935
2019	1420	515	440	460	830	225	220	210	30	520	4875
2019/18 Growth rate (%)	-4.1	-5.5	3.5	2.2	0.6	-10.0	0.9	-2.3	-5.4	6.1	-1.2

Table 1. *Output of castings in different industries in 2014-2019 (10,000 tons)*

2. Distribution of castings in different industries

The proportion of castings in different industries is shown in Figure 2. The castings for engineering machinery, cast pipes and fittings, mining and metallurgy machinery and rail transportation show an increase in the market; automotive castings still account for the largest proportion, but its proportion continually fall to 29.1% in 2019; the market share of agricultural machinery, machine tools and other industries has declined in different degree.

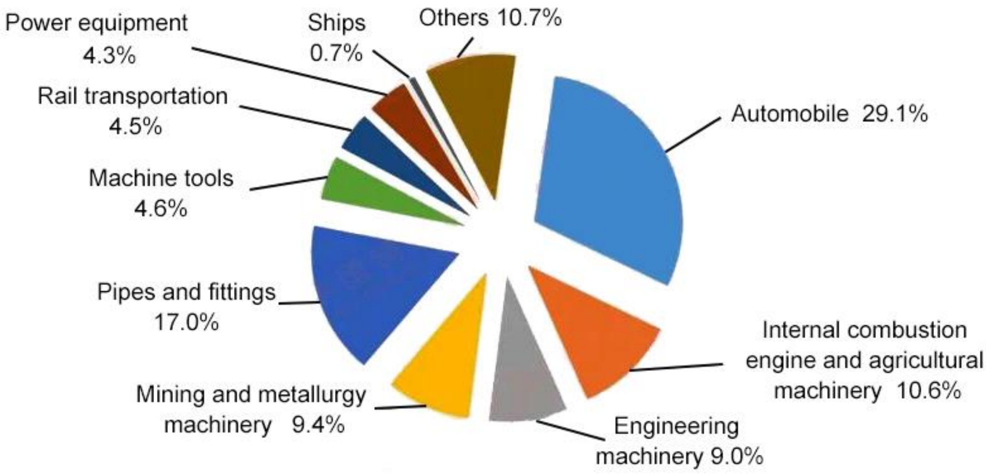

Figure 2. *Proportion of castings in different industries in 2019*

3. Output of castings of different materials

Due to the decline of automobile castings, the output of ductile cast iron was 13.95 million tons, decreased 1.4% compared to the 14.15 million tons in 2018 (Table 2), especially the Al (Mg) alloy, decreased 4.2% attributed to the sharp decline in passenger cars. Cast steel increased from 5.75 million tons to 5.9 million tons, an increase of 2.6% driven by rail transportation, mining and metallurgy, and engineering machinery.

Year	Grey iron	Ductile iron	Malleable iron	Steel	Al (Mg) alloy	Cu alloy	Others	Total
2014	2080	1240	60	550	585	75	30	4620
2015	2020	1260	60	510	610	75	25	4560
2016	2035	1320	60	510	690	80	25	4720
2017	2115	1375	60	555	730	80	25	4940
2018	2065	1415	60	575	715	80	25	4935
2019	2040	1395	60	590	685	80	25	4875
2019/2018 Growth rate (%)	-1.2	-1.4	-	2.6	-4.2	-	-	-1.2

Table 2. *Output of castings of different materials from 2014 to 2019 (10,000 tons)*

4. Proportion of different materials casting

In 2019, the output of cast steel products maintained growth, accounting for 12.1% (11.7% in 2018 and 11.3% in 2017) of the total production (Figure 3); aluminum (magnesium) alloy castings was slightly reduced to 14.1% (14.5% in 2018 and 14.8% in 2017); and the ductile iron castings accounts for 28.6%, almost keeps the same as that in 2018 (28.7%).

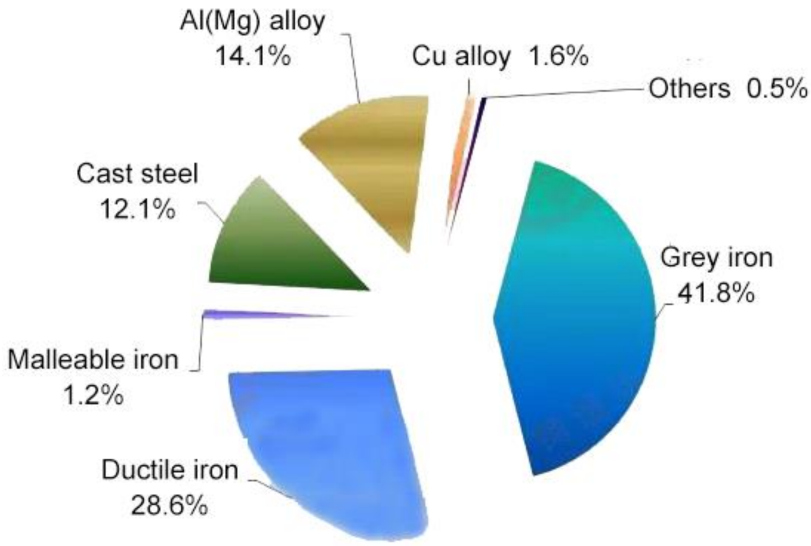

Figure 3. *Proportion of different materials casting in 2019*

FOUNDRY PRODUCTION IN GERMANY

National representation in the WFO:
CLAUSTHAL UNIVERSITY OF TECHNOLOGY
VEREIN DER FREUNDE UND FÖRDERER
DER GIEẞEREITECHNIK
WWW.TU-CLAUSTHAL.DE

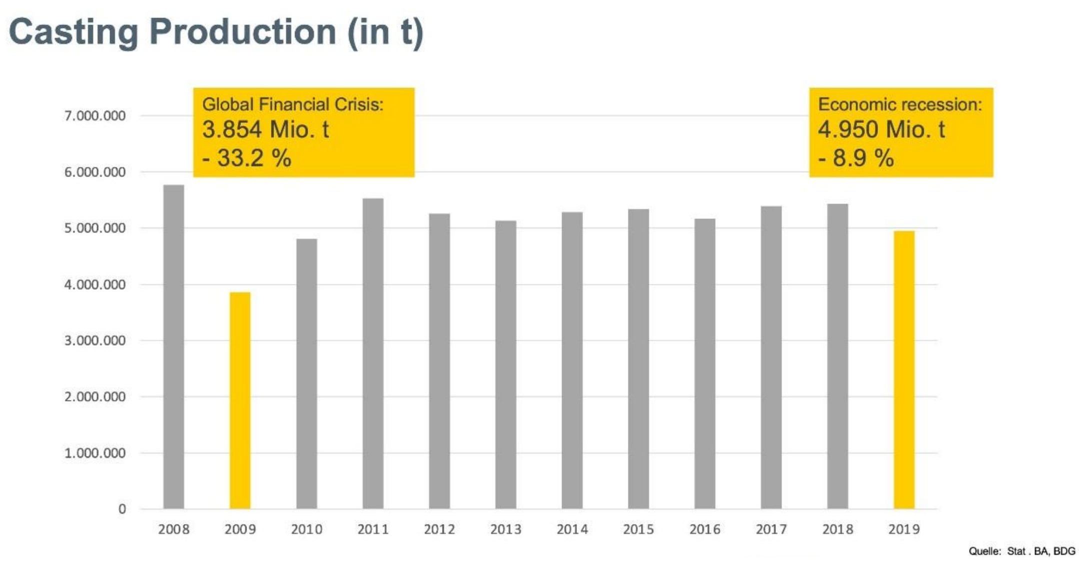

***Figure 1.** Casting Production*

Industry figures 2019 – WZ 24.5

	Production	Sales	Employees
Total	4.950 Mio. t - 8,9 %	12.429 Mrd. € - 8,5 %	75.200 - 4,6 %
Fe	3.805 Mio. t - 10,6 %	6.858 Mrd. € - 8,7 %	39.700 - 5,5 %
NF	1.146 Mio. t - 2,6 %	5.571 Mrd. € - 8,2 %	35.500 - 3,5 %

Quelle: Stat . BA, BDG, Beschäftigte: >50, Veränderungen im Vergleich zum Vorjahr, Fe = Eisen- und Stahlguss, NE = Nichteisen-Metallguss

***Figure 2.** Industry figures 2019*

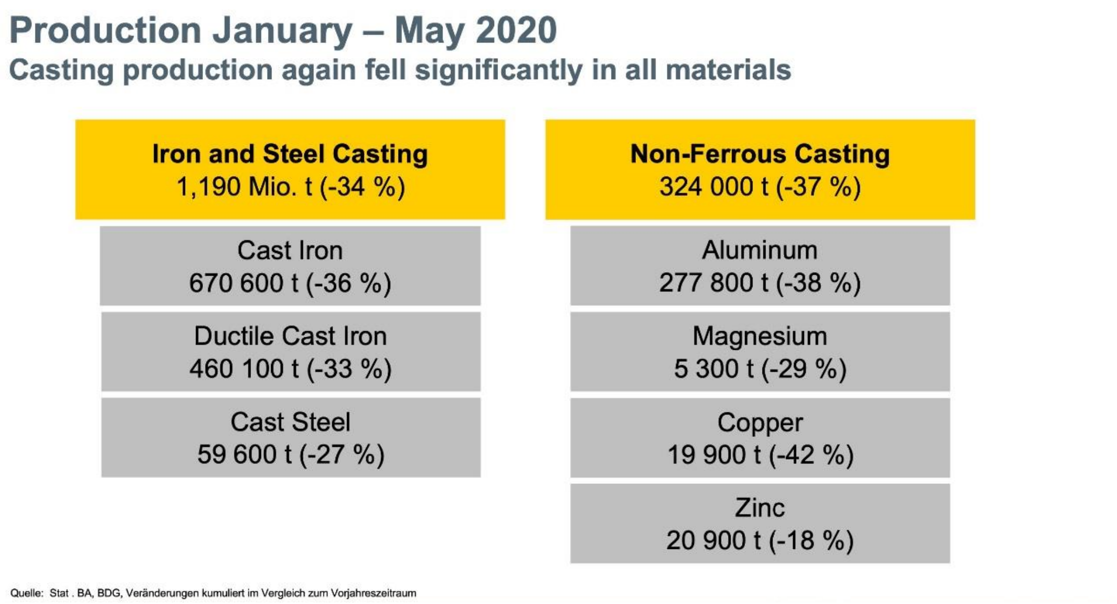

Figure 3. *Production January – May 2020*

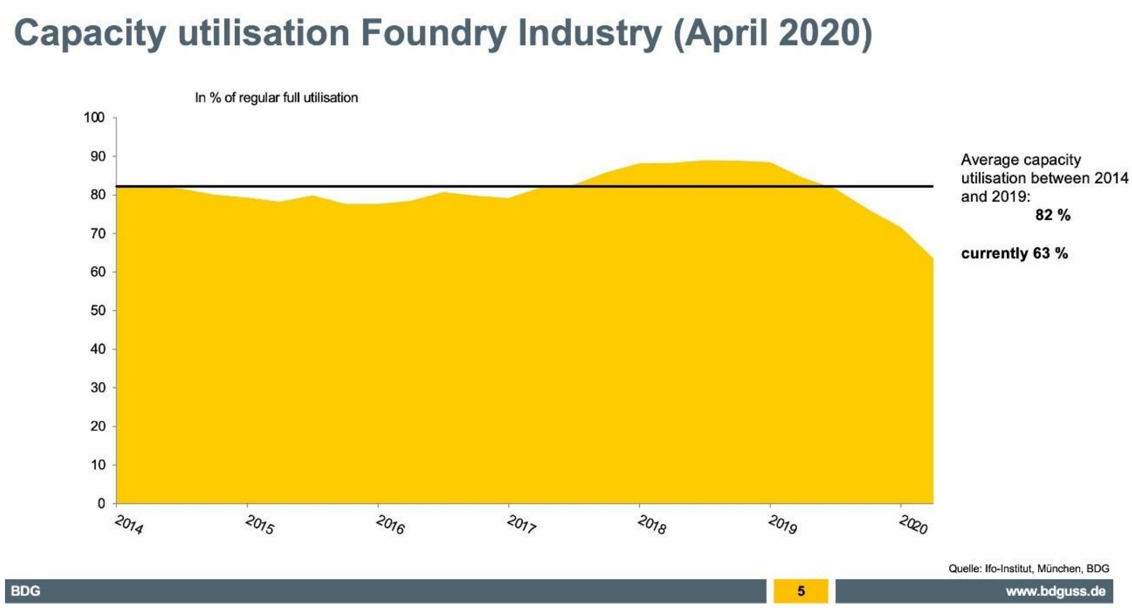

Figure 4. *Capacity utilisation Foundry Industry*

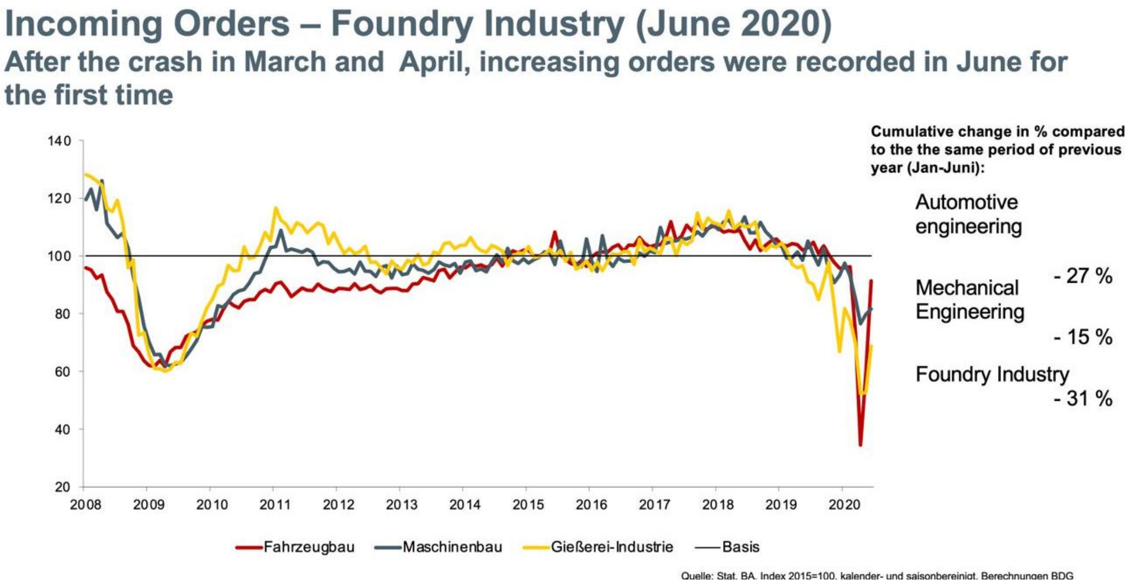

Figure 5. *Incoming Orders – Foundry Industry*

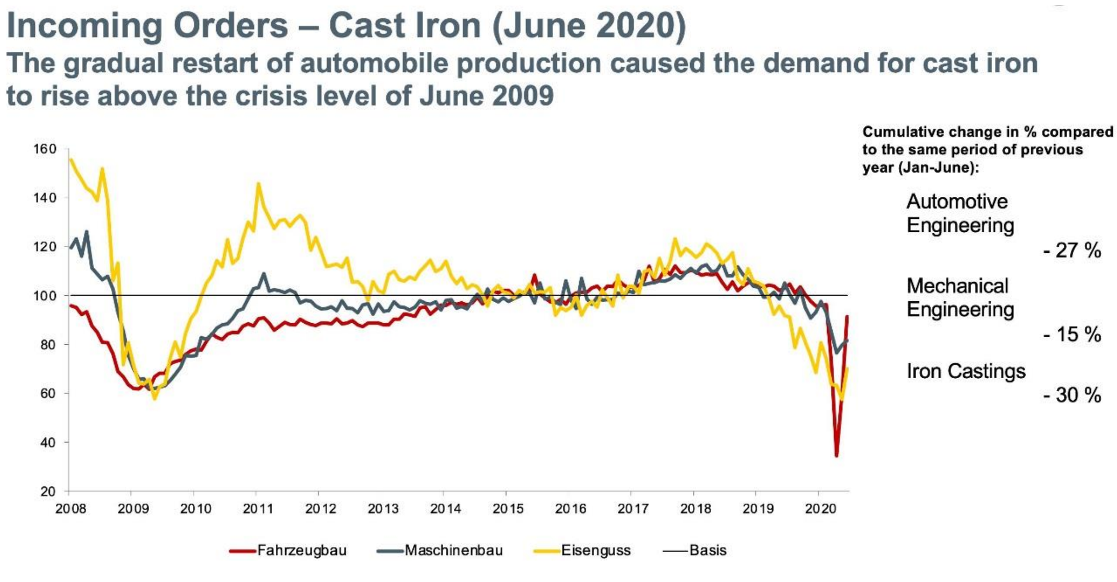

Figure 6. *Incoming Orders – Cast Iron*

Incoming Orders – Cast Steel (June 2020)

A lack of demand from abroad led to incoming orders again below the level of 2009

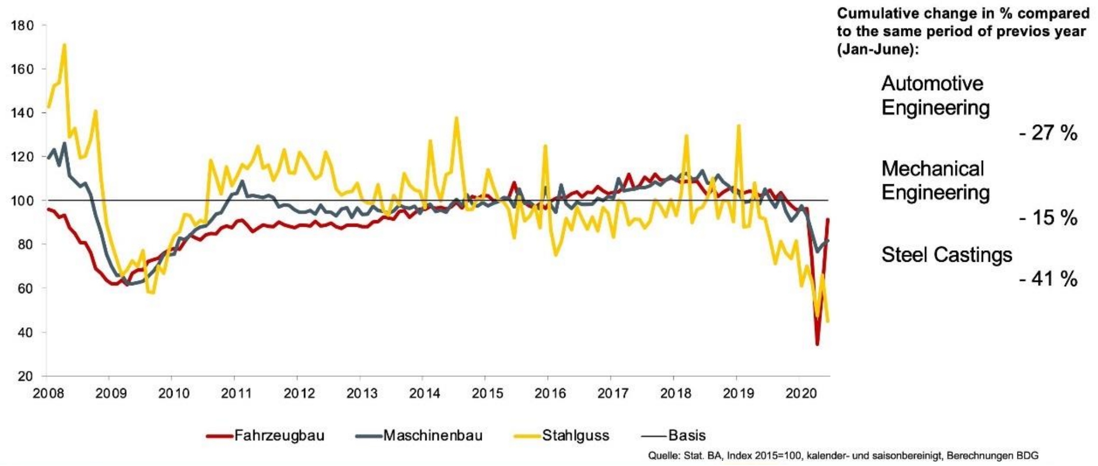

Figure 7. *Incoming Orders – Cast Steel*

Incoming Orders – Non-Ferrous Castings (June 2020)

After a slight increase in May, non-ferrous heavy metal foundries received less incoming orders again in June

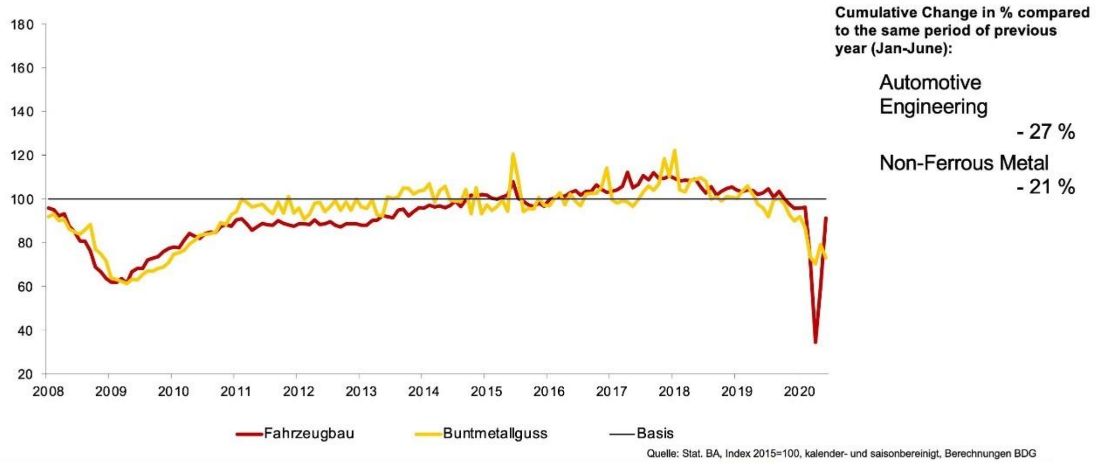

Figure 8. *Incoming Orders – Non-Ferrous Castings*

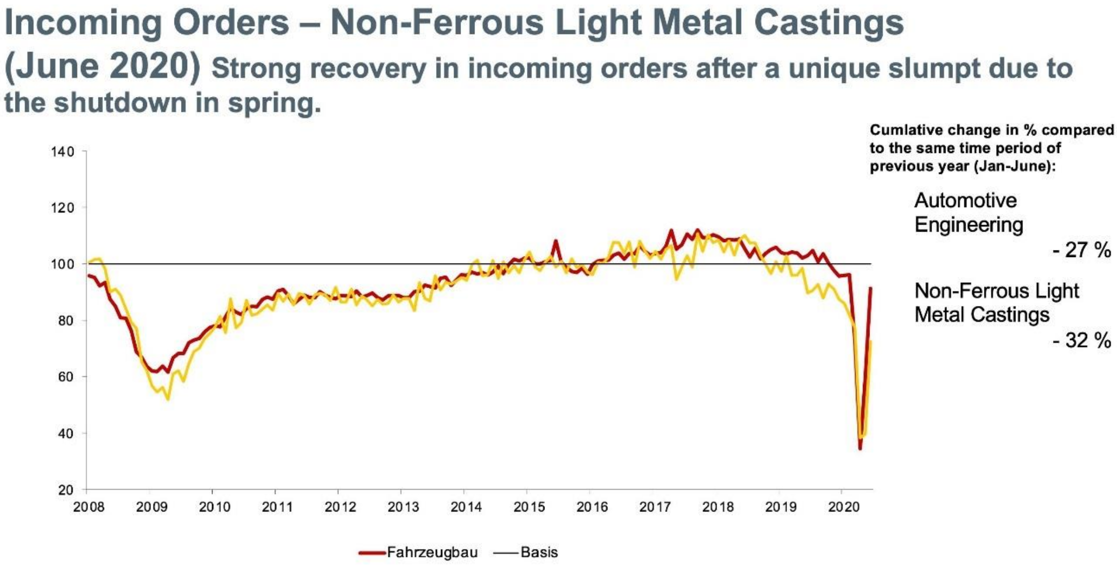

Figure 9. Incoming Orders – Non-Ferrous Light Metal Castings

Figure 10. Business situation

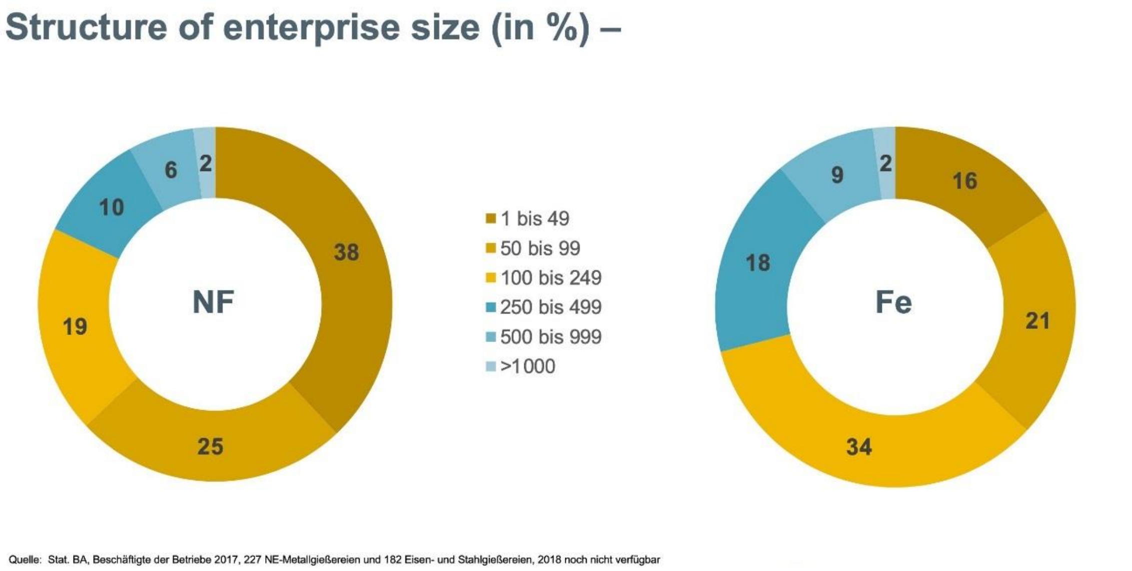

Figure 11. *Structure of enterprise size*

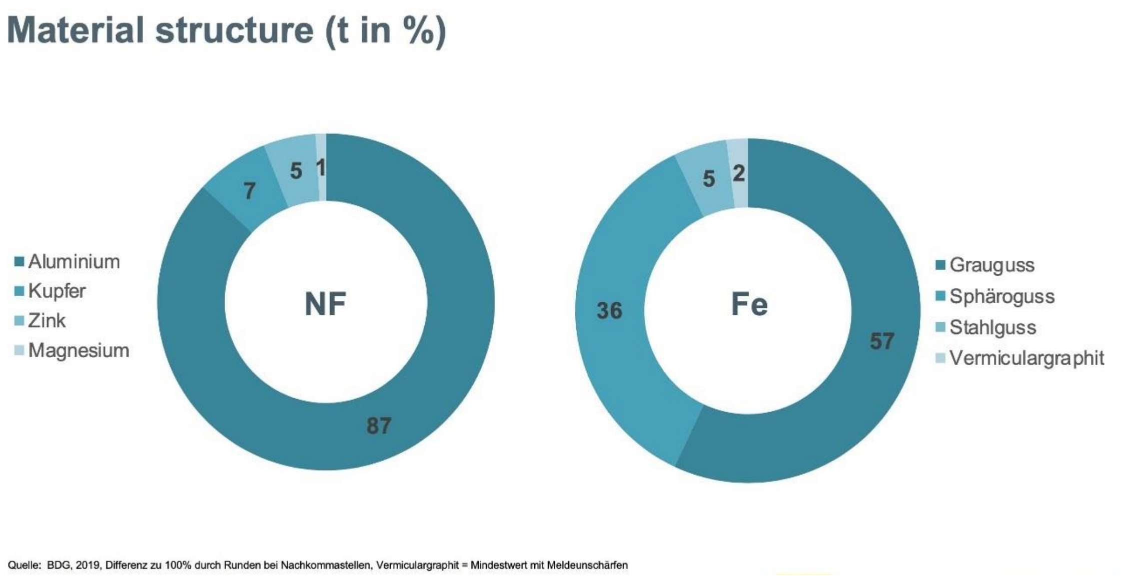

Figure 12. *Material structure*

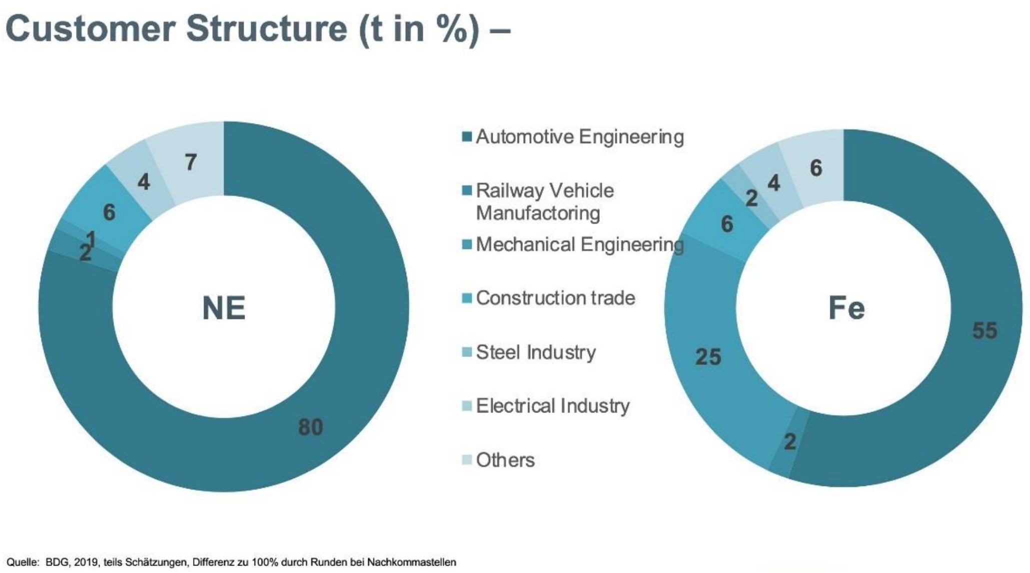

Figure 13. *Customer structure*

FOUNDRY PRODUCTION IN INDIA

National representation in the WFO:

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General Economic Scenario

India was fastest growing economy in the world. However, of late there is slowdown due to poor demand. Foundry Industry which had reasonable growth of 6-7% approx. till 2018-19, has also come under pressure due to falling demand from various sectors. Auto sector which is major sector driving demand from foundry sector has registered steep downtrend due to various reasons. COVID 2019 has totally disrupted the entire economy. India's overall economy is expected to register negative growth of 8-9 % as per ADB in 2020-21.

Foundry Industry

Since the foundry industry is the feeder to various sectors, its output is directly affected by the consumers. The demand from Auto has gone down steeply. However very recently PV & two wheelers are showing good demand .CV are still having low demand. Tractors industry is doing well & generating demand for foundry sector. Defence sector is expected to open new markets. However, Auto continues to be single largest sector driving demand from foundry sector. Due to lack of clarity on EV mobility, the future of foundries supplying castings to Auto is not very clear.

The trend of production of castings in India for last 5 years is indicated in table below. The foundries are presently operating at 50% capacity on an average. However, some are even operating at 60-70 % capacity depending upon the industry segment serviced by them. **However, in 2019-20, we estimate a fall of over 10-15% over last year** for which survey is in progress.

	2014-15	2015-16	2016-17	2017-18	2018-19
Grey C.I.	6.83	7.41	7.89	8.44	9.41
SG Iron	1.07	1.18	1.18	1.23	1.31
Malleable	0.06	0.08	0.08	0.05	0.05
Steel	0.968	0.88	1.01	1.03	1.21
Non Ferrous	1.093	1.25	1.22	1.3	1.40
TOTAL	**10.02**	**10.80**	**11.38**	**12.05**	**13.38**

Table 1. *Casting Production in India in Million Tons per Annum*

Category	2015-16	2016-17	2017-18	2018-19	2019-20
Passenger Vehicles	3,465,045	3,801,670	4,020,267	4,026,047	3,433,062
Commercial Vehicles	786,692	810,253	895,448	1,112,176	752,022
Three Wheelers	934,104	783,721	1,022,181	1,268,723	1,133,858
Two Wheelers	18,830,227	19,933,739	23,154,838	24,503,086	21,036,191
Quadricycle	531	1,584	1,713	5,388	6,095
Grand Total	**24,016,599**	**25,330,967**	**29,094,447**	**30,915,420**	**26,361,228**

Table 2. *Auto Sector Production Trends*

Source: SIAM

Figs in Units

Auto Sector was growing for the last 5 years, which has now registered a very steep downtrend. As a result, the foundry industry is also witnessing a slowdown in demand.

Moreover, the policy of EV mobility is not very clear, which is holding any major investments. In future, the demand for light weight components is likely to grow. The casting demand for iron & Aluminum castings could grow by 35-40% in next 3-4 years from current levels.

Government is fast tracking of infra projects, there are some green shoots visible in Mining, Earthmoving.

There is focus on infrastructure in India. Construction of roads & rural housing etc., will push demand from earthmoving & allied equipment.

Good monsoons augur well for agricultural sector which will drive demand for tractors. The tractor industry grew by 21% in 2016-17, by 14% in 2017-18 and by 13.5% in 2018-19 as compared to previous year after registering a decline of approx. 6.9% in 2015-16 compared to 2014-15.

	2015-16	2016-17	2017-18	2018-19	2019-20
Production	570791	691361	790673	897548	761075

Table 3. *Tractor Sector Data*

Exports

Foundries exporting from India generally have reported good demand for exports in spite of COVID 19. The exporters of castings expect this trend to continue in view of expected shift of business from China to other countries including India.

The exports of castings from India from 2016-17 onward have shown significant growth after showing declining trends for past few years as per following trends.

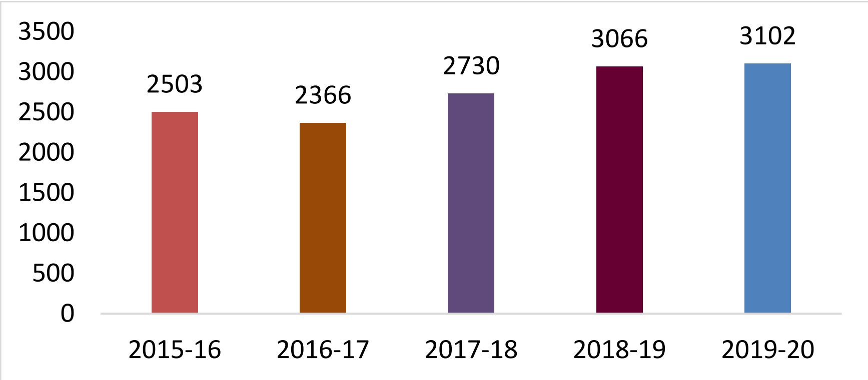

Figure 1. *Export Data of Major Castings (Fig in Million USD)*

Major Challenges

1. Rising input material Costs;
2. Shortage of skilled manpower;
3. Good quality Power at competitive rates:
4. Sand availability due to mining & environment issues;
5. Weak demand due to COVID 19;
6. Challenge from slowdown in China & threats of dumping;
7. Growing Protectionism & Trade wars;
8. Uncertainty due to Lack of clarity of Policy on EV Mobility.

Main activities performed in 2020

- The ***68th Indian Foundry Congress & Foundry Exhibition IFEX 2020*** were successfully organized at Chennai The theme of the IFC was " Paradigm Shift –Blue Print 2020".This was biggest show organized by IIF at Chennai Trade centre, Chennai from 28th Feb 20 to March 1'20 .There were over 1400 delegates & approx. 350 exhibitors.
- MSME Conclave was also organized on 27th Feb 2020. Development Commissioner, Ministry of MSME was invited for interaction with members.
- Due to COVID 2019, IIF promoted use of digital platform for interaction with various stakeholders including members. IIF & its various regions & Chapters conducted more

than 30 Webinars on technical & management topics digitally for the benefit of members. The digital platform was also used to conduct national council meeting, Region & chapter meetings etc.

- Interaction with Minister MSME was also done digitally to highlight issues of industry.
- Cluster Development Programme & Lean Manufacturing programme for MSMEs is being promoted in mini clusters (A group of 8-10 units). The objective is to improve overall competitiveness of the units.
- Monthly IIF Journal and weekly IIF Bulletin are being published regularly.
- To Promote energy efficiency IIF has joined hands with Bureau of Energy Efficiency for Energy Mapping Project for MSMEs. Five clusters have been shortlisted for detailed study.

Activities planned

- 69th Indian Foundry Congress & Foundry Exhibition IFEX 2021at Kolkata. **However due to COVID 2019 the dates are yet to be finalized.**
- Promote use of digital platform for interactions & services to members to the extent possible.
- Work on promotion of water conservation, energy & natural resources in foundries.
- Plan & Organize digital conference in Feb 2021.
- Promote export development by disseminating information & training for foundries. Three-day webinar has already been planned from 15th to 17th Oct 2020. More such programmes will follow.
- Upscale energy audit programme in foundries for improved energy management specially in SME units.
- Promote & Organize Lean Manufacturing programme in foundry clusters with the objective of improving the overall competitiveness.
- Create awareness & promote Common Facilities Center programme for creation of common facilities by cluster members.
- Active engagement with stakeholders for policy interventions for sustainable growth of the sector.
- Conduct modular examinations in foundry technology.
- Digitally Organizing seminar/ events on various technical topics in co-ordination with various chapters/ regions throughout India for the benefit of foundries.

FOUNDRY PRODUCTION IN JAPAN

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Japan Foundry Engineering Society

Industry Report of Japan Foundry Business

Total production amount in 2019 was down 5.3% over in 2018. Gray cast iron was down 5.4%, spheroidal graphite cast iron down 5.4%, malleable cast iron down 5%, steel castings down 8.8%, copper alloy castings down 5%, aluminum alloy castings down 3.7%, die castings down 4.6%. The production amount of castings was roughly even over the last 5 years (table 1).

The Covid-19 pandemic started drastically influencing the production amount of castings in April 2020 like Fig.1～6, table 2. Production amount of gray cast iron and spheroidal graphite cast iron, aluminum alloy castings and die castings were largely down in Mar and May 2020. On the information about the activities by the Japanese government against the Covid-19 Pandemic, you would refer to the information on the URL at the end of the report.

Around 70% of gray cast iron was consumed for vehicles, also 66% of spheroidal graphite cast iron for vehicles, 90% of aluminum die castings for vehicles, 95% of aluminum alloy castings for transportation machines, 24% of steel castings for construction machines and 37% of copper alloy castings for valves and stopcocks (table 3).

Fig. 7 shows the production amount of the gray cast iron and the spheroidal graphite cast iron for car industry since 1965. Both cast iron has stabilized at about 1.3million tons a year for the gray cast iron and 0.8million tons for spheroidal graphite cast iron. That was the reason for transferring the production overseas and some parts of the gray cast iron had been changed to the spheroidal graphite cast iron in order to get them lightweighted. On the whole, around 60～70% of castings are used by the car industry.

Also in Japan, there are a lot of issues on changing the car industry after arising the problems of the global warming. The next-generation cars xEV have been created in every car manufacturer. They have occupied Japanese market by about 30% in 2017. In the next 10 years, 50～70% of xEV cars will occupy Japanese market including 20～30% of EV and PHV. They don't need engine and transmission castings, so the casting production for cars are going to decrease dramatically in the near future.

Car companies are thinking about not only Electric but also Connectivity, Autonomous, and Shared & Service in car market of Japan.

Managers of almost all of the foundries have been changing their basic strategies for the casting production plans.

Production amount over the past 5 years

[x10^3 ton]

Year	Gray cast iron	Spher. graphite cast iron	Cast iron pipe	Malleable cast iron	Steel castings	Copper alloy castings	Aluminum alloy castings	Die castings	Precision castings	Total
2015	2,022.9	1,305.1	398.7	43.1	157.0	78.0	418.5	975.7	5.9	5,404.9
2016	1,933.7	1,301.3	290.3	41.0	150.1	77.4	423.7	980.4	5.4	5,203.3
2017	2,032.1	1,403.6	248.9	42.0	161.9	75.4	441.8	1,042.4	5.5	5,453.6
2018	2,064.3	1,440.8	249.0	39.9	167.7	74.6	454.1	1,075.3	5.1	5,570.8
2019	1,953.0	1,362.6	230.8	37.9	153.0	70.9	437.5	1,025.8	4.2	5,275.7
In 2019	37.1%	25.8%	4.4%	0.7%	2.9%	1.3%	8.3%	19.4%	0.1%	

Table 1. *Production amount over the past 5 years*

Recent impact of Covid-19 Pandemic on the production of castings in 2020 (Fig.1, 2, 3, 4, 5, 6 & Table 2)

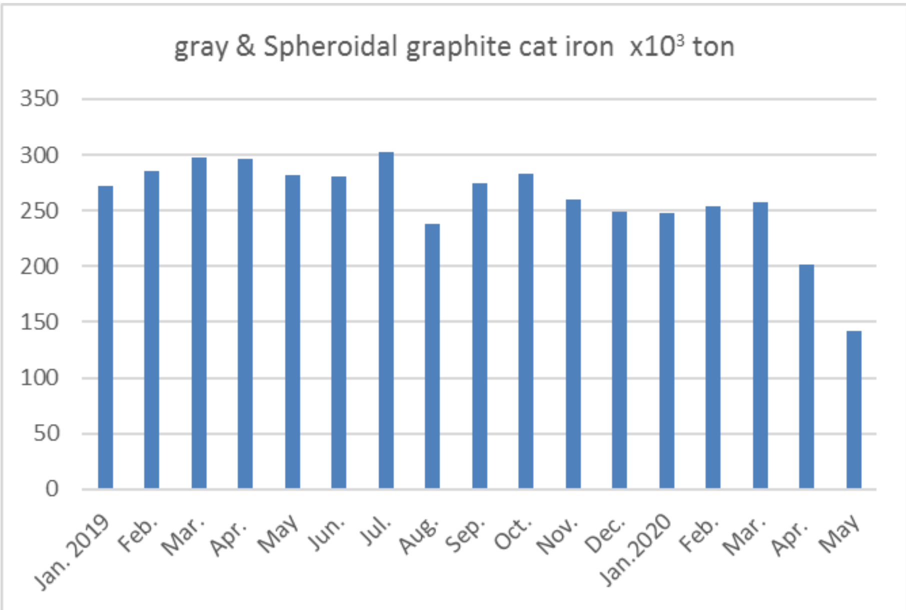

Figure 1. *Production amount of cast iron*

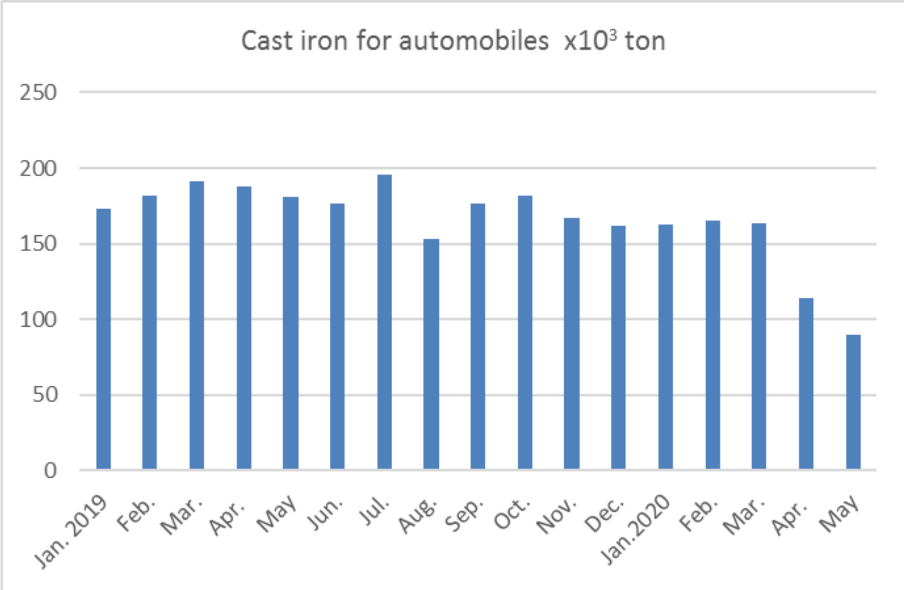

Figure 2. *Cast iron for automobiles*

Production amount of gray & spheroidal graphite cast iron and also castings for automobiles were down by about 20% in April 2020 (Fig. 1,2), aluminum alloy castings was down by 31% (Fig. 3), and die castings was down by about 33% (Fig.4). Those are the reasons of the reduction of the production of automobiles (Fig. 6). The production amount of 8 domestic automobile manufacturers reduced totally down about 53% in April 2020 compared with in April 2019, and they are anticipating the same trend for a while.

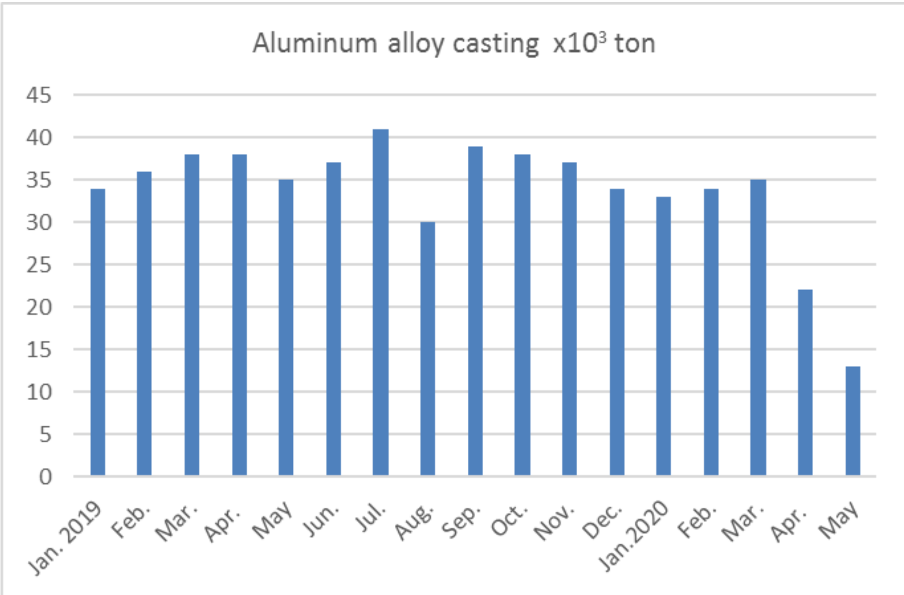

Figure 3. *Production amount of Aluminum alloy castings*

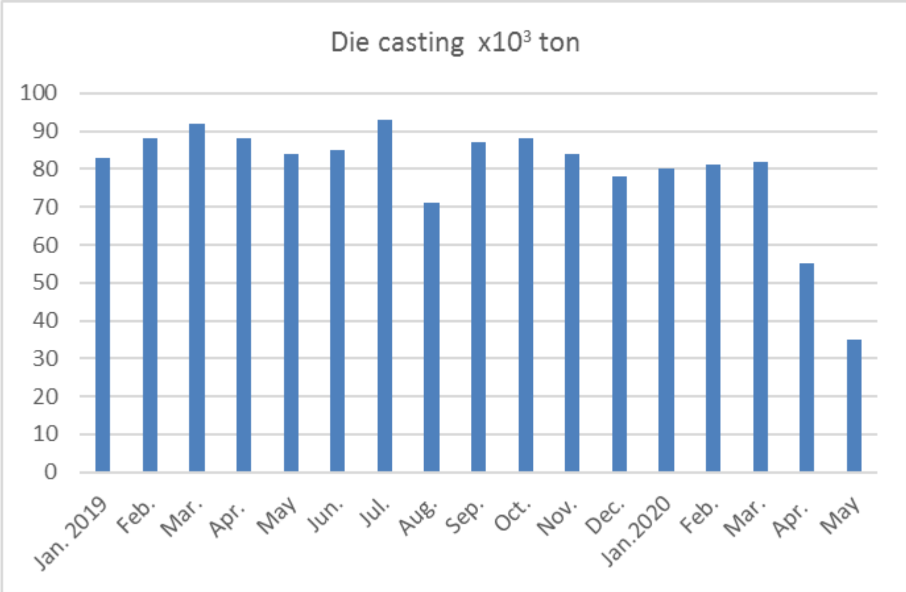

Figure 4. *Production amount of Die castings*

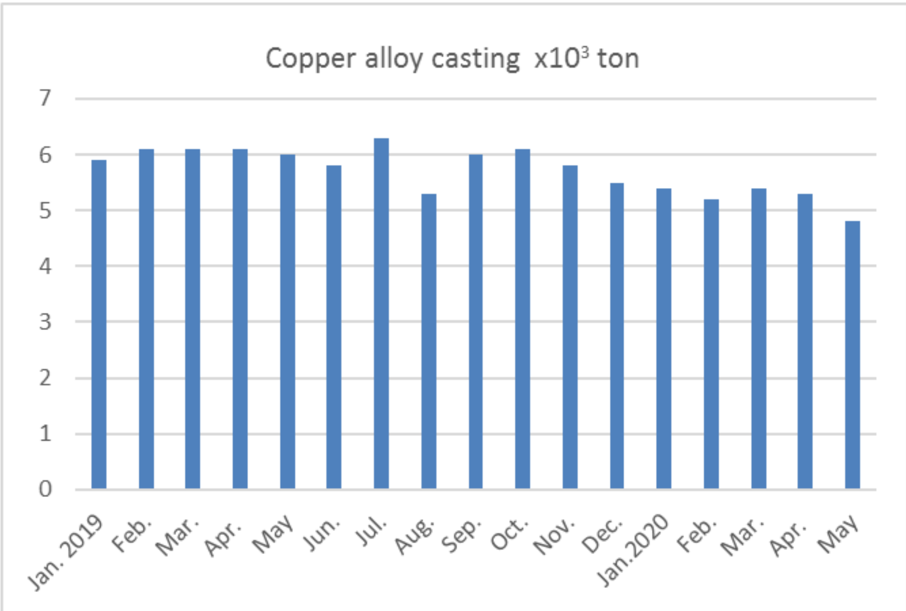

Figure 5. *Production amount of copper alloy castings*

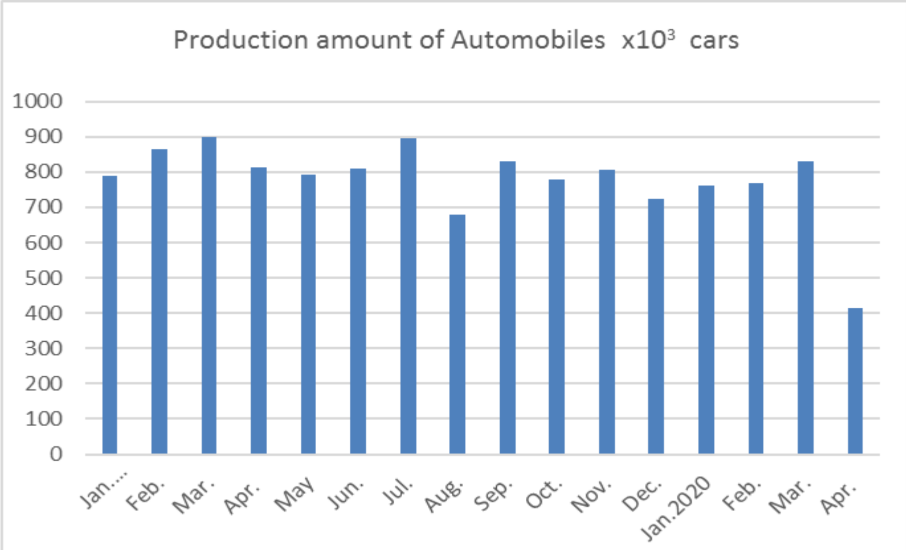

Figure 6. *Production amount of Automobiles*

	Jan.	Feb.	Mar. A	Apr.	May B	B/A
gray + spheroidal graphite cast iron	257,3	257,5	258,1	207,1	141,7	▲45.1%
steel castings	12,6	12,2	13,4	12,8	10,8	▲19.4%
copper alloy castings	5,4	5,1	5,4	5,3	4,8	▲11.1%
aluminum alloy castings	33,3	33,9	34,7	23,8	12,9	▲62.8%
die castings	81,2	81,6	82,1	54,6	34,8	▲57.6%

Table 2. *Recent impact of Covid-19 Pandemic on the production of castings (in 2020)*

Consumption of Castings in 2019

Vehicle	71,1%
Industrial machines & apparatus	25,8%
Others	3,2%

Table 3.1. *Gray cast iron*

Vehicle	66,2%
Industrial machines & apparatus	27,0%
Others	6,8%

Table 3.2. *Spheroidal graphite cast iron*

Aluminum Die Castings	
vehicle	90,0%
other machines	7,8%
Zinc & other Die castings	2,2%

Table 3.3. *Die castings*

Transportation machines	95,9%
Others	4,1%

Table 3.4. *Aluminum alloy castings*

Construction machines	24,1%
Ship industries	18,4%
Vehicle	9,7%
Shredding machines	6,9%
Others	40,8%

Table 3.5. *Steel castings*

Industrial machines	
Valve, stopcock (include coupling joint)	37,4%
Industrial machines & equipments	16,7%
Bearing metal	12,6%
Transportation machines	23,8%
Others	9,5%

Table 3.6. *Copper alloy castings*

Castings production amount for car industry

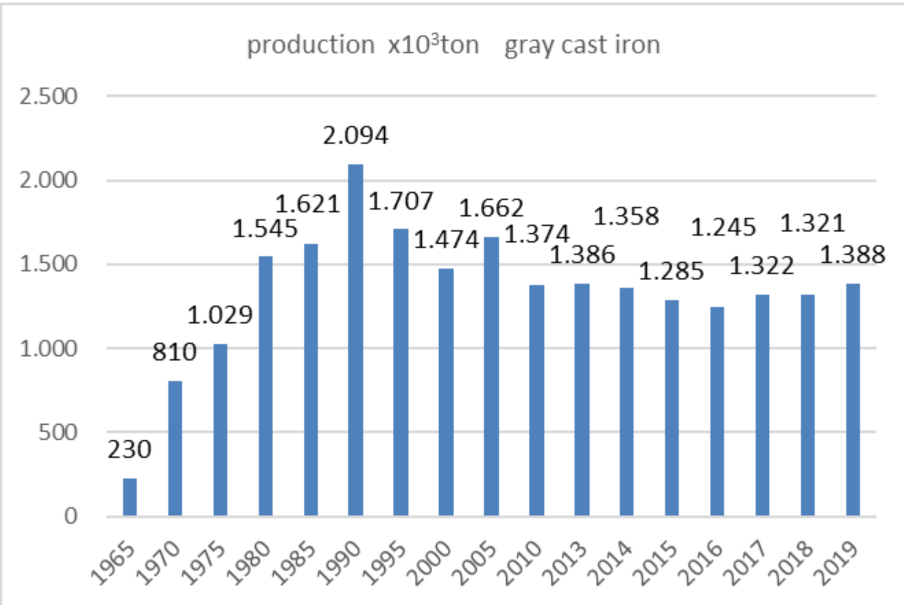

Figure 7.1. *Gray cast iron production amount for car industry*

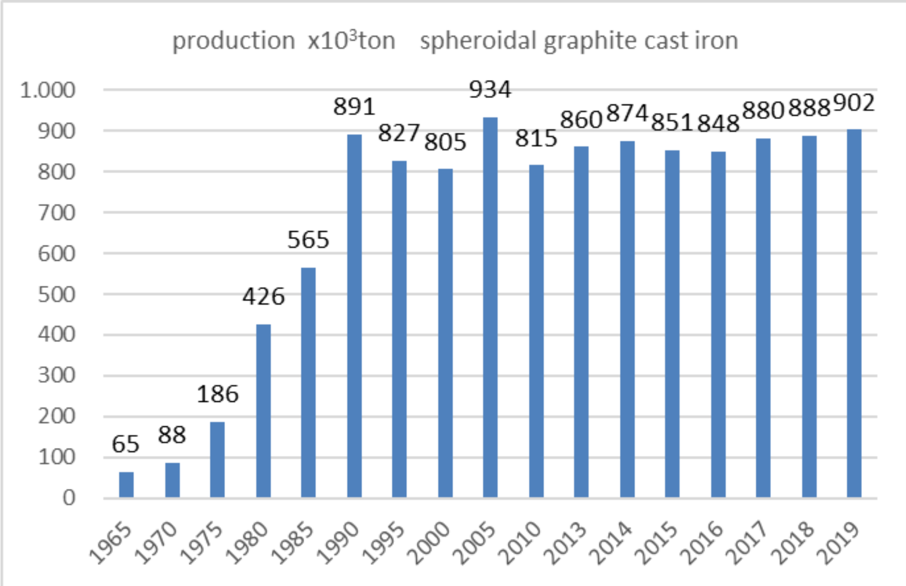

Figure 7.2. *Spheroidal graphite cast iron production amount for car industry*

In April 2020, the production amount of automobiles was down by 53.3% compared with in April 2019, and the effect of Covid-19 Pandemic to the automotive industry is anticipated to continue for a while, so the production amount of castings is anticipated drastically down in 2020.

Number of Foundries and Workforce

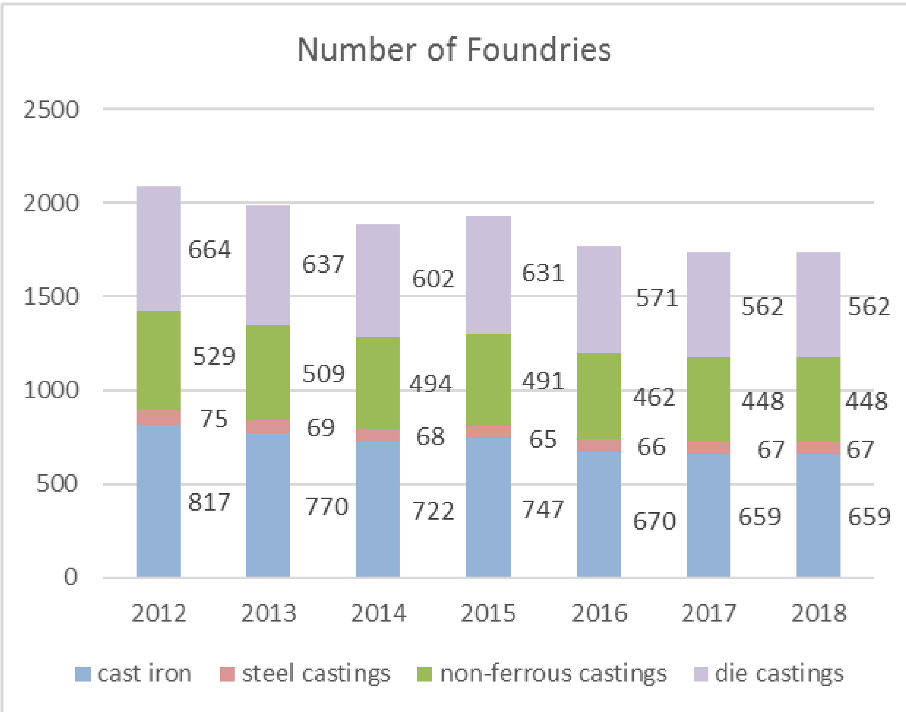

Figure 8.1. *Number of Foundries (for cast iron include cast iron pipe and malleable cast iron)*

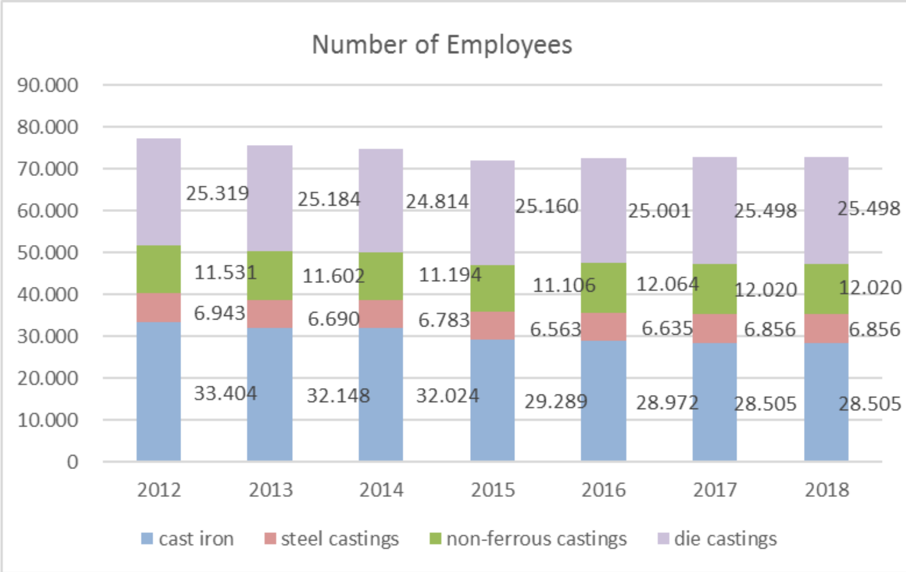

Figure 8.2. *Workforce (for cast iron include cast iron pipe and malleable cast iron)*

Fig.8 shows the number of foundries and employees. Those 2 items have been decreasing over the last 5 years. That is the reason for aging of not only workers but also managers, and fewer young people has been getting jobs in foundry industry. It is worried about that the number of foundries might be on a downward trend. We have been educating young foundry workers with special educational course and advanced educational course on all the casting technologies since 2007. Over 1,000 experts were graduated from those courses and have been playing in active parts (Fig.10). About 80% casting companies of the member of the Japan Foundry Society Inc. reduced the production amount in April 2020, and about 40% of companies might fall into the red.

Import and Export on Castings

[ton / year]

Year		Iron pipe	Cast iron tube connector	Malleable cast iron tube connector	Cupper alloy tube connector	Steel castings as cast	Other castings	Total
2014	Import	2,2	15,6	10,9	7,5	46,3	52,0	134,5
	Export	88,3	1,1	2,9	1,5	-	41,4	135,2
2015	Import	2,1	12,8	9,5	7,0	41,8	43,5	116,7
	Export	158,0	3,6	2,3	1,5	-	27,9	193,3
2016	Import	0,7	12,7	7,4	6,7	24,6	43,1	95,2
	Export	79,4	3,1	2,0	1,7	-	9,8	96,0
2017	Import	1,2	14,5	7,4	6,7	19,3	42,9	92,0
	Export	20,0	1,2	2,4	1,8	-	1,1	26,5
2018	Import	0,2	15,5	9,1	7,7	17,1	43,3	92,9
	Export	50,3	1,4	2,1	1,7	-	9,0	64,5

Table 4. *Import and Export on Castings*

Table 4 shows the amount of castings by import and export over the last 5 years. The amount of import in 2018 was about 90 tons, and export was 60 tons a year. Main castings in export was iron pipe, and in import was cast iron tube connector and steel castings. The amount of castings in both Import and export was reducing year by year.

The amount of castings imported and exported were low compared with the amount of production amount in Japan.

Import and Export on Casting Materials

[ton / year]

Year		Silica sand	Bentonite
2014	Import	1.264.397	184.630
	Export	12.649	8.551
2015	Import	1.141.750	190.501
	Export	4.718	8.906
2016	Import	1.075.499	130.162
	Export	5.705	9.302
2017	Import	1.164.073	121.302
	Export	4.885	8.145
2018	Import	1.184.031	168.625
	Export	6.054	7.394

Table 5. *Import and Export on Casting Materials (sand and bentonite)*

Table 5 shows the amount of silica sand and bentonite imported and exported over the last 5 years. Around 1.2 million tons of silica sand was imported in 2018 and 0.17 million tons of bentonite was imported. The amount of silica sand was roughly even over the last 5 years but bentonite increased in 2018.

Production for the same company's consumption

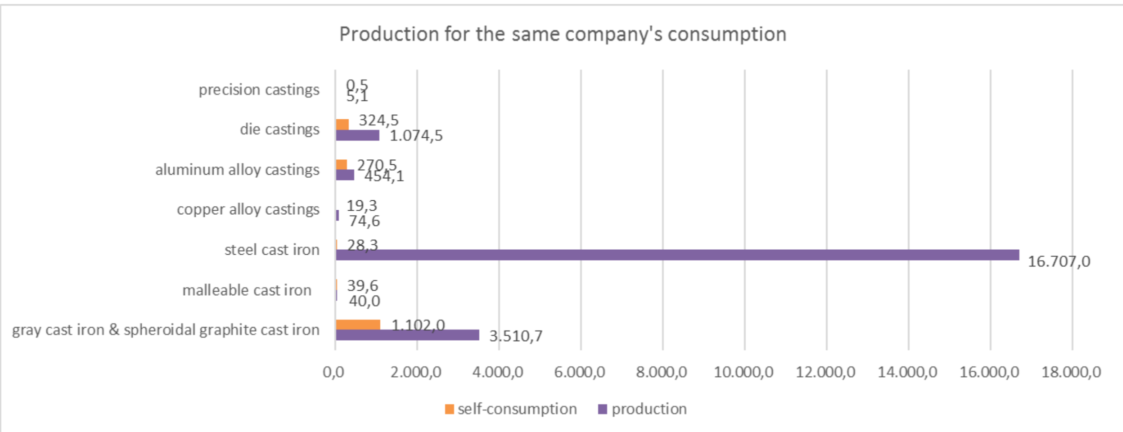

Figure 9. *Production for the same company's consumption (in 2018)*

Many of the casting companies in Japan are just producing castings not using their own products, so all of their castings are sold to another companies. Some foundries are belonging to the car companies, appliance companies or constructing machine companies, so they are consuming their castings for their own products. Self-consumption on the Fig.9 means that after making castings, they use the castings in the same companies for assembling their products. Self-consumption ratio was around 30% for gray cast iron, 99% for malleable cast iron, 20% for steel cast iron, 25% for copper alloy castings, 60% for aluminum alloy castings, 30% for die castings, and 5% for precision castings.

About 70% of gray cast iron in Japan were produced by the specialized companies in castings.

Senior Foundry Experts and Foundry Experts in Japan

Many foundry workers have got the title of “senior foundry expert” or “foundry expert” in specialized educational course at the General Incorporated Association (Japan Foundry Society Inc.). We call this course “Chuzo College” started in 2007 (Chuzo in Japanese means casting).

They are doing well in the foundry industry as managers and leaders in many foundries.

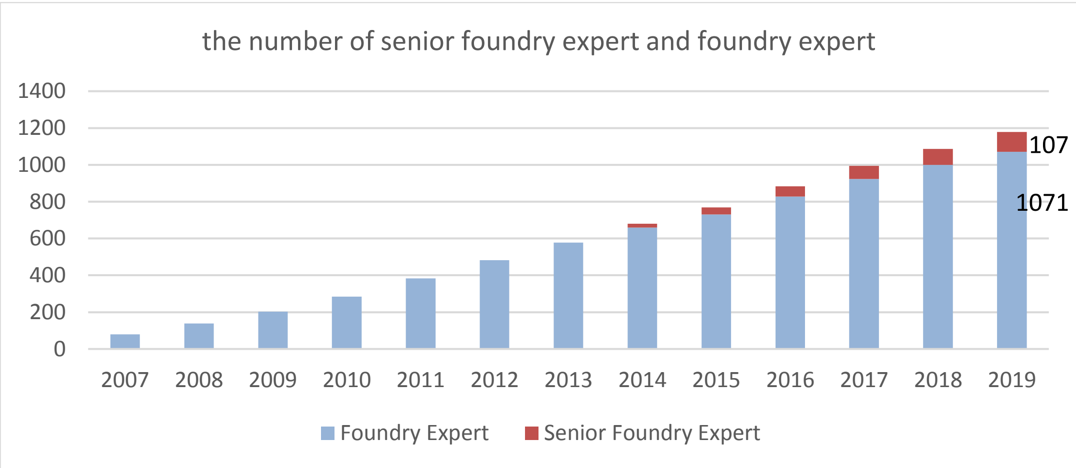

Figure 10. *Senior Foundry Experts and Foundry Experts in Japan*

References: SOKEIZAI NENKAN 2018 edition (Annual report on the formed and fabricated materials industries by SOKEIZAI CENTER, General Incorporated Foundation)

Others: Japanese government gives all industries a lot of information about specific resources or legislation on the activities against the Covid-19 Pandemic. They are opening on the next URL in english site:

(1) Cabinet Office	*https://corona.go.jp/en/*
(2) Ministry of Economy, Trade and Industry	*https://www.meti.go.jp/english/covid-19/index.html*
(3) Ministry of Health, Labour and Welfare	*https://www.mhlw.go.jp/english/*

FOUNDRY PRODUCTION IN UNITED STATES

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Overview

The U.S. metalcasting industry saw positive growth continue through 2019, with strong demand in several manufacturing sectors, led by automotive, aerospace, and water infrastructure. Reshoring by U.S. based companies has contributed to the increase in casting demand, along with the new USMCA trade agreement with Mexico and Canada, which was completed in December 2018. Foundries continue to invest in new technologies to improve efficiency in energy, quality, design and production. Additive manufacturing has become more widely adopted by foundries as a means of printing molds, cores, shells, patterns, and tooling.

Industry Census

The U.S. continues to see contraction in the overall number of metalcasting facilities, with 1,759 locations in total, a 3.6% decrease from 2018. Despite some closures and consolidations, there have been large expansion investments that have counteracted the loss of overall capacity. For instance, Toyota pledged $112 million to invest in two of its Bodine Aluminum plants in Troy, Missouri, and Jackson, Tennessee. Weir Group invested $15 million to add capacity at its Newton, Mississippi, plant, and a new zinc diecasting facility was established for Bruschi USA in Milwaukee, among other expansion announcements.

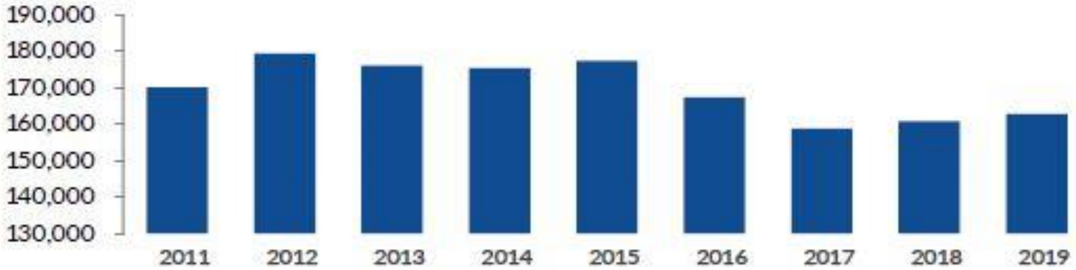
Number of Facilities (Excluding Art Foundries and Educational Foundries)

	2011	2012	2013	2014	2015	2016	2017	2018	2019
Facilities	1,947	1,985	1,917	1,871	1,866	1,787	1,800	1,821	1,765
Annual Growth		1.9%	-3.5%	-2.4%	-0.2%	-4.2%	0.7%	1.2%	-3.1%

Compound Annual Growth Rate -0.4% 3-Year -1.2% 5-Year

In 2019, the U.S. unemployment rate was as low as 3.5%, making it difficult for foundries to find labor. Many invested in automation and robotics to become more efficient and less labor dependent. Despite labor shortages, overall foundry employment increased for the second consecutive year to 162,816, reversing a five-year trend of declining employment.

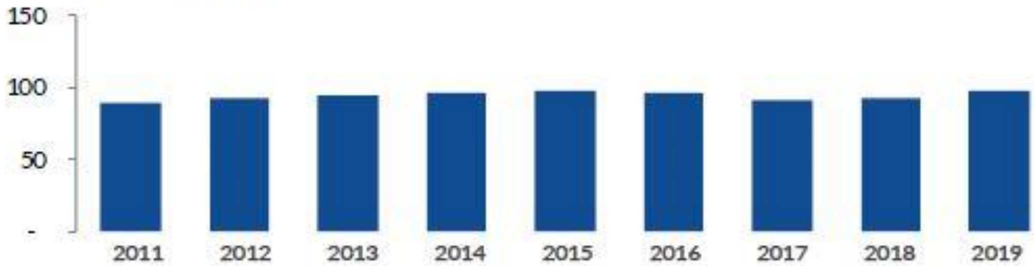
Total Industry Employees



	2011	2012	2013	2014	2015	2016	2017	2018	2019
# of Employees	169,979	179,321	176,009	175,705	177,667	167,162	158,516	160,874	162,816
Annual Growth		5.5%	-1.8%	-0.2%	1.1%	-5.9%	-5.2%	1.5%	1.2%

Compound Annual Growth Rate	-0.9%	3-Year	-1.5%	5-Year

Employees per Company



	2011	2012	2013	2014	2015	2016	2017	2018	2019
Emp. Per Co.	89	92	94	97	98	96	90	93	97
Annual Growth		2.9%	2.1%	2.9%	1.5%	-1.8%	-6.2%	2.5%	5.0%

Compound Annual Growth Rate	0.3%	3-Year	0.1%	5-Year

Financial Analysis

The American Foundry Society conducted an extensive economic study of the financial impact of the U.S. metalcasting industry in 2019, showing for the first time the revenue foundries contribute to states and local areas as well as the induced effect they have in the supply chain. The study determined that the U.S. metalcasting industry is directly responsible for $110.52B in economic output, including $32B in direct wages and 490k jobs when considering indirect and supporting job. The results of the Economic Impact Analysis (EIA) study have been published on the AFS website and feature an interactive map, allowing users detailed analysis in total, by state, and congressional district.

TOTAL OUTPUT
$110,521,692,900

TOTAL JOBS
492,565

TOTAL WAGES
$32,164,203,700

Total casting sales were estimated to have grown for a third consecutive year in 2019 to $44.3 billion, a 7% increase from a strong 2018, which saw 9% growth. The three-year growth rate of the foundry industry places it in the top 40% of all U.S. manufacturing industries.

	2011	2012	2013	2014	2015	2016	2017	2018	2019
($ Millions)	37,785	38,793	38,715	40,670	38,889	35,640	37,835	41,354	44,290
Annual Growth		2.7%	-0.2%	5.1%	-4.4%	-8.4%	6.2%	9.3%	7.1%

Compound Annual Growth Rate 7.5% 3-Year 1.7% 5-Year

Operating Benchmarks

Operating expenses continue to increase along with revenues, with many foundries reporting the rising cost of raw materials as the primary expense driver, accounting for 51.5% of operating costs. Employee expense was the second largest cost, at an average operating cost of 33.6%. Operating expense as a percentage of revenue for the industry was 79.1%, and during the past three years, total operating expenses for the industry grew at 5.9% per year.

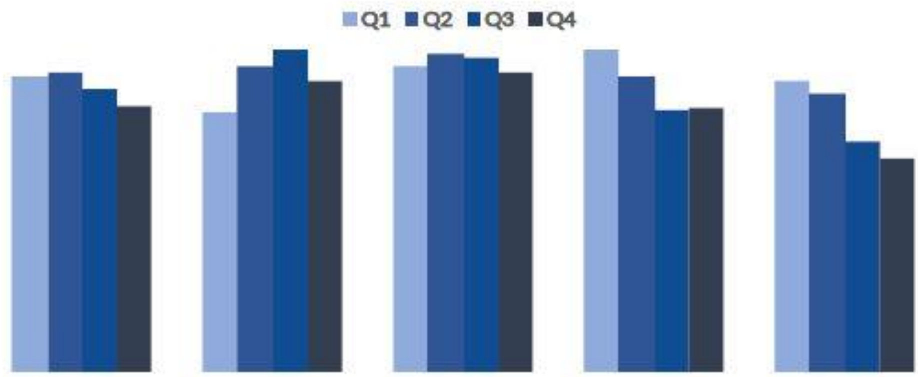
Industry Operating Expenses

	2011	2012	2013	2014	2015	2016	2017	2018	2019
($ Millions)	32,083	32,004	31,939	33,780	31,887	29,504	30,768	33,134	35,043
Annual Growth		-0.2%	-0.2%	5.8%	-5.6%	-7.5%	4.3%	7.7%	5.8%

Compound Annual Growth Rate	5.9%	3-Year	0.7%	5-Year

American foundries have a current capacity of 14 million tons and an average capacity utilization in 2019 of 68%, which is a slight decrease from 72.4% utilization in 2018. As noted previously, labor has limited some foundries' ability to reach full capacity.

Plant Utilization (% of Capacity)



	Average	2016	2017	2018	2019
Q1	73.6	69.1	75.0	77.1	73.0
Q2	74.2	75.0	76.8	73.7	71.4
Q3	71.9	77.1	76.1	69.3	65.2
Q4	69.9	73.0	74.1	69.5	62.9

Production

Iron casting sales increased 20% from 2018 to $11.8M while steel casting sales declined 18% to $8.4M. Aluminum castings saw a 13% drop YoY while copper, zinc and lead and magnesium realized modest gains.

Metals	2019 casting sales in million USD	2019 casting shipments in metric tons
Gray Iron	5,526.02	4,062,373
Ductile Iron	6,008.32	3,325,750
Malleable Iron	72.18	37,195
CGI	187.28	Included with ductile iron
Steel	2,623.15	931,675 (includes investment cast steel)
Investment cast steel	4,269.13	(included with steel, above)
Aluminum	9,256.61	1,609,346
Copper-base alloys	1,612.32	288,485
Zinc & lead	981.39	313,886
Magnesium	1,160.50	140,614
Ni, Co & Ti-base	849.68	47,174

Top casting industries include motor vehicle manufacturing (NAICS 3361), aerospace product and parts manufacturing (NAICS 3364), transportation equipment manufacturing (NAICS 336), iron pipe, fittings, and ingot molds (NAICS 331511), engine, turbine and power transmission (NAICS 3336), pump and compressor manufacturing (NAICS 33391), and industrial valve manufacturing (NAICS 332911). Those industries account for more than 40% of all US casting sales.

Category	Industry	2019 casting sales in millions USD
Iron and steel castings (rough and semifinished)	Motor vehicle transmission and power train parts	5,282.6
Nonferrous (aluminum, copper, etc.) castings (rough and semifinished)	Industrial valve	377.4
Copper and copper-base alloy castings (rough and semifinished)	Plumbing fixture fitting and trim	266.7
Other nonferrous metal castings, rough and semifinished (excluding alum. & copper)	Fluid power valve and hose fitting	103.7
Zinc and zinc-base alloy castings (rough and semifinished)	Hardware	40.2
Metal mill shapes and forms, including castings (steel, aluminum, etc.)	Motor vehicle seating and interior trim	1,041.3
All other fabricated metal products, including forgings and castings (excluding sheet metal)	Light truck and utility vehicle	5,260.6
Steel shapes and forms (including castings, forgings, fabricated metal products, bars, , plate, sheet)	Motor vehicle body	1,212.6
Other metal shapes and forms, including castings	Motor and generator	458.6
Nonferrous shapes, forms, metals castings (rough and semifinished)	Railroad rolling stock	47.0

NATIONAL REPORTS

Alphabetical order

FOUNDRY PRODUCTION IN AUSTRALIA

National representation in the WFO:

NATIONAL AUSTRALIAN FOUNDRY INSTITUTE

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Situation of the foundry industry

Majority of Foundries remain busy in all areas. No major Foundry closures to report this year. At the time of this report many foundries are uncertain of the future effect of COVID19. Some non-Ferrous Foundries have reported large reductions in orders as the first recession in 20 years in Australia takes hold. Many Foundries have introduced split shifts to ensure the Foundry can still operate at some capacity should a team member be infected with COVID19. Split meals times have also been common to ensure physical distancing of 1.5 meters. Non-ferrous tones produced approximately 35,000T and ferrous tones produced approximately 60,000T.

Employment

Head count in all foundries remains flat. Skilled Foundry trades remain challenging to obtain. Some Foundries have stood down casual employees due to COVID19 slowing the economy and many Foundries currently have an employment freeze in place.

Incoming orders

New orders have been unstable since COVID19 hit Australia mid-March 2020.

Investments plans

Investment plans are mixed across the foundry industry with many waiting to see the outcome of new energy policy from government before committing on investment. COVID19 has also placed many projects on hold. Much investment is replacing existing equipment aging and past the current use by date.

Personal cost

The range of increase to employee wages has been from 1% to 3% on average.

Supply of commodities and energy

Steel Scrap prices have reduced approximately 15% over the last 12 months and pig iron supply remain tight from all suppliers. Energy cost is the most feared cost in the industry currently. Energy cost has double on average in the last 10 years and some state policies having the potential to drive prices up further, however for the first time in years it appears that draft policy tabled by the Government will see electricity prices reduce.

Cost development

Majority of suppliers are freezing cost due to COVID19 unless the supply is affected by the low value of the Australian Dollar exchange rate.

Outlook 20201

Although the majority of foundries are busy, it is unknown at this stage the impact of the recession. Governments are encouraging businesses to purchase Australian made where possible to support local employment. Late June unemployment has risen to 7.2% which is the highest in 20 years.

FOUNDRY PRODUCTION IN AUSTRIA

Report provided by
FACHVERBAND METALLTECHNISCHE INDUSTRIE
Berufsgruppe Gießereiindustrie
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Preface

For the Austrian as well as the European foundry industry, 2019 was a challenging business year. Our member companies again occupy very different niches, the development of which is by no means homogeneous. The majority (approx. 75%) is dependent on the vehicle industry, so that this area has a massive impact on the economic figures in our industry.

Unfortunately, the mentioned industry development had announced itself and drew its nutrients from a political discussion about the environmentally relevant aspects of the various drive systems for automobiles, whereby existing alternatives are not really fully developed and further optimizations are available for combustion engines. While tampering with the measurement of exhaust gas values was reported in advance, the interest of potential buyers has decreased, and uncertainty has increased at the same time. Such developments influence every industry and in 2019 caused capacity problems for the European and thus also the Austrian foundry industry. We all hoped for a turnaround after GIFA, but the downward trend, especially for component foundries in the vehicle sector, has continued and intensified.

Education and training

In 2019, a total of 30 apprentices began their final apprenticeship exams in the industry's own apprenticeships, metal foundry and foundry technology with a focus on iron and steel casting and non-ferrous metal casting. We are pleased that all the apprentices who took part passed the test, 9 of them with distinction, and we congratulate the apprentice training companies!

Foundry companies and employees

The structure of the member companies managed by the foundry industry in 2019 is unchanged compared to 2018 and is broken down in terms of production as follows:

Pure iron foundries	14
Pure non-ferrous metal foundries	21
Foundries that produce iron and non-ferrous metal castings	3
Total	38

Table 1. *Foundry companies*

At the end of 2019, there were 38 industrial foundry companies in Austria. The following table shows the regional distribution of foundry establishments and the number of employees:

State	Number of companies	Employees
Vienna	3	29
Lower Austria	11	2.389
Upper Austria	10	2.382
Styria	7	1.378
Salzburg	1	283
Carinthia + Tyrol	2	278
Vorarlberg	4	194
Austria	**38**	**6.933**

Table 2. *Regional distribution of foundries*

In total, there were 6,933 employees in the foundry industry in 2019. Compared to the previous year, the structure of the Austrian foundry industry has changed somewhat: the proportion of foundries with more than 500 employees and under 20 employees has decreased. The proportion of employees with more than 100 and more than 50 employees has increased.

3	Foundries with 500 - 1.000	Employees
11	Foundries with 201 - 500	"
7	Foundries with 101 - 200	"
8	Foundries with 51 - 100	"
5	Foundries with 21 - 50	"
4	Foundries under 20	"
38	**Total foundries**	

Table 3. *Structure of foundry industry*

Total employees

		2019	2018	%
WIEN		29	28	3,6
NIEDERÖSTERREICH		2 389	2 543	-6,1
OBERÖSTERREICH		2 382	2 535	-6,0
STEIERMARK		1 378	1 421	-3,0
SALZBURG		283	270	4,8
KÄRNTEN + TIROL		278	295	-5,8
VORARLBERG		194	194	0,0
		6 933	7 286	-4,8
Angestellte		1 578	1 592	-0,9
Arbeiter		5 355	5 694	-6,0
	*)	6 933	7 286	-4,8
Brancheneigene Lehrberufe **)				
Metallgießer/in		8	10	-20,0
Gießereitechnik - Schwerpunkt Eisen- und Stahlguss		16	22	-27,3
Gießereitechnik - Schwerpunkt Nichteisenmetallguss		16	11	45,5
		40	43	-7,0

Table 4. *Employees in the foundry industry 2019*

**Apprentices have not been included since 2016 **Overall overview of the industry's own teaching profession in the Austrian industry, as evaluation by occupational group is no longer possible.*

Total employees, total production and employment productivity in the foundry industry

Year	*Total employees*	*Total production (t)*	*Employment productivity t/employees*
1985	8.606	212.605	24,7
1986	8.262	200.690	24,3
1987	7.730	192.567	24,9
1988	7.965	216.452	27,2
1989	8.581	243.242	28,4
1990	8.541	251.685	29,5
1991	8.151	246.610	30,3
1992	7.699	233.701	30,4
1993	6.841	209.545	30,6
1994	7.135	221.646	31,1
1995	7.410	246.704	33,3
1996	7.262	242.325	33,4
1997	7.324	252.913	34,5
1998	7.494	280.433	37,4
1999	7.493	274.140	36,6
2000	7.691	297.329	38,7
2001	7.521	305.732	40,7
2002	7.465	297.460	39,8
2003	7.404	299.223	40,4
2004	7.397	325.205	44,0
2005	7.570	324.400	42,9
2006	7.665	337.966	44,1
2007	7.686	357.013	46,4
2008	7.997	357.733	44,7
2009	6.994	243.513	34,8
2010	6.991	305.857	43,8
2011	7.023	323.911	46,1
2012	7.085	306.478	43,3
2013	7.154	316.795	44,3
2014	7.381	317.954	43,1
2015	6.599	309.449	46,9
2016	6.828	314.859	46,1
2017	7.098	318.190	44,8
2018	7.286	327.574	45,0
2019	6.933	303.287	43,7

***Table 5.** Total employees, total production and employment productivity in the foundry industry (at the end of each year)*

Orders

Overall, it appears that the current economic situation will be severely affected by the current economic situation in 2019.

Production

Total production in 2019 is approximately 303,287 t and has fallen by approximately 7.41% compared to 2018. The total turnover of the industry, amounting to approx. €1.4 billion, shows a drop of 9.36% compared to 2018.

Iron casting has a total production of 158,514 t in 2019 and has fallen by 3.4%. Sales rose by 1.1% to around €432 million.

Production of cast iron ductile iron is 104,730 t, a decrease of -4.6% compared to 2018.

The cast iron has risen to 11,444 t, which is almost the same as in 2018.

In the grey cast iron sector, production fell by -1.5% compared to 2018 and has 42,340 t.

	2018		***2019***	
Materials division	***t***	***€***	***t***	***€***
Iron and steel casting	164.162	427.268.314	158.514	431.824.351
Non-ferrous metal casting	163.412	1.123.394.720	144.773	973.652.224
Sum	***327.574***	***1.550.663.034***	***303.287***	***1.405.476.575***

Table 6. *Production by materials*

Production development

Year	Cast iron	Ductile cast iron	Stahlguss	Zinc die casting & heavy metal casting	Light-metal casting	Total production
1986	87.369	59.830	19.353	7.618	26.520	200.690
1987	72.194	65.764	17.408	7.530	29.671	192.567
1988	83.852	73.267	16.117	8.392	34.824	216.452
1989	90.141	80.484	20.804	8.691	43.122	243.242
1990	90.568	84.028	22.248	8.525	46.316	251.685
1991	92.135	84.884	14.382	8.957	46.252	246.610
1992	81.604	78.734	16.305	9.624	47.434	233.701
1993	60.475	78.153	16.558	9.733	44.626	209.545
1994	63.336	81.938	12.828	10.758	52.786	221.646
1995	69.904	93.714	12.868	10.384	59.834	246.704
1996	64.412	89.626	12.621	11.204	64.462	242.325
1997	62.429	94.903	12.625	11.955	71.001	252.913
1998	65.058	111.313	13.674	12.214	78.174	280.433
1999	62.889	107.084	11.728	12.334	80.105	274.140
2000	63.491	114.775	13.154	13.214	92.695	297.329
2001	62.129	114.848	15.409	13.285	100.061	305.732
2002	53.385	113.821	14.026	13.525	102.703	297.460

Year	Cast iron	Ductile cast iron	Stahlguss	Zinc die casting & heavy metal casting	Light-metal casting	Total production
2003	48.427	113.660	13.769	14.220	109.147	299.223
2004	49.938	127.889	16.287	15.799	115.292	325.205
2005	47.501	130.804	17.712	18.456	109.927	324.400
2006	49.080	138.383	19.671	16.722	114.110	337.966
2007	51.196	150.893	21.019	15.690	118.215	357.013
2008	48.370	153.026	20.756	15.387	120.194	357.733
2009	29.233	89.741	19.771	12.394	92.374	243.513
2010	38.689	113.071	16.094	16.577	121.426	305.857
2011	40.583	113.854	18.575	15.524	135.375	323.911
2012	39.700	104.527	17.258	15.441	129.552	306.478
2013	40.751	116.966	13.084	14.408	131.586	316.795
2014	40.709	108.397	16.936	13.883	138.029	317.954
2015	40.637	105.745	9.504	12.814	140.749	309.449
2016	42.362	101.770	11.284	12.347	147.096	314.859
2017	42.922	102.903	10.764	13.314	148.287	318.190
2018	42.988	109.731	11.443	12.853	150.559	327.574
2019	42.340	104.730	11.444	11.367	133.406	303.287

Change in 2019 compared to 2018						
Tons	-648	-5.001	1	-1.486	-17.153	-24.287
Percent	-1,51	-4,56	0,01	-11,56	-11,39	-7,41

Table 7. *Production development*

Casting production divided by materials and casting process

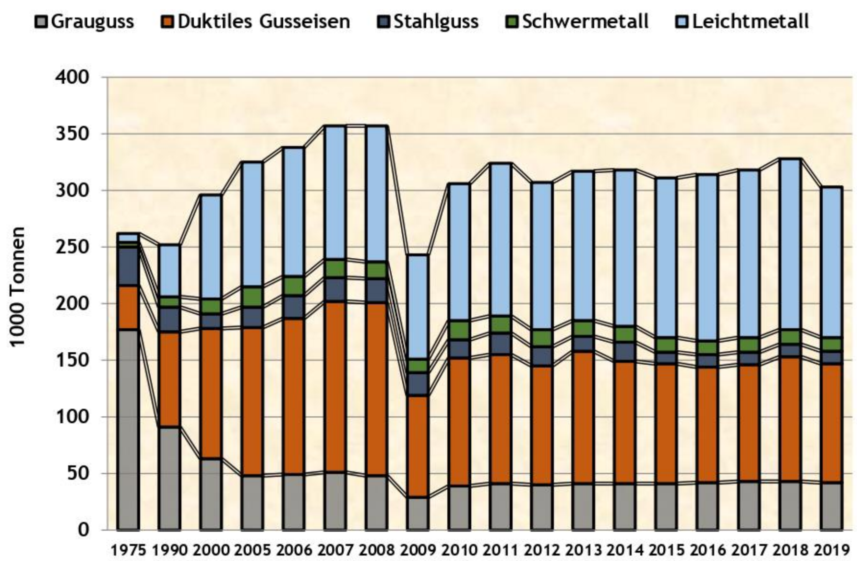


Figure 1. *Development of the production quantity, divided by casting type*

Cost and rationalization pressures

The graph below shows the changes in the specific average price by kilogram since 2000. For 2019, kilo prices in the iron casting sector were slightly rising and in the light metal casting sector slightly lower.

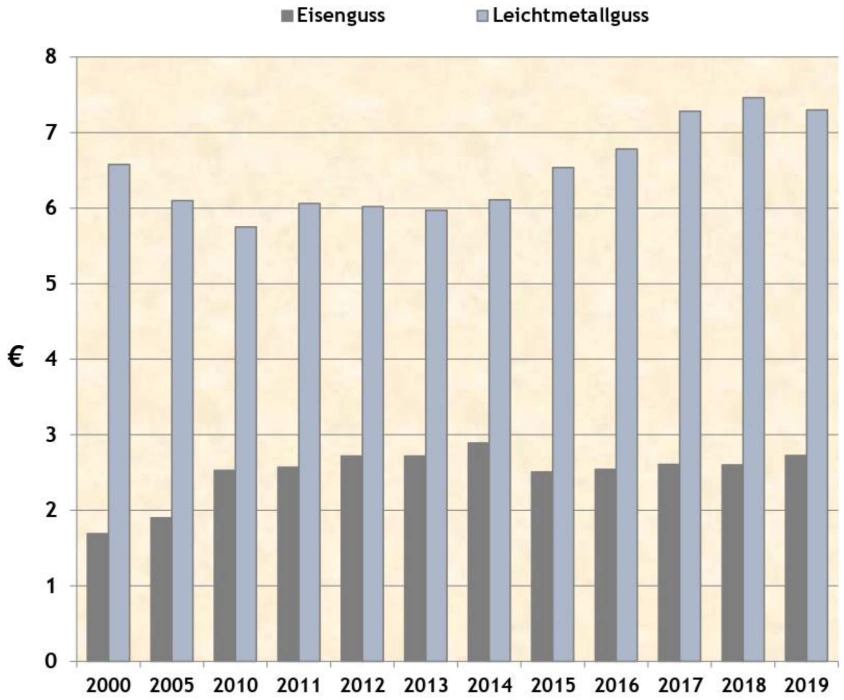


Figure 2. *Development of specific kilogram prices*

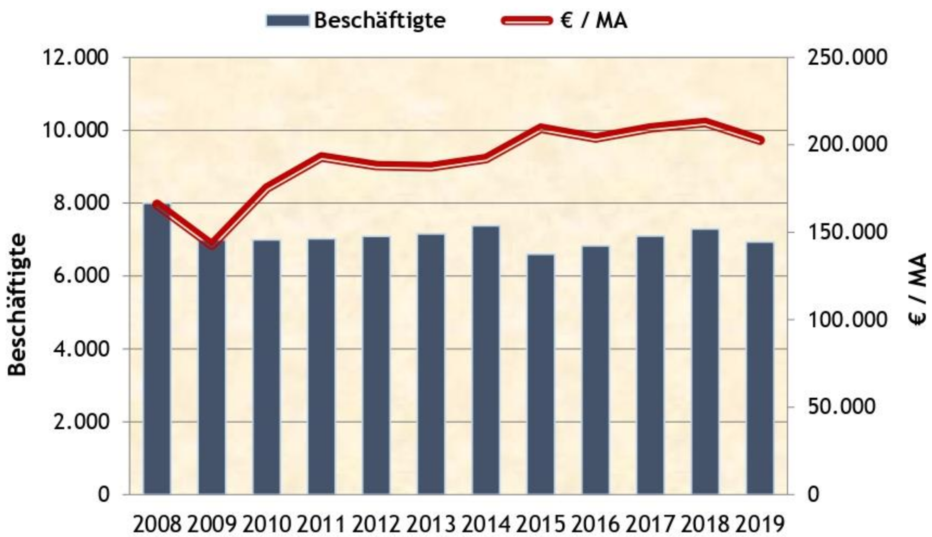


Figure 3. *Employees Development and turnover per employee (€/MA)*

The graph shows that, on average, sales per employee fell to €202,723 in 2019 compared to 2018.

Raw materials, auxiliary materials and consumables

In 2019, commodity prices have fallen steadily. At the end of the year, these were in the range of the lows of the crisis year 2009.

Energy

According to the Austrian Energy Agency, energy prices in 2019 have continued to rise compared to 2018.

The crude oil market in 2019 was marked by "political tensions, trade wars and sabre-rattling in the Middle East." As a result, the crude oil market was strongly influenced.

Due to a series of price increases in 2019 and the previous separation of electricity prices in October 2018, the price of electricity rose sharply. At the same time, the price of gas also became somewhat more expensive year-on-year.

Cupola scrap

The average value for cupola scrap in 2019 was €268/t. The peak was €293/t in January and the lowest level in November was €212/t.

Steel scrap for e-ovens

The average value for steel scrap for e-ovens was €345/t, with a peak of €423/t in January.

Foundry pig iron

In the foundry raw iron sector, the average value was €399/t and the peak was €427/t in January.

Foundry coke

The average value of foundry coke in the year under review was €359/t.

Aluminum

The value of aluminium in 2019 averaged around €1.60/kg, with the lowest value being around €0.90/kg in September and the highest value at approx. €1.70/kg in March.

Nickel

in 2019, the lowest value was around €9.20/kg in January and the peak was approx. 16.90 €/kg in September.

Commodity prices - Overview

The price developments shown in Figure 4 are based on separate surveys of the foundry industry and represent averages over the last 11 years.

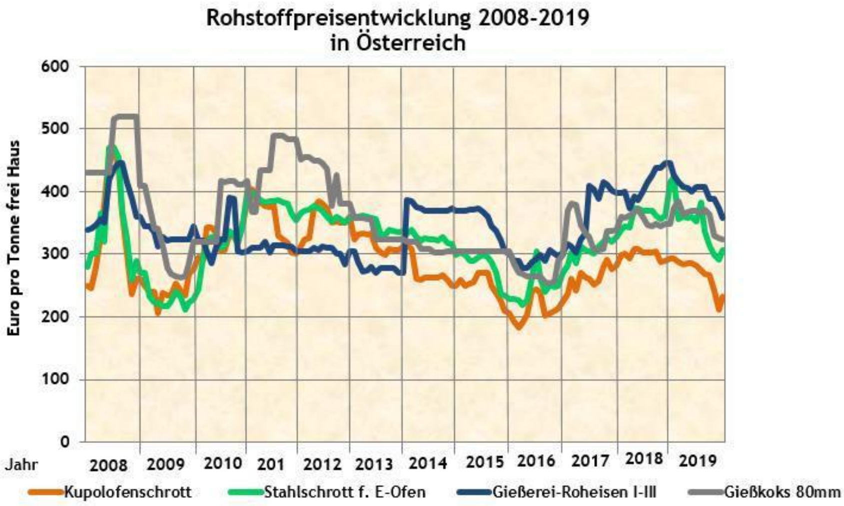


Figure 4. *Trends in raw material prices in Austria in the period 2008-2019*

External trade statistics

Due to changes in statistical allocations for the foundry industry, the values of external trade statistics from 2016 are no longer directly comparable with previous years.

1998	210,3	Mio. Euro
1999	238,3	Mio. Euro
2000	297,3	Mio. Euro
2001	235,3	Mio. Euro
2002	155,6	Mio. Euro
2003	195,7	Mio. Euro
2004	249,6	Mio. Euro
2005	339,6	Mio. Euro
2006	382,0	Mio. Euro
2007	501,4	Mio. Euro
2008	542,3	Mio. Euro
2009	385,1	Mio. Euro
2010	552,0	Mio. Euro
2011	642,3	Mio. Euro
2012	619,5	Mio. Euro
2013	600,3	Mio. Euro
2014	638,4	Mio. Euro
2015	737,6	Mio. Euro
*)2016	531,5	Mio. Euro
*)2017	512,4	Mio. Euro
*)2018	495,3	Mio. Euro
*)2019	466,3	Mio. Euro

Table 8. *Casting balance: export minus the import value*

**) Change in statistical observations. In 2019, the trade balance was € 466.3 million.*

General economic data

Review 2019 - Outlook for 2020

Even before Corona: the Austrian economy showed weaknesses in 2019.

WIFO Prognosen 06-2020, in %	2019	2020	2021
BIP	1,6	-7,0	4,3
Bruttoanlageinvestitionen	2,7	-6,5	4,8
Warenherstellung Wertschöpfung	0,9	-13,0	7,0
Güterexporte	2,9	-14,8	9,5
Inflation	1,5	0,6	0,9

Table 9. *Austrian Institute of Economic Research (WIFO) outlook*

2019 was not a good year for the Austrian economy as a whole and especially for domestic industry. With growth of 0.9%, the industry in particular has already put a full brake on it in autumn 2019. A slight recovery in early 2020 was brutally ended with the outbreak of the Covid19 crisis. The decline did not only start with the lockdown in Austria and Europe, already the lockdown in China and the associated declines in demand from Asia have already massively added to the industry. The projected 7% fall in GDP is the sharpest correction in the post-war period. The production of goods is even more affected, at -13%.

Even before the onset of the crisis, the industrial environment was very unfavourable.

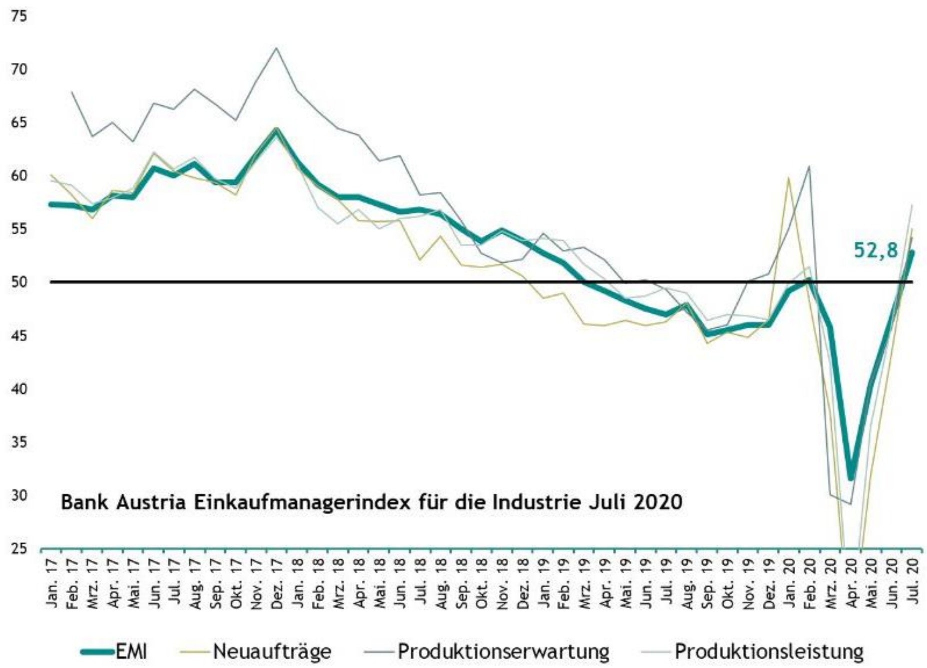


Figure 5. *Purchasing Managers Index evolution*

The current crisis must not hide the fact that structural and external problems have worsened industrial sentiment long before the Covid19 crisis. Even if the negative effects of the Covid19 crisis settle down, and there is still a big "if" associated with it, then the pre-crisis problems arise again. The Purchasing Managers' Index for industry shows that it has already fallen below the crucial 50-point limit in spring 2019. In other words, the industry was already in recession for several months when the crisis began. The reasons for this were, among other things, trade conflicts at the global level, which have damaged the willingness to invest, global protectionism in the goods trade and, especially in Austria, unfavourable wage costs development. For the foundry industry, the weak demand for industry was already noticeable in 2019. Since the low point of the crisis in April/May 2020, the Purchasing Managers Index has been rising again. The current figure above 50 indicates that the situation will improve for industry, but compared to the current very low level. This does not yet indicate a sustainable upswing, but at least at the industrial level it feeds the hope of a turnaround.

An unprecedented slump for the foundry industry and little hope of a rapid recovery

According to the information provided by the companies of the Austrian foundry industry, sales fell by about 30% in the first half of the year, and foundries expect a decline of 26% in the second half of the year compared to the previous year. This decline is unprecedented for the sector and in its severity also exceeds the decline in the total industry and the metalworking industry. The massive weakness in demand in the automotive industry is also likely to be an important factor in this. The outlook for the second half of 2020 shows that there are no high hopes for a rapid recovery in the demand situation in the foundry industry. It is still expected to be a deeply red second half of the year.

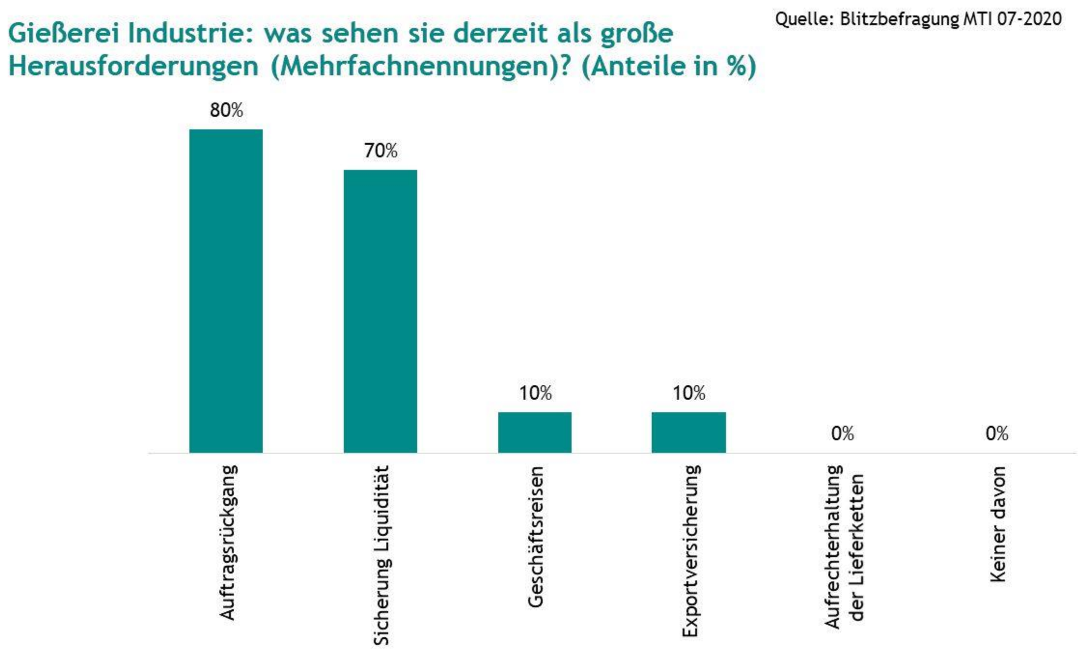


Figure 6. *Major challenges*

FOUNDRY PRODUCTION IN BELARUS

National representation in the WFO:

ASSOCIATION OF FOUNDRYMEN AND METALLURGISTS OF THE BELARUS REPUBLIC

WWW.ALIMRB.BY

The economy and foundry industry of Belarus

The population of Belarus is 9.4 million people. GDP growth in recent years: 2017 - 102.4%; 2018 - 103.0%; 2019 - 101,2%. GDP at Purchasing Power Parity (PPP) - US $ 20,100 per capita in 2019; in 2010 - US $ 16,900.

Belarus is an export - oriented country, with exports of goods and services accounting for about 65% of GDP in 2019. The main trading partners are Russian Federation and the European Union.

Belarus has a well - developed industry. One quarter of GDP is generated by industry, and the country is one of the world's leading manufacturers and exporters of large - capacity dump trucks, tractors, road construction equipment, household refrigerators and agricultural equipment. The share in the world production of large and super large - capacity BelAZ dump trucks is about 30%; agricultural harvesters and combines - about 15%; tractors - about 5%.

The foundry is not a separate industry in the Republic of Belarus, but it is the main base of machine - building industry and has a significant impact on the country's economy.

In general, there are about 140 foundries and foundry workshops in the Republic. The total installed capacity for the production of castings is 557.5 thousand tons. In 2019, the capacity utilization of the plants was approximately 59% (in 2018 – 44,3%), so 329 thousand tons were produced in real terms.

According to the established annual production capacity of castings, all organizations with foundries can be divided into four groups:

- Group I - 50 thousand tons or more per year: three organizations: Minsk Tractor Works (OJSC “MTW” or MTZ), Minsk Automobile Plant (OJSC "MAZ"), OJSC Gomel foundry "Tsentrolit”.
- Group II - from 10 to 50 thousand tons: seven organizations.
- Group III - from 1 to 10 thousand tons: 17 organizations.
- Group IV- less than 1 thousand tons.

A distinctive feature of the foundries of the Republic is a large range of manufactured castings - more than 15 thousand names of 18 grades of alloys, the weight of castings from 20 g to 15 tons.

It should be noted that majority of castings are made by casting in wet sand-clay forms. Various processes are used for the manufacture of casting rods, such as Cold-box- amin, hot boxes, Croning process, various variants of the no-bake process (Alfacet process, Resol-CO2, etc.).

The distribution of casting production volumes by type of alloy is as follows: grey cast iron - 62%; steel -15 %, high-strength cast iron - 13%, aluminum alloys - 7 %, other non-ferrous alloys - 3%.

The Companies have implemented international quality standards.

According to information from official sources, the total amount of financing for machine-building enterprises, including those with their own foundry and metallurgical production, will amount to 8.5 billion euros in the period up to 2030. The money will be allocated for the period until 2030.

It is planned to invest 500 million US dollars for the development of OJSC MAZ. As part of the investment program for the development of OJSC BelAZ, it is planned to invest 800 million US dollars. Other companies within the Holding Company “BelAZ” will receive funding in the amount of 234 million US dollars for the development of production of trucks with a load capacity from 90 to 450 tons and other projects.

In order to provide the machine-building industry of Belarus with metal of its own production, it is planned to invest 800 - 850 million dollars in OJSC "BSW " (Belarusian Steel Works - Belarusian metallurgical plant).

OJSC MTZ plans to carry out a deep modernization of production until 2030, the plant needs investment of US $ 2.0 billion.

High competitiveness and a good price / quality ratio of products of the foundry industry of Belarus are confirmed by deliveries to the countries of the European Union, which requires compliance with numerous technical, environmental and other EU standards. Deliveries from Belarus to the EU countries of foundry products in accordance with the "Harmonized Commodity Description and Coding System” (HS Nomenclature) for Section XV, group 72 " Iron and steel " and group 73 –" Iron and steel Products " increased by 31% from 2016 to 2019 and amounted to 634.6 million euros.

Many countries of the world are trying to break through with exports to the EU. But even with such high competition, Belarus is among the top three exporting countries of the world in some commodity items, sometimes ahead of such countries as China, Turkey, South Korea and other well-known exporting countries.

In connection with the planned launch of the Belarusian nuclear power plant (NPP), there is a possibility to reduce the cost of electricity tariffs, which will allow the energy - intensive foundry and metallurgical production of Belarus to increase the competitiveness of its products.

Since 1993, the Association of foundrymen and metallurgists of Belarus together with the Belarusian National Technical University has been holding an annual International scientific and technical Conference " Foundry and metallurgy. Belarus».

In October 2019, the XXVII International scientific and technical Conference and information exhibition "Foundry and metallurgy 2019. Belarus" was held in Zhlobin, where one of the largest enterprises in Europe "Belarusian Steel Works” (Belarusian Metallurgical Plant) is located. The conference was dedicated to the 35th anniversary of the Belarusian Metallurgical Plant. The General partners and sponsors of the Conference were well - known companies for the production of foundry equipment and casting materials - Heinrich Wagner Sinto (Germany), LK (China), FURTENBACH (Austria), ASK Chemicals (Czech Republic), OJSC "Soligorsky Institute of resource conservation problems with pilot production" (Belarus).

More than 60 reports were presented at the plenary session and in the sections "Foundry production", "Metallurgy" and "Materials Science".

The reports were devoted to topical issues of foundry and metallurgical production: improving the quality and reducing the material consumption of products, energy and resource conservation, recycling of production waste and environmental protection, modernization of foundry and metallurgical workshops, new technologies and materials.

The Association of foundrymen and metallurgists of Belarus has an opinion that the World Foundry Organization and National Associations - members of the WFO should participate more actively in Conferences of National Associations. This will help to strengthen business and personal ties between Associations and foundry specialists from different countries. In particular, when International scientific and technical Conferences are held in Belarus, a "Collection of Conference proceedings" is published and given to each participant, provided that the materials are submitted within the established time frame.

In 2020, the XXVIII International scientific and technical Conference “Foundry production and Metallurgy 2020. Belarus" is planned to be held on November 4 – 5 in Minsk; November 4 – a Plenary session; November 5 - other events at OJSC "Minsk tractor plant"(MTZ), one of the largest enterprises in Belarus (5 out of every 100 tractors in the world are produced at MTZ).

We cordially invite all member Associations and the management of WFO to take part in our Conference and make interesting presentations!

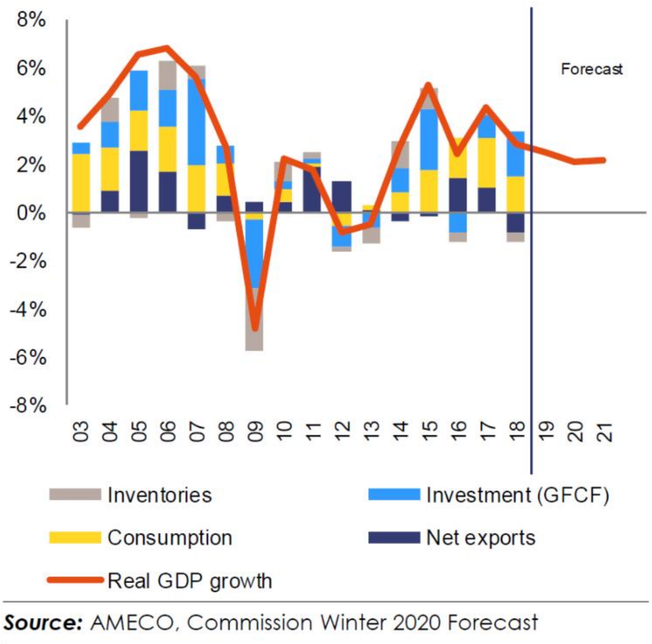
FOUNDRY PRODUCTION IN CZECH REPUBLIC

National representation in the WFO:
CZECH FOUNDRYMEN SOCIETY
WWW.CESKASLEVARENSKA.CZ

Economic situation of Czech Republic and outlook

Economic situation / the situation and outlook before COVID-19 pandemic

The economy continued to grow at a more moderate pace than in 2018, reflecting external developments. In 2019, the economy is estimated to have grown at 2.5% (Commission Winter 2020 Forecast), continuing the decelerating trend observed in 2018 (2.8%). Private consumption was the main driver of growth, supported by a continuous and strong wage increase in a tight labour market. By contrast, investment decelerated sharply in 2019. Net exports are estimated to have contributed to growth, but the slowdown in external demand and geopolitical uncertainties led to a lower increase in both imports and exports.



Graph 1. *Real GDP growth and its components*

An economic slowdown is expected in coming years, mirroring developments in main trading partners. In 2020 and 2021, the economy is projected to continue to grow at a slower pace, at 2.1% and 2.2% respectively (Commission Winter 2020 forecast). Domestic demand growth will moderate but is likely to remain the main growth driver. Investment is expected to decelerate in 2020. Czechia's exports and imports will continue to be strongly influenced by the economic developments of its main trading partners.

Global developments, trade uncertainties, a tight labour market and the transition to a greener economy pose challenges to growth. Ongoing geopolitical tensions are expected to reduce the demand from the main trading partners. This is particularly relevant for a small open economy like Czechia.

The tight labour market and the resulting high wage growth can pose an increasing risk to the cost-competitiveness of exports. With the lowest unemployment rate in the EU and the highest job vacancy rate, the labour market risks overheating. The increase in real wages (5.3% in 2018) and unit labour costs (6.3% in 2018) and the subdued growth in productivity (with sector-specific variations) point in that direction. There were nevertheless signs of a slight ease in both labour shortages and wage growth in the first half of 2019. Finally, the green transition for a highly industrialised and carbon-intensive economy like that of Czechia may require significant investment.

After two very positive years, investment was more restrained in 2019. Following a growth of 3.7% in 2017 and 7.6% in 2018, investment is estimated to have increased by only 1.1% in 2019 and is projected to grow by 1% in 2020 (European Commission Autumn 2019 forecast). Private investment has decreased in 2018, particularly in machinery. The economic slowdown in the main trading partners and the global trade tensions translated into a decreasing number of orders and very weak confidence indicators.

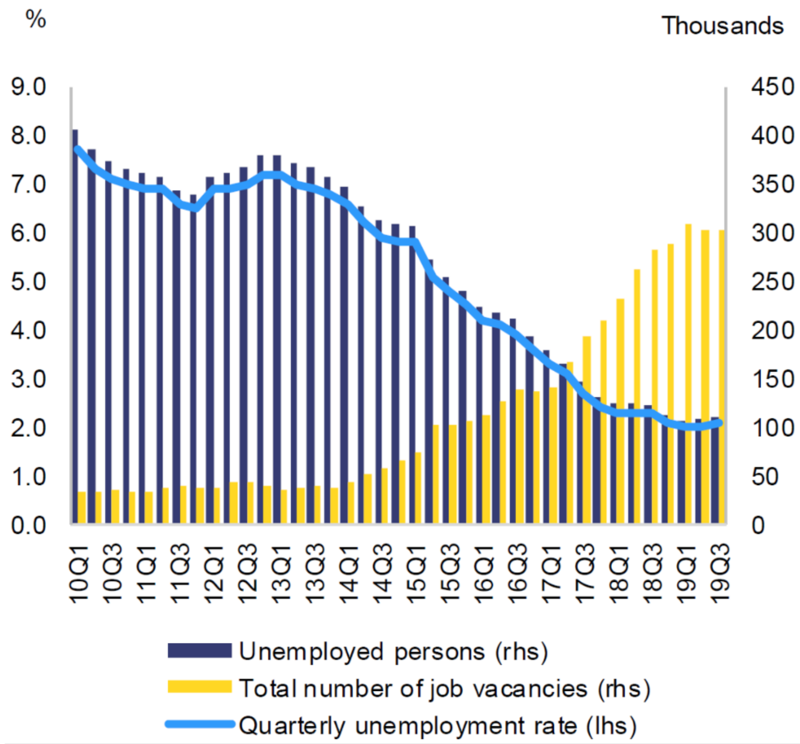
The manufacturing Purchasing Managers' Index (PMI) has decreased to the lowest levels in the last decade – from almost 60 points at the end of 2017, to below 45 at the end of 2019. Public investment, accounting for around 15% of total investment, grew solidly in 2018 due to an inflow of EU funds, but then significantly slowed down in 2019 (see Graph 1.4).

Investment activity remained above the EU average thanks to the manufacturing sector. In 2018, investment activity remained above the EU average: 25.5% of GDP compared to 20.9% (see Graph 1.5). It increased in most sectors, but especially in manufacturing and construction. Labour shortages and wage increases have made investment in automation a priority for firms, particularly in manufacturing, to keep their competitiveness and counter the demographic and technological changes ahead.

Low unemployment levels pushed wages upwards, potentially reducing overall cost-competitiveness. Nominal wages per employee increased by 8% in 2018 following a 6.3% growth in 2017, significantly above the EU average of 2.7%.

The contribution of manufacturing to the economy remains very high. With one of the highest contributions of manufacturing to GDP (23.1%), Czechia ranks above the other Visegrad countries as well as the EU average (14.3% of GDP). The automotive sector is the largest branch of the Czech industry in terms of output. In 2017, it accounted for around 25% of gross total output, 18% of total value added, 13% of total employment and 35% of total exports in the industry.

The strong labour market performance continues but may reach its limits. The employment rate of those aged between 20 and 64 reached 80.4% in Q3-2019, 6.3 pps above the EU average. The activity rate (82.1%) was also well above the EU average (78.8%). The unemployment rate dropped further to around 2%, making Czechia the best performer in the EU. The labour market expansion may have already reached its limits, in particular in Prague and the surrounding region.



Source: Eurostat

Graph 2. *Unemployment and job vacancies*

Foundry production and trends in the Czech Republic

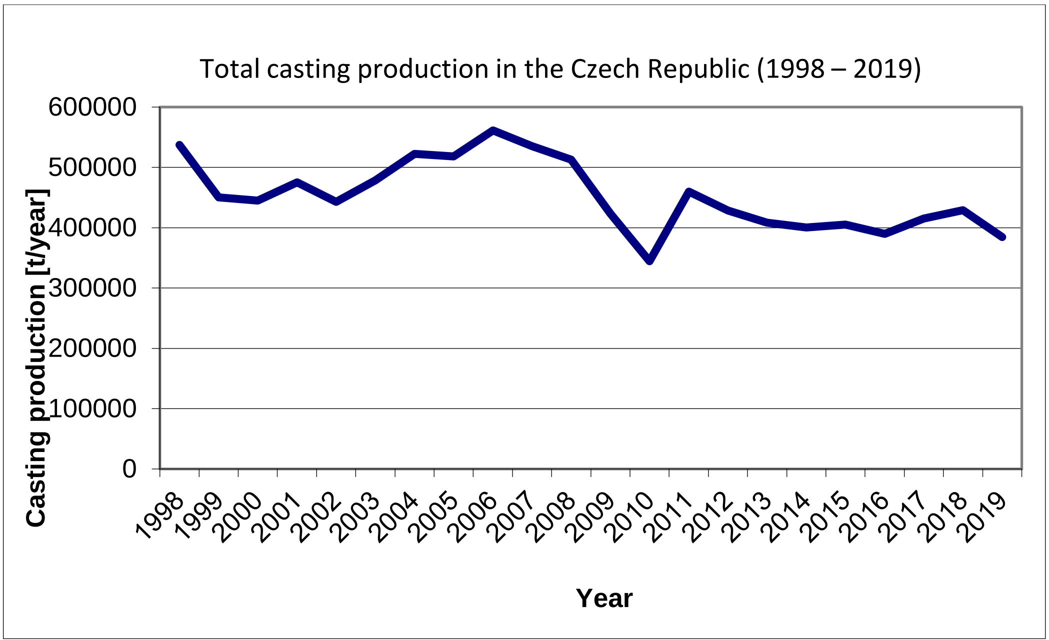
Foundry production in 2019 was like "on the swing." The decline in production at the end of 2018 continued in early 2019. In the spring months the production was fulfilled but during the summer there was a recurrent decline. Autumn did not bring the volumes of orders that foundries would need. Although the production was catching up at the end of the year, the economic result for a number of companies was in the red. Total production was therefore lower in 2019 than in the previous year.

The beginning of 2020 was very "cold" and the expectations of companies did not materialize. In March, the COVID-19 pandemic began, completely paralyzing the foundry industry.

Values given in the table result from investigations of the Czech Bureau of Statistics and investigations made by the Association of Foundries of the Czech Republic.

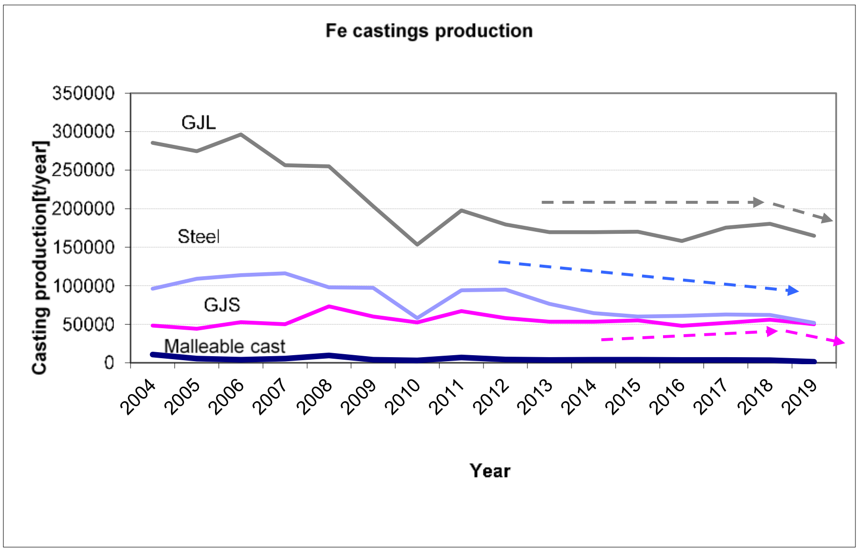
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Malleable cast iron	4068	3145	6951	4307	3722	4100	4000	3800	3760	3500	1500
GJS	60106	52412	67025	58058	53193	53352	55000	48000	51850	56000	50000
GJL	203238	153344	197666	179394	169456	169654	170000	158000	175450	180500	165000
Steel	97366	57888	94013	94929	76380	64606	60000	61000	62650	62000	52000
Fe metals total	**364778**	**266789**	**365655**	**336688**	**302751**	**291712**	**289000**	**270800**	**293710**	**302000**	**268500**
Light metals	52896	65369	80049	77457	88125	88826	95000	98000	100953	105000	96000
Other non-ferrous metals	5498	12227	14241	14506	17482	20034	21000	21000	20650	22000	20000
Non-ferrous metals total	**58394**	**77596**	**94290**	**91963**	**105607**	**108860**	**116000**	**119000**	**121603**	**127000**	**116000**
Total	**423172**	**344385**	**459945**	**428651**	**408358**	**400572**	**405000**	**389800**	**415313**	**429000**	**384500**

Table 1. *Casting production*



Graph 3. *Total casting production in the Czech Republic (1998 – 2019)*

After a healthy 5% year-on-year growth in production in the period 2012 to mid-2018, 2019 continued to fall sharply in orders starting at the end of 2018. Despite the fulfilment of production capacities in spring and autumn, comparable production volumes did not accumulate cumulatively as in the previous year. There was no major revival during the year in which many foundries had hoped. The outlook for orders for ferrous castings was no longer than one and a half months. Existing customers reduced volumes, new projects were difficult to find with an uncertain future. In total, approximately 385,000 tons of castings were produced in the Czech Republic. Production volumes are therefore lower than in the previous year. The foundries optimised production in proportion to orders. Despite the lack of orders there was an aim to maintain a key skilled workforce. Labour productivity is determined by the pieces of orders. For ferrous castings, where seriality is low, it is difficult to find ways to streamline and saves. Foundries are looking for optimization in information technology and software control of individual items. Another way to profitability of foundries is the sale of machined castings or whole components. However, the cost of investment and service personnel is high, and not everyone can afford it.

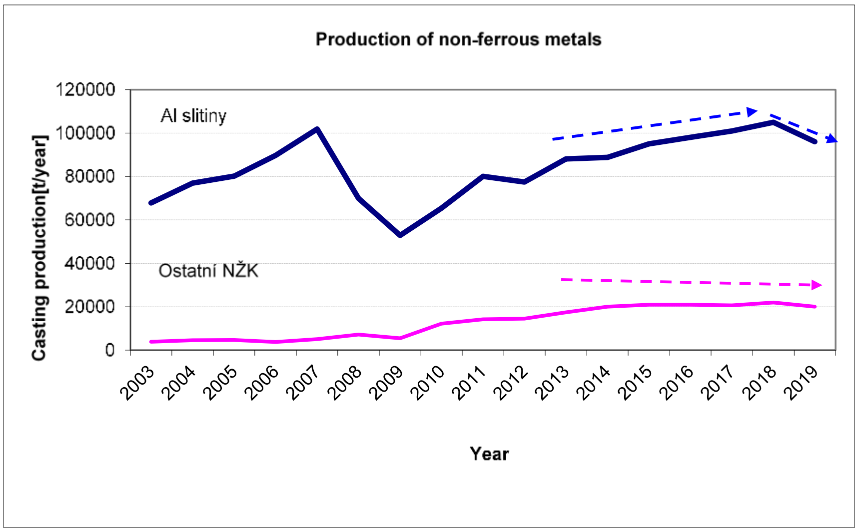


Graph 4. *Production of Fe castings in the Czech Republic (2003 – 2019)*

The total production of Fe castings in 2019 was about 269 thousand tons of castings. The production of cast iron, both GJL and GJS, is comparable to 2010. The year-on-year decrease of production was 11 %. This decline also reflected the stagnant engineering. Composition of orders does not allow to introduce automation in bulk. Low seriality continues to go against productivity. Outputs are influenced by the composition of workers, the profit is dissolved in wages, investments are hardly received. Foundries have stabilized the order volumes according to the existing composition of workers. Small investments are made to help productivity increase, time and energy savings. The advantage have foundries with higher seriality of orders where investments in special purpose equipment have a faster return. The current orders of both GJL and GJS castings are very strongly affected by the COVID crisis, which has manifested itself in its entirety. Due to the low number od orders the delivery dates are kept. Limited mobility has stopped the possibility of finding new projects.

Graph 5. *Production of steel castings in the Czech Republic (2000 – 2019)*

After a stable period up to 2016, the volumes of steel casting production decreased slowly. Total production in 2019 was 52 thousand tons, which is the least in the history of the Czech Republic. Interest in "carbon steel" which is replaced by GJS continues to decline. The remaining production of steel castings is based on alloyed and special steels. The low productivity of steel plants is given by the low seriality of orders. High input prices, metallurgical complexity and emphasis on the quality of alloyed steels drive the prices of these castings up. Not everyone is able to accept prices and is looking for adequate substitutions. For small pieces one of the ways is 3D printing of metals. This trend will continue in the coming years. The production of steel castings is specific only to a certain segment of the market that is willing to accept the price.



Graph 6. *Production of non-ferrous metals in the Czech Republic (2003 – 2019)*

In case of non-ferrous metal castings, the growth of die-cast castings from Al alloys stopped. The total production in 2019 was about 96 thousand tons. The main driver of orders is the automotive industry. Production volumes increased slightly at purpose-built foundries (Škoda auto, Ronal). Commercial foundries have adapted to the agreed volumes from the end of 2018, in the second half of 2019 there was a decrease in orders. Cumulatively the production volumes are comparable to 2015. High productivity relies on modern technologies with the mass use of robots. It's the only way to succeed in the pressure of competition on casting prices.

The production of copper alloy castings has not seen any changes and it continues to reach about 20 thousand tons. Power engineering continues to be the main customer. The current order volumes correspond to the production possibilities of foundries. Labour productivity is low and relies on the skill of qualified personnel.

The total production of the Czech foundry industry in 2019 was lower compared to 2018. The total production of 384,500 tons of castings means a decrease of about 11 % compared to the previous year. The expected recovery did not occur, rather the opposite. At the end of the year, there was a further decline in the outlook for new orders and the production began to decline even in early 2020. By the end of the year, the entire foundry industry had seen this approximately 8% decrease. In 2018/2019 there was a 15% increase in workers' wages. This significant increase in the cost of companies has weakened their competitiveness. Despite the wage increase it is not possible to find new young employees and the age average of foundry employees continues to grow. The year 2020 was very strongly influenced by the COVID-19 crisis, which totally paralyzed our foundry industry. This crisis has put not only our foundries in an unenviable position. This situation most affected suppliers in the automotive industry, i.e. pressure foundries of Al alloys. Companies are waiting for the emergency to be lifted and are calling for the lifting of restrictions and the opening of business premises as soon as possible. The year 2020 will be difficult for many foundries, we will see what steps the Government of the Czech Republic will take to save the Czech industry, which historically includes foundry industry too.

REFERENCES

[1] COMMISSION STAFF WORKING DOCUMENT, Country Report Czechia 2020, Brussels, 26.2.2020, SWD (2020) 502 final

FOUNDRY PRODUCTION IN EGYPT

National representation in the WFO:
EGYPTIAN FOUNDRYMEN SOCIETY

Report provided on their behalf by
Prof. Adel Nofal, CMRDI

Production

The total casting production of the Egyptian foundry industry has suffered as the whole industry worldwide due to the unexpected health crisis that hit the whole world starting from spring of 2020. However, a new automotive foundry for iron and steel castings has been launched in the beginning of this year, with a total capacity of 30,000 t/year at Helwan Iron Foundries in Cairo. Moreover, another automotive foundry has been contracted at Delta Steel Mills with total capacity of 20,000 t/year and the production is planned to start by the end of 2021.Meanwhile, the Egyptian Company of Aluminum is ready to invest in a new modern foundry for aluminum wheels with an annual production of 1 million wheels in the 1st stage to be doubled in the 2nd.

Challenges

The same serious challenges mentioned in the last year's report are still facing the Egyptian foundry industry, namely:

- Dependence of the industry on import of a good part of the input raw material, a situation is aggravated by the serious devaluation of the Egyptian currency;
- The continuous rise of the energy prices;
- Lack of human resources development programs;
- The need to revise the investment incentive regulations.

All these drastically detract from the competitiveness of the Egyptian foundry industry.

Technical Support

The start of the initiative of the National Scientific Foundry Network jointly organized by the Academy of Scientific Research and Technology of Egypt together with the Central Metallurgical Research and Development Institute has been postponed as a result of the current health situation in the country. Hopefully, the Network will take off by the start of 2021 with its planned short R&D programs oriented to solve some of the technical problems facing the foundry industry in the country, particularly in the small and medium sectors.

Conferences

The international Egyptian Foundry Conference was organized in Hurgada, in the beginning of this year, with rather limited international contribution.

FOUNDRY PRODUCTION IN FINLAND

National representation in the WFO:

ASSOCIATION OF FINNISH FOUNDRY INDUSTRY

WWW.TEKNOLOGIATEOLLISUUS.FI/EN/FEDERATION/BRANCH-ASSOCIATIONS

ECONOMIC BACKGROUND

The Finnish Technology Industry as a whole

The turnover of technology industry companies in Finland grew by 6 per cent in 2019 from 2018. Turnover was up in all main sectors except metals industry. In 2019, the turnover in Finland amounted to EUR 83 billion. The effects of global economic uncertainty and weakening demand remain apparent in Finnish technology industries. The rise in the value of technology industry companies' new orders in the fourth quarter is almost exclusively attributable to very large ship orders. Without these, the value of new orders would have remained more or less unchanged from the previous quarter.

The number of requests for tender received by technology industry companies dropped further. The companies that took part in the Federation of Finnish Technology Industries' survey of order books reported that the monetary value of new orders between October and December was 15 per cent higher than in the preceding quarter and 17 per cent higher than in the corresponding period in 2018. At the end of December, the value of order books was slightly higher than at the end of September and 9 per cent higher than in December 2018. It is important to note that shipyards' share of the total value of books is exceptionally large. The strengthening of the ship building industry drives broad-based growth in many sectors. The number of personnel employed by technology industry companies in Finland was up slightly more than 3 per cent from the 2018 average. The average number of personnel employed was 319,000, approximately 10,000 more than in 2018. Technology industry companies' recruitments also took a downward turn towards the end of the year. They recruited a total of 40,500 new employees in 2019. In 2018, total recruitments came to 50,000.

Mechanical Engineering in Finland

The turnover of mechanical engineering companies (machinery, metal products and vehicles) in Finland increased by approximately 3 per cent in 2019 from 2018. In 2019, their turnover in Finland amounted to EUR 32.8 billion. The value of new orders in mechanical engineering was up 21 percent from the previous quarter in the October-December period. Year-on-year, the value of new orders increased by 7 per cent in the last quarter. The increase in the value of new orders towards the end of 2019 is almost exclusively attributable to very large ship orders. Without these, the value of order books would have dropped notably from the previous quarter. Differences between individual companies have widened notably also in this sector.

At the end of December, the value of order books remained at the same level as at the end of September and 5 per cent higher than in December 2018. Shipyards' share of the total value of order books is exceptionally large. The strengthening of the ship building industry drives broad-based growth in many sectors.

The number of personnel employed by mechanical engineering companies in Finland grew by approximately 2 per cent from the 2018 average. The industry employed some 134,200 people, up 2,900 from 2018.

Metals Industry in Finland

The turnover of metals industry companies (steel products, non-ferrous metals, **castings** and metallic minerals) in Finland decreased by approximately 5 per cent in 2019 from 2018. In 2019, their turnover in Finland amounted to EUR 10.6 billion. The total production of steel products, non-ferrous metals, **castings** and metallic minerals in Finland in the January-November period decreased by as much as 10 per cent year-on-year.

The number of personnel employed by metals industry companies in Finland decreased by approximately 0.5 per cent from the 2018 average. The industry employed some 15,800 people, approximately 100 less than in 2018.

FOUNDRY INDUSTRY IN FINLAND

Foundry industry as a whole

In the year 2019 the total production of castings in Finland decreased about 10 % in 2019 from 2018. The production of iron and steel castings was 57.843 tons which is 10 % less compared to year 2018. Iron and nodular iron casting production decreased about 13 %, but steel casting production increased about 3 %. Metal castings production was 5.308 tons, which is about 4 % less than the previous year. The value of the casting production of Finnish foundries was 229 m€, which is 14 % less compared to year 2018.

The foundry industry employed 1,645 people, 131 less than in 2018.

Grey cast iron sector in Finland

Overview of the Finnish grey cast iron production, year 2019:

	2018	2019	%
▪ Number of GJL foundries	11	11	
▪ GJL production	18.390 t	18.161 t	- 1 %
▪ Value of the GJL production	37,73 m€	34,35 m€	- 9 %
▪ Export of GJL castings	3.599 t	3.905 t	+ 9 %
▪ Employees in iron foundries	800	724	- 10 %

Ductile cast iron sector in Finland

Overview of the Finnish ductile cast iron production, year 2019:

	2018	2019	%
Number of GJS foundries	11	11	
GJS production	36.161 t	29.285 t	- 19 %
Value of the GJS production	89,21 m€	71,54 m€	- 20 %
Export of GJS castings	14.893 t	8.957 t	- 40 %
Employees in iron foundries	800	724	- 10 %

Steel castings sector in Finland

Overview of the Finnish steel casting production, year 2019:

	2018	2019	%
Number of steel foundries	7	7	
Steel casting production	10.094 t	10.397 t	+ 3 %
Value of the GS production	76,08 m€	71,85 m€	- 6 %
Export of GS castings	2.945 t	1.597 t	- 46 %
Employees in GS foundries	563	540	- 4 %

Non-ferrous casting sector in Finland

Overview of the Finnish non-ferrous casting production, year 2019:

	2018	2019	%
Number of non-ferrous foundries	14	14	
non-ferrous production	5.526 t	5.308 t	- 4 %
Value of the non-ferrous production	62,10 m€	51,00 m€	- 18 %
Export of non-ferrous castings	2.591 t	1.657 t	- 36 %
Employees in non-ferrous foundries	413	381	- 8 %

FOUNDRY PRODUCTION IN FRANCE

National representation in the WFO:
ASSOCIATION TECHNIQUE DE FONDERIE (ATF)
WWW.ATF.ASSO.FR

Review of French Foundry for 2019 and tendency for first half of 2020

France maintained his position as a major foundry country in 2019 and will do surely the same in 2020. After many decades in second position in "competition" with Germany, France has the 3rd position in Europe with a position in line with general world foundry economy. France continues to be on the top 15 countries in the world for the foundry activity with a volume close to 1.69 MTons and with a turnover around 5.14 billion of euros lower than 2018 at 5.1%… but similar to 2018 in term of number of employees and working sites.

Focus on : Casting industry in France in 2019 data from FFF

5,14	29 724	1,69	380
billion € turnover	people	million tons de produits	production sites
(5,7 in 2018)	(30 025 in 2018)	(1,78 in 2018)	(380 in 2018)

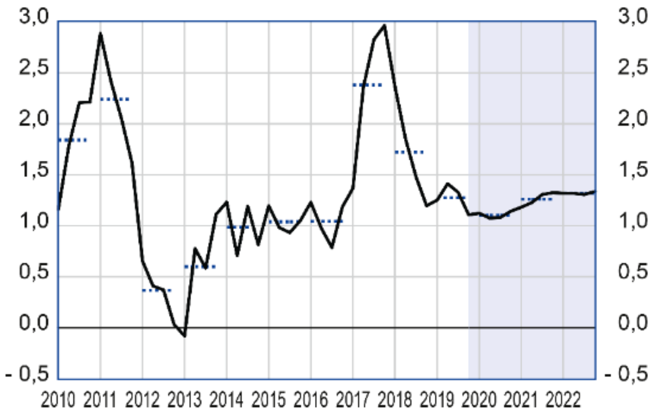
French foundry association networks

The foundry organisation in France is still organised around 3 associations-federation: ATF – FFF & AAESFF. ATF (www.atf.asso.fr), representative of France at the WFO, continues to federate the foundry technicians including students, researchers, engineers, technicians, foundry owners or managers, suppliers and foundry retired persons. FFF (www.forgefonderie.org/en), one of the members who created the WFO with ATF, is the official representative of Foundry Industry to the French governmental institutions and federates a certain number of French foundry companies. FFF is representative of France at the CAEF and publishes 4 to 5 times a year the newspaper: "La Revue Forge et Fonderie". AAESFF (https://www.aaesff.fr) is the Academy of past graduated Foundry Technicians and Engineers from "ESFF": the French foundry engineer school, one of the unique foundry engineer schools in the world: (http://www.esff.fr/)

And to finish this French overview, ATF is publishing an e-revue: « TECH News FONDERIE » which proposes 7 times per year, a national, local, international, technical and scientist review: http://atf.asso.fr/wordpress/tech-news-fonderie/

France: general economic information's

GDP-PIB in France decreased month by month and 2019 presented a result around + 1.3% after a relative better number of 1,7 % for 2018 (according Insee or Banque de France). However, beginning of 2020 would be less exciting and "specialists" of economy looks for a GDP ratio around 1,1% for the present and next years. This decreasing is mostly due to the COVID-19 pandemic which slows down the economy and the activities of most of the companies:



SYNTHÈSE DES PROJECTIONS FRANCE

	2016	2017	2018	2019	2020	2021	2022
PIB réel	1,0	2,4	1,7	1,3	1,1	1,3	1,3
IPCH	0,3	1,2	2,1	1,3	1,1	1,3	1,4
IPCH hors énergie et alimentation	0,6	0,5	0,9	0,6	1,0	1,3	1,4
Déflateur du PIB	0,5	0,5	0,8	1,5	0,8	0,9	1,2

In the euro area, consumer price inflation is measured by the Harmonised Index of Consumer Prices (HICP). It measures the change over time in the prices of consumer goods and services acquired, used or paid for by euro area households.

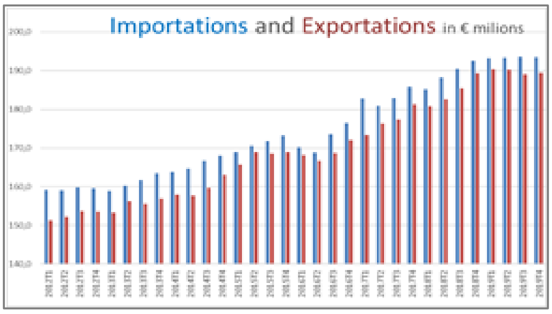
Figure 1. *Banque de France prédictions: https://www.banque-france.fr/*

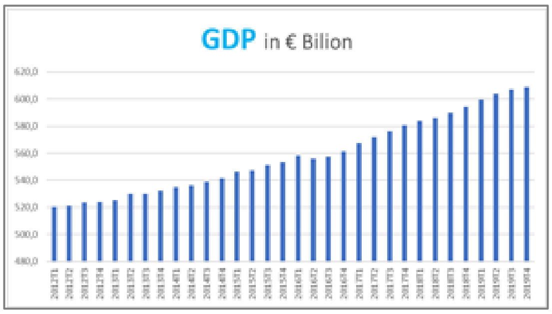
GDP-PIB and IPCH evolution in % and future estimation for France

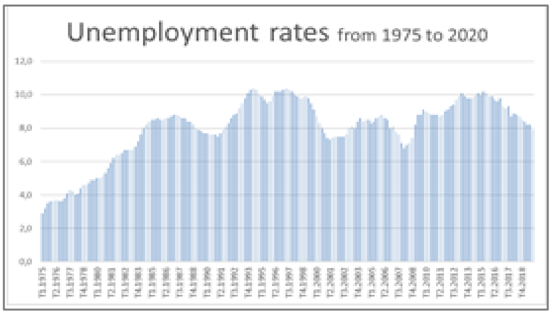
For inflation rate, after an increase in 2019 around 1.3% (IPCH was at a level at 2,1% in 2018) that factor would go back at a level of 1,1 (excluding potential energy effect).

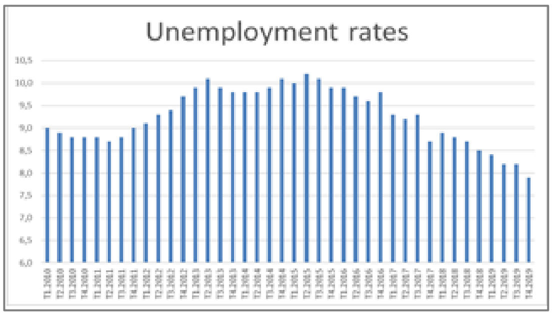
Regarding "import-export balance": France continues to be strongly penalized by import of energy supplies and by all imported industrial goods like machine tools and for foundry, for example, robot for any domain as core making shop, remoulding, fettling, …

But, the imports/exports rates which remain stable since 2018 is desynchronized with GDP increase due to the latest commercial strategies from the companies which are looking for local suppliers. Anyway, the French foundries continue to present a respectable activity at the export due to their strong and technical recognized knowledge and their capacity to produce difficult and technologic castings.







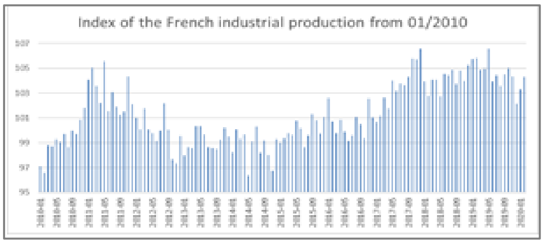


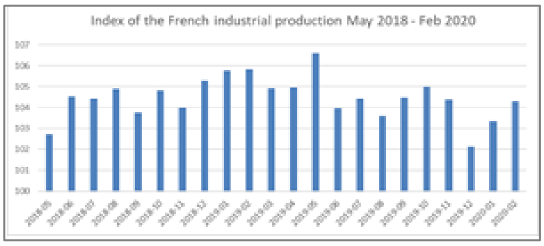
***Figures 2 to 5.** Insee data and charts: CVS & CJO adjustments*

Unemployment: this parameter takes in consideration all the persons who look for a job and who receive a subsidiary from the government. This data could have not the same perimeter in other countries … so the comparison must be moderate.

The tendency is looking for a decrease. The demand for employment in foundry is effective but the problem is dramatically the following: “a lot of foundries cannot find employees or have difficulties to find employees mainly for “hand works” activities and now, more and more frequently for “technical expert” job “.

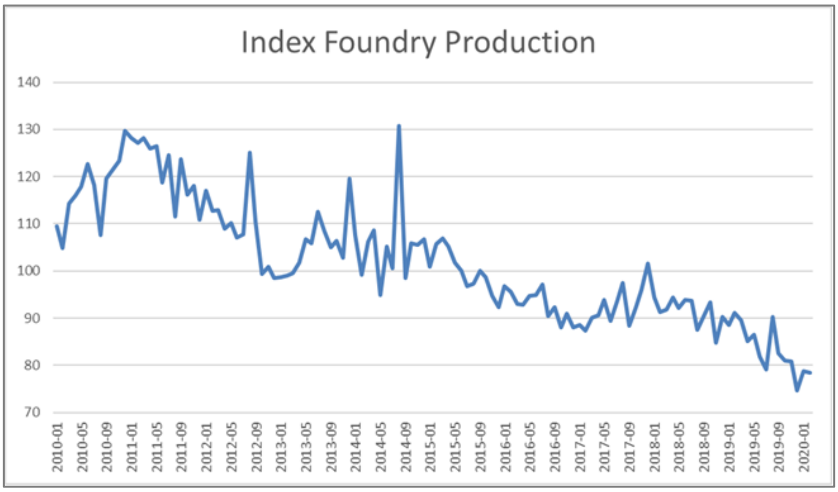
If the French Industrial Production index (all manufacturing industries) presented a general positive increase from 2014, the last 24 months confirm a stable activity with a very small tendency for mostly due to the COVID-19 pandemic.

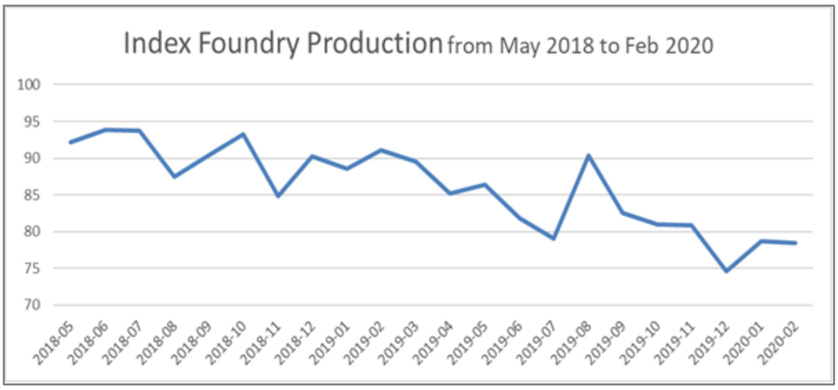




***Figures 6 to 7.** French Industrial Production*

French Foundry review for 2018, 2019 and beginning of 2020





Figures 8 to 9. *Insee data and charts: CVS & CJO adjustments*

The French foundry activity, in term of index (http://www.insee.fr), but not in term of volume, continues to present a decrease from 2011. But for the period May 2018 – February 2019, the deflation is looking to become stabilized but still a in decrease mostly due to COVID-19. That effect is mainly due to the reorganisation of the market; some old and no "efficient foundries" (for an economic aspect) were closed and others invested and invest for automatization like robot, simulation, new automatic lay-out, computer integrated chain and Foundry 4.0!

The global French production of castings for 2019 is according FFF (French Foundry Federation) at a level of 1 696 000 tons less than 2018 a year at 1 781 212 Tons!

2018 Casting Production (metric tons)

Country	Gray Iron	Ductile Iron	Malleable Iron	Steel	Copper Base	Aluminum	Magnesium	Zinc	Other Nonferrous	Total
France	597,400	682,100	-	60,400	19,307	394,727	-	24,854	2,424	1,781,212

Figure 10. *French foundry production in 2018 (Census – Modern Casting –dec 2019)*

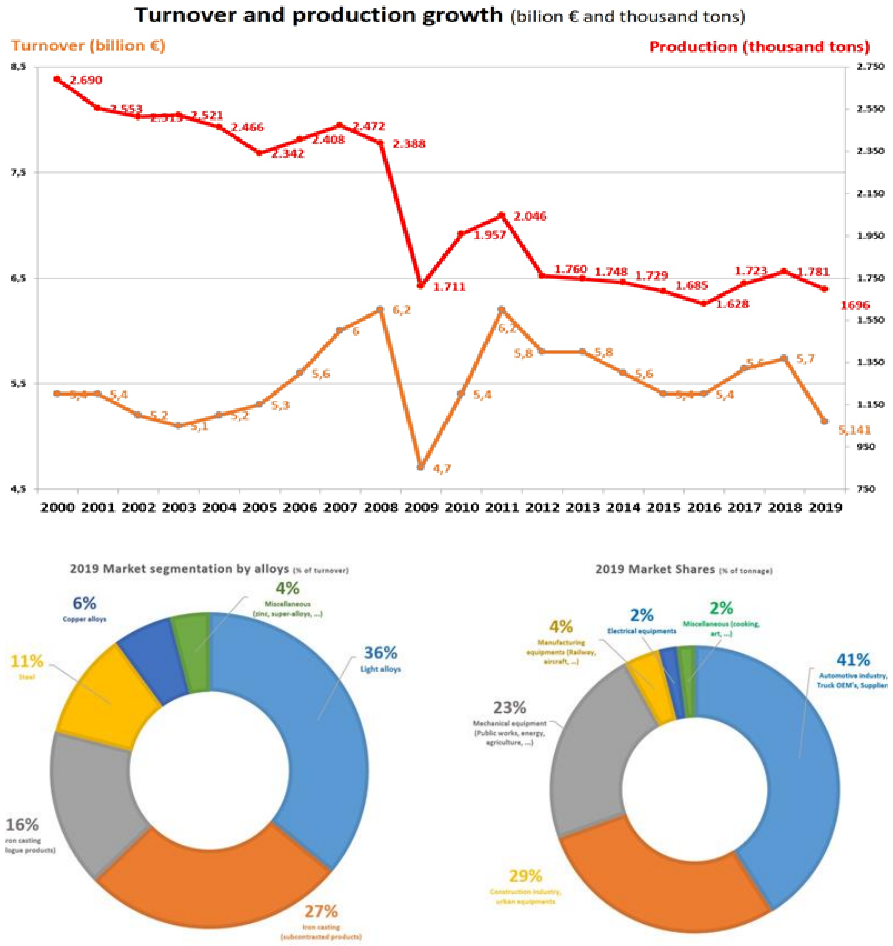


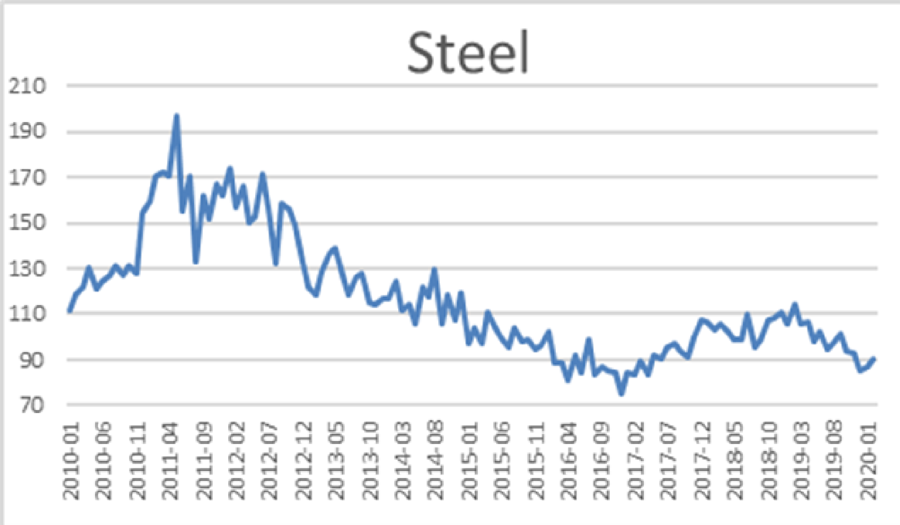
Figure 11. *French foundry production in 2019 (Federation Forge et Fonderie)*

In detail and according the upper charts (www.forgefonderie.org) the French foundry presents a half-half business between Iron or no-Iron activity: 54% in volume for Iron & steel and 46% for light and "others" alloys. Automotive continues to represent 41% of the orders.

These figures show a minor decrease of the automotive industry compared to the last year (45% in 2018 and 41% in 2019) the main reason is the decrease of the automotive industry activity which oblige some foundries to diversify their activities. The "foundry alloy overview" is beginning to change: a certain number of "automotive foundries" decrease their production or are looking for re-organisation including delocalisation-relocalisation … and two or three are close to a potential stop!

However the next lines of this paper and analysis alloys by alloys could propose different conclusions.

Steels foundry statistics after many years in a deflation situation show a small positive improvement comparing with the steel production from the last year. This evolution is to be confirmed with the global heavy industry demands who consume mainly steel parts.


Steel
210
190
170
150
130
110
90
70
2010-01
2010-06
2010-11
2011-04
2011-09
2012-02
2012-07
2012-12
2013-05
2013-10
2014-03
2014-08
2015-01
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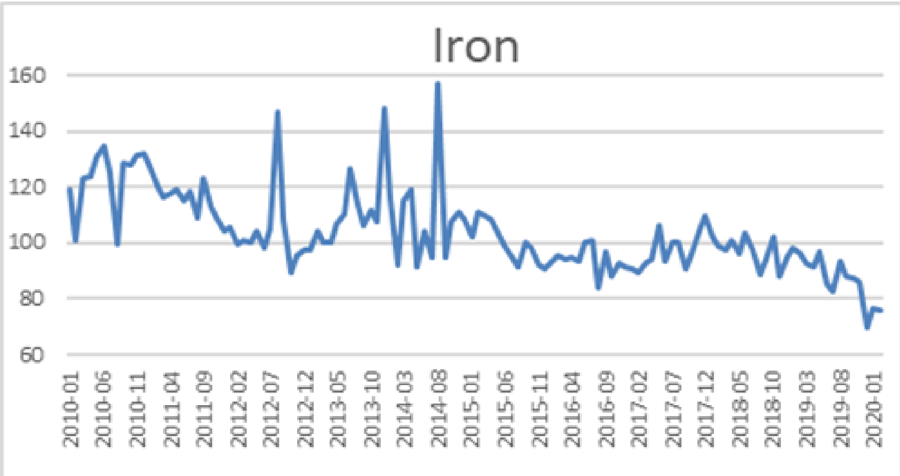
2019-08
2020-01


Iron
160
140
120
100
80
60
2010-01
2010-06
2010-11
2011-04
2011-09
2012-02
2012-07
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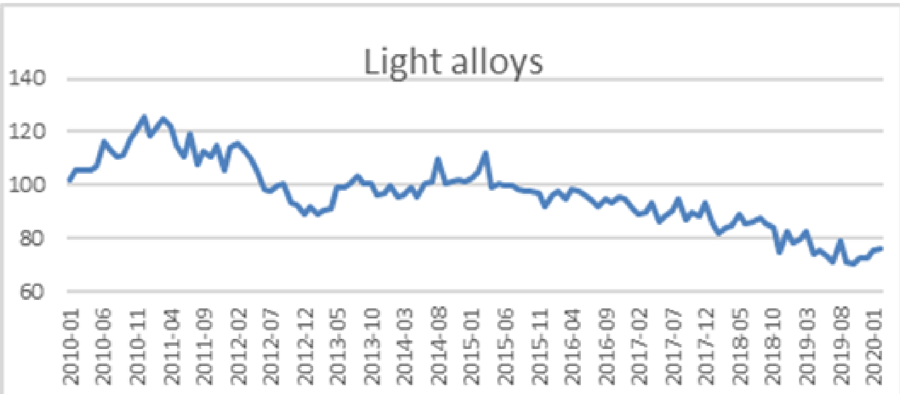
Light alloys
140
120
100
80
60
2010-01
2010-06
2010-11
2011-04
2011-09
2012-02
2012-07
2012-12
2013-05
2013-10
2014-03
2014-08
2015-01
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2019-03
2019-08
2020-01

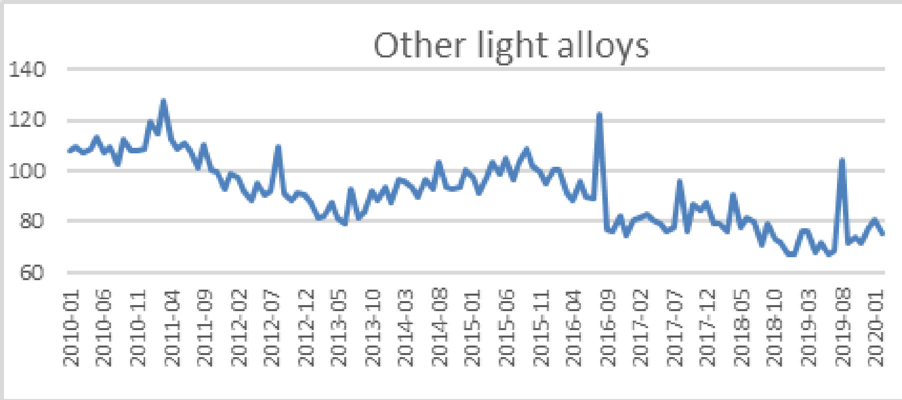


***Figure 12 to 15**. All the previous charts and Indices of foundry production per alloy – Feb 2020 (January 2010 – Feb 2020) are coming from Insee website (Insee data and charts: CVS & CJO adjustments)*

Iron evolution in France is strongly depending to ""pipe, street, heating parts, named "catalogue product" in the French statistics"" with a level of 16%" versus 27% for "subcontracted parts" as described in upper picture from FFF. The last estimations and tendencies show stability and a potentially low increase for the next years.

Light alloys business, mainly aluminium, is directly connecting with automotive activity. Due to demand for reducing working capital plus the huge number of new models, the volume of production for automotive has to be adjusted at the demand. And by same time, the demand for local suppliers to reduce time of deliveries had a direct effect of French foundries involved in international market. That is not new, but that is more and more stick to the final area's demand for car!

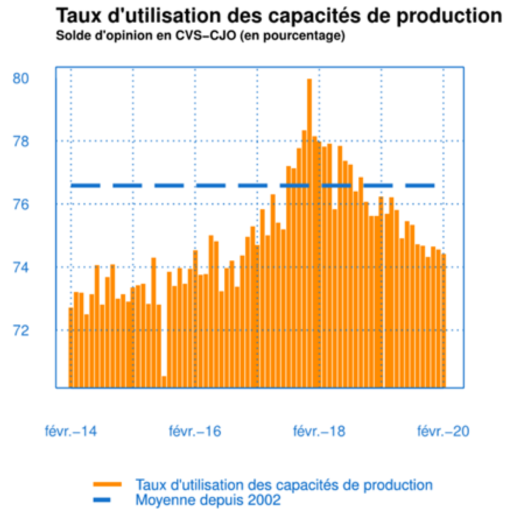
For other alloys, France has a good and well recognized technical knowledge for these special alloys like magnesium, titanium, zinc and copper alloys used in many domains like aeronautic, special pumps & valves, nuclear and chemical plants, ships & boats, railways and train, all medical domains, arts, …but the business is confronted at a low price completion. Only aeronautic with Mg & Ti business presents a potential increase to compensate the other alloys deflation!

French Foundry Tendencies for 2020

After a past autumn and winter with many conflicts and the Covid-19, the industry in France, including foundry, will need some years to recover and make some companies closing due to bankrupt. According some newspaper like "Figaro" the number of unemployment (people who receive a governmental subsidiary) would continue to increase in 2020. For the "Echos" a business-economy newspaper, a drastic decrease of GDP is to be predicted proposed. The government is managing to restart the industries to prevent further bankrupts and decrease the unemployment. The inflation remains still under control.

But the Economic situation of mechanical & metallurgical industries by end of February 2020 according "Banque de France" would be not so positive. The example of "Using rate of production facilities for metallurgical industries" (Banque de France data's) in France is not so enthusiastic! After a pic by end of 2018, the industry (metallurgy) has a present use of its capacity at 75% better than two years ago but in a decreasing tendency.

Using rate in % of production facilities (saison fluctations integrated)
orange line = current using
blue line : average until 2002



Conclusion

France, its foundries, and its economy were in a more difficult situation than in 2018 even some national and local conflicts and the productions losses caused by the COVID-19 created a lake of around 0.4 point for its GDP. The French foundry activity would be better but the global turnover, but the tonnage is in a small decreasing tendency! That means the French foundries didn't accept to reduce their price for a bigger volume! That confirms also that France continues to maintain its capacity to produce difficult castings with a high ratio: price – weight - mechanical demands and quality.

Reference:

http://www.insee.fr/fr/bases-de-donnees/

http://www.atf.asso.fr

http://www.forgefonderie.org

https://www.banque-france.fr/

FOUNDRY PRODUCTION IN HUNGARY

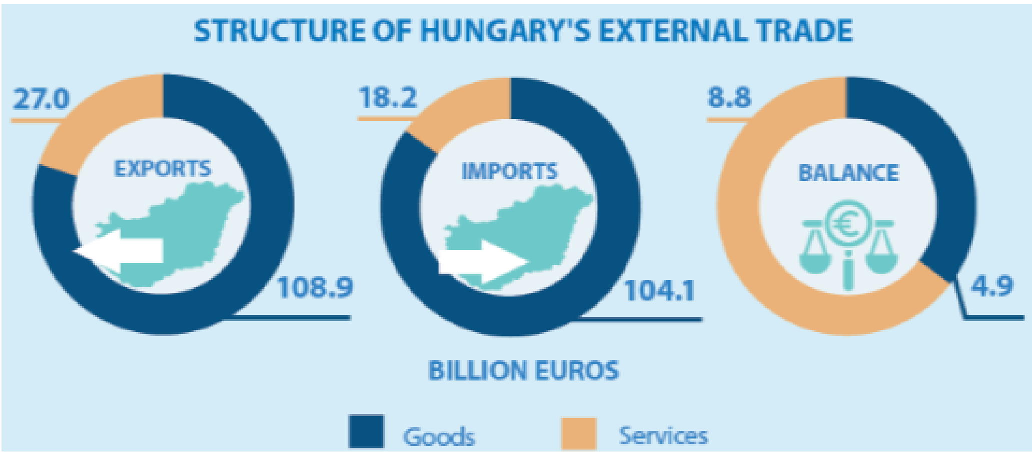
National representation in the WFO:
ASSOCIATION OF HUNGARIAN FOUNDRIES
WWW.FOUNDRY.HU

Report provided with the collaboration of the
HUNGARIAN MINING AND METALLURGICAL SOCIETY
WWW.OMBKENET.HU

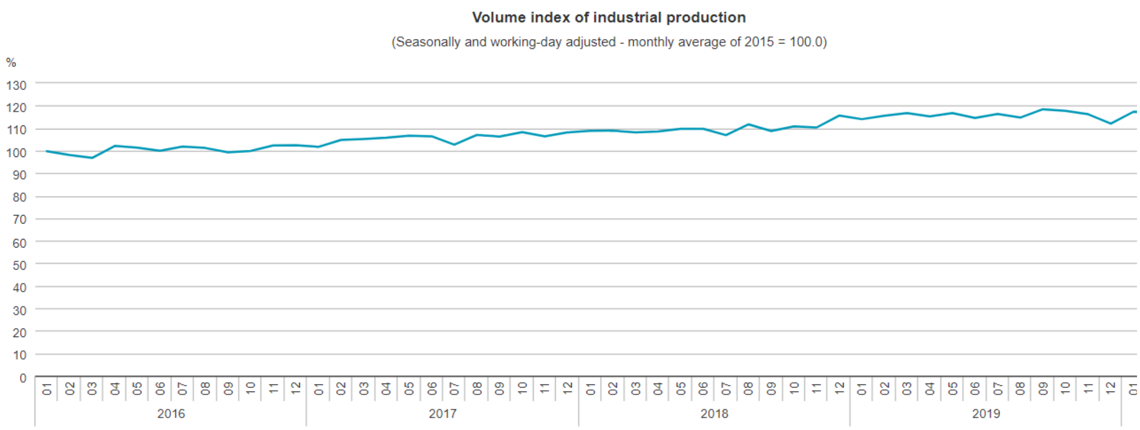
Some figures of the Hungarian average economy

2.2 %	2.2 %	9.8 million persons	3.7 %	69.7 %	-5.6 %
Inflation	GDP	Population	Unemployment rate	Employment rate	Industrial production
May 2020	Q1 2020	2020	Q1 2020	Q1 2020	March 2020

Hungarian external trade



Hungarian industrial production until the end of year 32019



Short report of the Hungarian foundry industry 2019

The basically export orientated Hungarian foundries have had a relative steady market position during the last years. But after 6 years the production of Hungarian foundry industry in 2019 showed a decrease to the former years. The real reducing is -13% - according to the comparison of years, 2019 and 2018. It was more than natural that the figures for 2020 was created on a moderate but still optimistic basis again.

The producing of the first half of 2019 in the Hungarian foundry industry was significantly not different to the former year. From the 3rd quoter of the year (even the 4th one) has showed already that the increasing is stopped, and a slow decreasing has started practically in all segments of the Hungarian foundry business – see the next table of the last three years' data of the Hungarian casting productions.

Hungarian casting productions 2017-2019 (Value in tons)				
Denomination	**2017**	**2018**	**2019**	**19/18**
Grey iron casting	24 210	21 616	18 016	
Nodular iron castings	37 783	38 468	36 408	
Compacted graphite iron castings	16 740	26 969	19 210	
Alloyed iron castings	389	401	378	
Malleable iron castings	10	7	3	
Total iron castings	**79 132**	**87 452**	**74 015**	-15%
Unalloyed steel castings	2 216	1 361	1 419	
Alloyed steel castings	911	1 452	763	
Total steel castings	**3 127**	**2 813**	**2 182**	-22%
Aluminium gravity die castings	61 328	57 410	49 234	
Aluminium pressure die castings	61 450	78 962	73 058	
Aluminium sand castings	124	146	133	
Total aluminium castings	**123 902**	**136 518**	**122 425**	-11%
Bronze castings	417	230	181	
Brass castings	1 305	475	302	
Zinc castings	1 717	1 610	763	
Other heavy metal castings	76	93	48	
Total heavy metal castings Incl. investment cast.	**3 515**	**2 408**	**1 294**	-46%
Magnesium castings	**327**	**273**	**250**	
TOTAL	**210 003**	**228 462**	**200 166**	-13%
Investment casting all together in total	**753**	**762**	**766**	

Table 1. *Hungarian Casting production 2017-2019*

FOUNDRY PRODUCTION IN INDONESIA

National representation in the WFO:

APLINDO (Indonesian Foundry Industries Association)

WWW.APLINDO.WEB.ID

Report provided with the collaboration of

GROWTH STEEL

WWW.GROWTHSTEEL.COM

What is APLINDO

INDONESIAN FOUNDRY INDUSTRIES ASSOCIATION (Asosiasi Industri Pengecoran Logam Indonesia), abbreviated as APLINDO, established on December 9, 1981 is an organization that is used as a tool of struggle to create a healthy industrial climate in Indonesia, striving for industry to grow and develop towards a self-reliant industry that is strong and efficient so that its products can compete strongly in the global market.

Vision

To place the Indonesian foundry – a strategic up-stream industry – in a strong and firm position and to become the foundation for developing machinery and metal industry, so that it will be able to help accelerate the national economic growth.

Mission

To assemble companies which are working on foundry and those involved with foundry. To strengthen relationship, to initiate cooperation and to harmonize common steps among foundry industries. To realize a self- supporting machinery and foundry industry. To apply valuable and appropriate technology, so that the products are able to compete on the global market.

Secretariat Address

Komplek Perkantoran Graha Kencana, Jl. Pejuangan No.88, Blok GK, Lt.6 No. 6C, Kebon Jeruk, Jakarta-Indonesia 11530.

Members Association

Aplindo's members consist of the ductile and steel casting industry, malleable casting, aluminum casting and die casting, lead recycling dan smelter aluminum which are engaged in automotive components, heavy equipment, weaponry, medical devices, Agriculture, mining, manufacturing tools and equipment.

Note: not all foundry industries in Indonesia are registered as APLINDO members

1. Ferro Casting (Malleable, Ductile, Grey, Steel Casting)

Aplus Pacific, PT.
Asia Raya Foundry, PT.
Asian Isuzu Casting Center, PT.
Bakrie Autoparts, PT.
Barata Indonesia, PT.
Bina Usaha Mandiri Mizusawa, PT.
Cipta Baja Raya, PT.
Geteka Founindo, PT.
Growth Asia, PT.
Hansa Pratama, PT.
Indoprima Gemilang, PT
Inter Satria, PT
Jatim Taman Steel, PT
Karya Hidup Sentosa, CV
Komatsu Indonesia, PT
Pakarti Riken Indonesia, PT
Pindad (Persero), PT
Prima Alloy Steel Universal, PT
Sinar Agung Selalu Sukses, PT
Yanmar Indonesia, PT

2. Investment Casting

Metinca Prima Industrial Works, PT
Peroni Karya Sentra, PT.
Stainless Steel Primavalve Majubersama, PT.
Trieka Aimex, PT.
Zenith Allmart Precisindo, PT

3. Alumunium Casting (Sand and Die Casting)

Aluzindo Paduan Mulia, PT
Astra Daihatsu Motor, PT
AT Indonesia, PT.
Central Motor Wheel Indonesia, PT
Moradon Berlian Sakti, PT
Nakakin Indonesia, PT
Pakoakuina, PT
Chemco Harapan Nusantara, PT.
Wijaya Karya Industri Dan Konstruksi, PT
Yamaha Motor Parts Manufacturing Indonesia, PT

4. Alloy Aluminum Industries

Indra Eramulti Logam Industri, PT.
Non Ferindo Utama, PT.
Muhtomas, PT.

5. Lead Recycle Industries

Daiki Aluminium Industry Indonesia, PT
Indonesia Smelting Technology, PT
Molten Aluminum Producer Indonesia, PT

6. Foundry Material / Equipments Suppliers

Caprefindo, PT.

Dover Chemical, PT

Foseco Indonesia, PT

Sinto Indonesia, PT

Prolimas Utama Jaya, PT.

Tochu Silika Indonesia, PT

Present Condition

The installed capacity of the Indonesian metal casting industry is predicted for ferro casting to be 550,000 tons / year, aluminum casting 250,000 tons / year, aluminum ingots 500,000 tons / year, and lead ingot (pb) 149,000 tons / year.

The casting industry production of APLINDO members in 2019 for iron casting (ductile, gray) amounted to 221,000 tons / year. Investment casting of 4,300 tons / year, steel casting of 65,000 tons / year, aluminum casting 148,000 tons / year, for aluminum ingots amounting to 153,000 tons / year. This amount of production does not include companies that are not affiliated with APLINDO, so it is difficult for us to get accurate data.

In 2020 Indonesia was hit by the Covid-19 pandemic, the foundry industry works around 16-50% of its production capacity, and in Indonesia it has implemented social distancing to the industry provided that the industry continues to operate, the workforce is limited to 50%.

Description	Installed Capacity (Tone/Year)	Performance (%)
Ferro Casting (Ductile, grey, malleable, steel, Stainless Steel)		
Members	393.900	50,2%
Other*	156.100	
Total*	550.000	
Non Ferro Casting (sand and die casting Al)		
Members	168.400	16,5%
Other*	81.600	
Total*	250.000	
Aluminum Ingots		
Members	298.000	23,7%
Other*	202.000	
Total*	500.000	
Lead Ingot (Pb)		
Members	99.000	20,0%
Other*	50.000	
Total*	149.000	

Table 1. *Installed Capacity Casting Industry in Indonesia*

*Note * = predictions*

FOUNDRY PRODUCTION IN ITALY

National representation in the WFO:
ASSOFOND
– ASSOCIAZIONE ITALIANA FONDERIE
WWW.ASSOFOND.IT

The Italian economy and the casting customer industries

Macroeconomic developments

GDP slowed last year, posting a growth of 0.3 per cent. Investment increased considerably less than in 2018, held back by the uncertainty that spread among firms following the slowdown in the global economy and the persistent protectionist tensions. Household consumption was affected by the slow growth in disposable income.

Against a backdrop of a significant weakening in world trade, Italian firms have largely retained their market shares. This was reflected in a widening in the current account surplus, driven among other things by the improvement in the tourism balance; Italy's net international investment position was close to balance at the end of 2019.

As regards the geographical breakdown, economic activity grew in Northern Italy while remaining at the same levels as the previous year in the Centre and in the South.

Employment continued to rise, albeit at a slower pace than in 2018. Its growth, which was stronger in the first half of the year, subsequently faltered, reflecting the cyclical weakening. The unemployment rate declined to 10.0 per cent on average in 2019.

The fiscal policy stimulus, as measured by the cyclically adjusted change in the primary surplus, was slightly restrictive, after being expansionary for the previous five years.

Since the end of February, the spread of the COVID-19 epidemic has had a strongly negative impact on economic activity. GDP fell by around 4.7 per cent in the first quarter; according to the estimates, the reduction appears to have been more pronounced in the Northern regions. The contraction in GDP seems mainly attributable to the sharp drop in household spending. Since March, foreign trade and international tourist flows have been affected by the fall in global demand and the suspension of 'non-essential' productions decreed by the Government to counter the spread of the epidemic. The available indicators signal a significant drop in GDP for the second quarter as well, which will likely be reflected in a sharp fall for this year as a whole.

The public health emergency has led to a reduction in the number of people in employment since March, above all among fixed-term employees; there was a reduction of 0.4 per cent for the first quarter as a whole, compared with the last quarter of 2019. The fall in jobs was in part mitigated by the freezing of layoffs for financial reasons and the boosting of the wage supplementation scheme. The deterioration in labor market conditions may be more pronounced in the spring months, especially in the fixed-term employment segment.

Inflation was very subdued in the first quarter and was barely positive in April. Both the inflation expectations recorded in the euro-area financial markets and Italian firms' intentions regarding their own prices for the next 12 months were revised downwards.

The outlook for the public finances has been drastically changed by the public health emergency. According to the official forecasts, the deficit-to-GDP ratio for 2020 and 2021 is expected to be higher by 8 and 4 percentage points respectively, compared with the figures planned during the last budget session; the debt-to-GDP ratio is expected to increase by more than 20 percentage points this year, to 155.7 per cent, and to diminish in 2021 thanks to the economic recovery.

A return to growth for the Italian economy in the next ten years is possible provided there are adequate increases in labour market participation and in employment, in investment, and in productivity.

The situation in the major casting customer industries

In 2019 the situation of the most important customers was not good. With the exception of construction machinery and equipment and agricultural machinery, all other industries closed with a negative sign:

- automotive: -14%
- crude steel: -5%.
- machine tool, robot and automation industry: -2.6%
- agricultural machinery (flat)
- weak growth for general engineering +1% and building sector +2%
- strong growth for construction machinery and equipment industry: +15%

In the first quarter of the 2020, with the exception of building, the other industries had double-digit declines, exception made for general engineering: -8%.

- automotive: -24%
- crude steel: -16%.
- machine tool, robot and automation industry: -11%
- agricultural machinery: -20%
- construction machinery and equipment industry: -14%

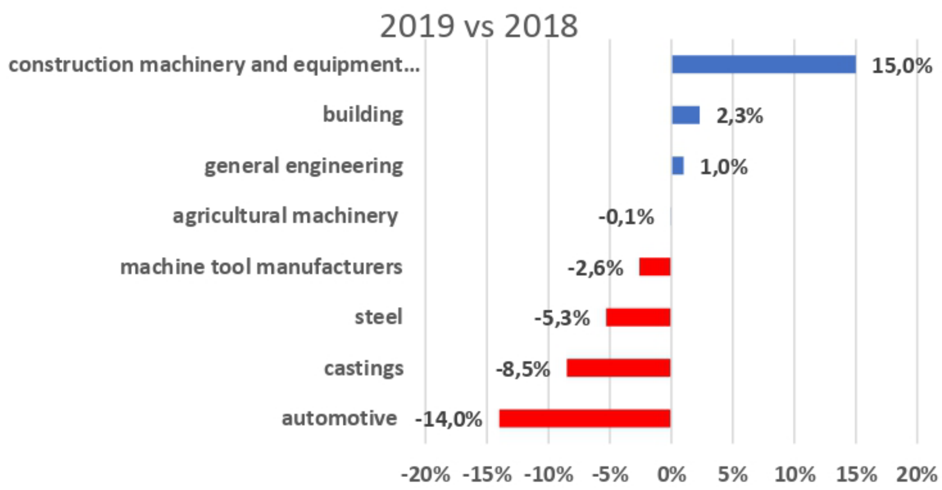


Figure 1. *Situation 2019 vs 2018*

According to figures from ANFIA (the Italian Association of the Automotive Industry), in 2019 the total number of vehicles made in Italy was **915,305 units**, a fall of **-14%** compared to 2018 (**-7%** in 2018). This comprised **542,007** passenger cars (**-19%** on 2018), **312,377 light vehicles** (**-4%**), **60,294 trucks** (**-6%**) and **627 buses** (**+67%**).

The year 2019 marked the end of the positive trend, started in 2014 by the Italian **machine tool, robot and automation industry**. Nevertheless, the registered decrease is very moderate and shows how the values of the main economic indicators are returning to normal levels, after the exploit supported by the measures of Industry/Enterprise 4.0.

The slowdown will continue in 2020. There has been a strong fall of the index regarding the orders collected by Italian machine tool manufacturers in the first quarter 2020, in which an 11% decrease was registered in comparison with the same period of the previous year. This is reported in the last survey carried out by the Economic Studies Department & Business Culture of UCIMU-SISTEMI PER PRODURRE, the Italian machine tools, robots and automation systems manufacturers' association.

The overall outcome is affected by the collapse of the orders collected by the manufacturers in the domestic market, down by 41.3% compared with the period January-March 2019.

In the 2019, the **output of crude steel** in Italy was registered with a volume of 24 million tons, -5.3% lower than in 2018. The Italian Steel Association (Federacciai) forecast a minus in steel production from -10% to -15% for the current year.

A weak growth for **general engineering** +1% and **building sector** +2%. The residential building sector grew by 1.9% in 2019. Public building investments increased by 2.9%. Other sectors were stable (+0.4%). All in all, the volume of the building industry increased by 2.3% in 2019.

Developments in the foundry industry

In 2019, production activity in the ferrous metals foundry industry was marked by a strong downward trend, which gradually worsened before reaching its most critical point at the end of the year.

Over the course of the year, production of **ferrous castings** showed a decline of **-11.5%** compared to 2018, when the sector registered **growth** of **1.5%**. It comes after a cycle of partial recovery, interrupted only by the 2015 fall of **-2.8%**.

This represents the first double-digit decline since the 2012 collapse, when the drop in production almost hit **10%**.

Overall production volumes were just above **1.11 million tons.**

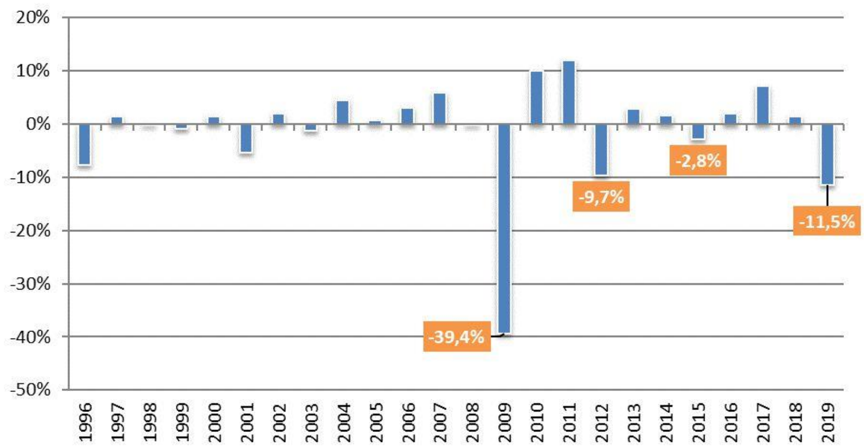


Figure 2. *Trend in % variations in volume (ferrous castings in tons)*

Source: CSA analysis of ISTAT data and Assofond sample surveys

But behind the overall picture of decline in activity, in reality there lies a broad variation in performance across categories.

Looking at the main categories, the decline can be traced back to **iron castings** (down **-12.3%**), which accounts for more than **94%** of the ferrous sector with 1.049.067 tons its performance has inevitably had a large effect on the overall result.

Much more encouraging results emerged from the **steel castings** and **investment castings** categories, where trends that differ from the overall picture are not difficult to find.

In terms of **steel castings**, the figures show uneven progress over the course of 2019 – this is especially apparent when the various production specializations are compared. Overall, however, the year finished on a positive note, marked by growth of **+5.2%.** This is a significant result, especially given that it comes after a particularly challenging three years (2015-2017) for this category, which saw volume declines of **-13%**, **-8%** and **-5%** respectively over the period.

Investment castings saw a similarly positive trend, with an **increase** in volume terms of **+5.5%**.

In 2019, presales to foreign markets also slipped into negative territory

The decline in demand from abroad hit **exports of ferrous castings**, which in volume terms fell **-6%** in 2019. That was in contrast to an increase the previous year of **+10%.** Here, too, the steepest decline was in the last quarter of the year, with a fall of **-14%** compared to the same period in 2018.

In terms of the most significant destinations for Italian ferrous castings, the markets that registered the biggest shifts were the **EU-28**, with a fall of **-8%** – in particular, **Germany** and **France**, with declines of **-11%** and **-10%** respectively.

Overall, the EU-28 was the destination for 65% of Italian ferrous castings, with Germany and France accounting for **17%** and **12%**.

Further afield, despite heightened tensions over tariffs and the ensuing sharp slowdown in global trade, the **United States** – surprisingly – was a significant market. Exports to the country grew by **+5%**, which meant that it accounted for **18%** of the total volume – a full two percentage points more than in 2018.

Imports too showed a marked decrease: from **+7%** in 2018 to **-5.8%** in 2019, with the familiar end-of-year collapse.

The results of foreign trade were notably more positive in terms of value. In fact, in this area, **imports** fell by just **half a percentage point** with **exports** decreasing by a modest **-1.2%**.

Cast iron foundries: worst result since 2009 crash

Following a year of very modest growth in 2018 (**+1.3%**), 2019 saw the production of iron castings undergo a significant collapse in terms of volumes.

At first, signs of a slowdown in the first part of the year seemed limited mainly to foundries producing cast iron for the automotive industry; however, as early as the second third of the year the negative trend gained momentum and struck – albeit at different levels of severity – all the main markets for iron castings (mechanical engineering, industrial vehicles, earth-moving equipment, agricultural machinery, machine tools and construction).

The double-digit fall in orders from the German market – above all from the automotive industry, but also in machine tools, drive systems and from mechanical engineering in general – had a huge impact on production levels in this category. In particular, the final three months of the year had a significant effect on 2019 as a whole.

At the close of the year, Italian national production of iron castings showed a decline of **-12.3%** compared to 2018 – the final volume of **1.049.067 metric tons** was the worst result since 2009 (during the global financial crisis), and 2012, when there was a fall of around **-10%**.

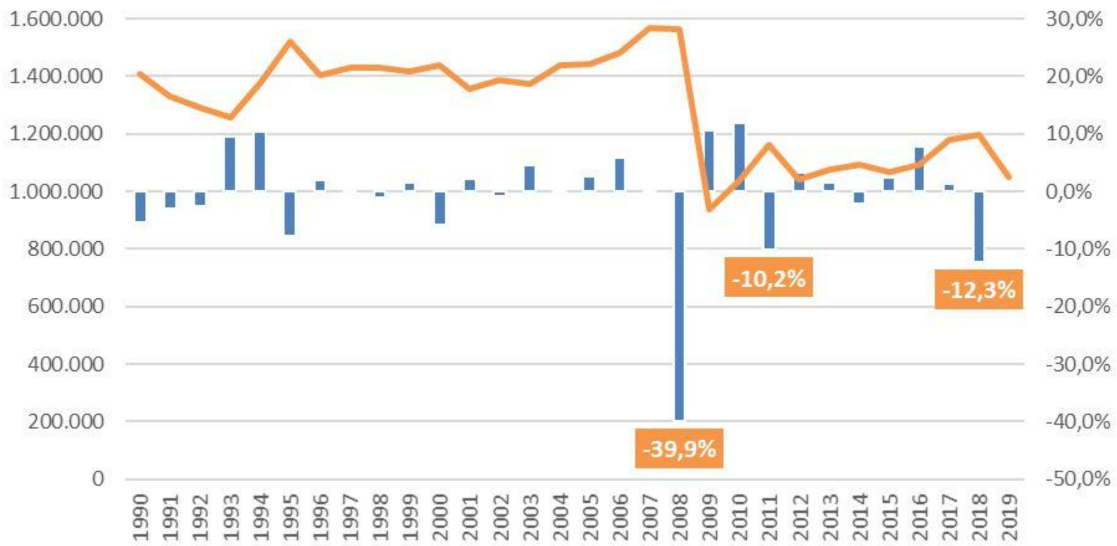


Figure 3. *Production of iron castings*

(right axis: % var. in trends; left axis: volumes in tons)

Source: CSA analysis of ISTAT data and Assofond sample surveys

Large falls in all main markets: mechanical engineering, transport, construction and steelmaking. The challenges facing its target markets were reflected – and occasionally magnified – in the production of iron castings.

Over half of the volumes of iron castings made in Italy are destined for the **mechanical engineering industry**, which comprises machine tools, agricultural machinery and earth-moving equipment, as well as various other products.

In 2019, the production of castings for this category, around **528,000 tons,** saw a decline of more than **60,000** tons – a drop of **-10.3%** compared to 2018. In terms of the detailed production breakdown, this category accounted for **319,000** tons of **grey iron** (**-11.2%** compared to 2018) and **209,000 tons** of **ductile iron** (malleable and spheroidal), with a decrease compared to the previous year of **-8.9%**.

Meanwhile, there was a sharp fall in the volumes produced by **foundries serving the automotive industry,** which felt the effects of the significant European slowdown, and in particular, the strong headwinds in the German car market – as well as the global crisis, compounded by issues in the domestic market.

According to figures from ANFIA (the Italian Association of the Automotive Industry), in 2019 the total number of vehicles made in Italy was **915,305 units**, a fall of **-14%** compared to 2018 (**-7%** in 2018). This comprised **542,007** passenger cars (**-19%** on 2018), **312,377 light vehicles** (**-4%**), **60,294 trucks** (**-6%**) and **627 buses** (**+67%**).

In 2019, the **transport** industry was the destination for around **339,000 tons** of iron castings, or **32%** of the total output. This comprised **223,000 tons** of **grey iron** (**-13.4%**) and **116,000** tons of **ductile iron** (**-11.4%**). This production category closed the year down **-12.7%**.

Globally, the picture for the automotive industry gradually worsened over the course of 2019, with increasingly concerning and widespread recessionary trends in the final part of the year.

Despite being one of the few areas of the economy to have enjoyed a positive 2019 and showing only limited signs of the severity of the 10-year crisis, the **construction** industry was unable to give much of a boost to the production of iron castings. Production destined for the industry actually took a further step backwards, with a drop of over **12,000 tons** – a decline of **-14%** compared to 2018.

Production output closed at just over **75,000 tons**.

The most significant production areas in this category are manhole covers, grilles, drain covers and hatches. These products have seen aggressive competition – first from countries in eastern Europe in the 1990s, and later from Asia, which has led to the large scale downsizing of Italian firms, who have been reduced to very low numbers. Last year's volumes account for **7%** of total iron castings – a third of what the typical figure would have been 20 years ago.

The performance of **castings for the steelmaking industry** also enjoyed mixed fortunes in 2019: the production of **ingot moulds** fell by **-8%** compared to 2018, losing by some distance the ground it had made up the previous year, while **cylinders** made a small gain **(+2.8%)**. Overall, **33,000 tons** of castings were produced for the steelmaking industry and the average result saw a fall of two percentage points against the one point gained in 2018.

Finally, the contribution of the remaining category, **"other castings"**, which accounts for **7%** of the total, saw a big decline (**-25%**).

Production (t.)	2019	% variation on 2018
Grey iron	662,138	-13.7%
Ductile iron	387,330	-9.6%

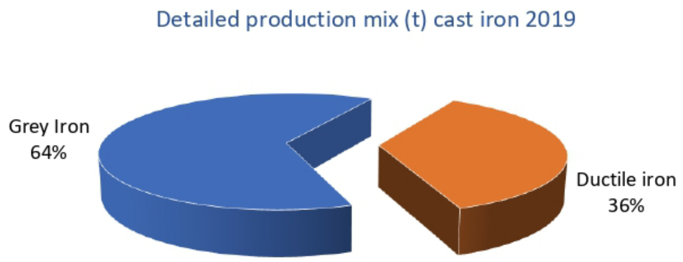


Figure 4. *Detailed production cast iron*

Developments in cast iron category mix

2019 brought confirmation of the contribution of the two sub-categories of cast iron in the production mix (grey iron, at **64%** of the total, and ductile iron, at **36%**). The slowdown hit both sub-categories, with the production of grey iron castings affected most, falling almost **14** percentage points, against a decline of **-10%** in ductile iron volumes.

Steel foundries: previous year's positive trend continues (+5.2%), but significant differences across firms and target markets

2019 is not an easy year to interpret when it comes to production data for steel castings due to a very marked fragmentation of the results that determine the average. In general, though, the picture is a broadly positive one with growth of +5.2% and output just shy of **60,000 tons**. In absolute terms, the category enjoyed growth of almost **3,000 tons** compared to the previous year.

The 2019 result is particularly satisfying for two reasons. Firstly, because it was achieved against the backdrop of a marked contraction in the other categories of ferrous castings and, secondly, because it comes after a three-year period (2015-2017), which was especially challenging, leading to declines in volumes of **-13%**, **-8%** and **-5%** respectively.

The category felt the effects of the collapse in the transport industry but benefited from investments in the oil and gas supply chain, which saw greater demand for turbines, compressors and other equipment.

The mechanical engineering and steelmaking industries also made positive contributions. However, demand for castings for quarries, mines and building and earth-moving equipment was more disappointing.

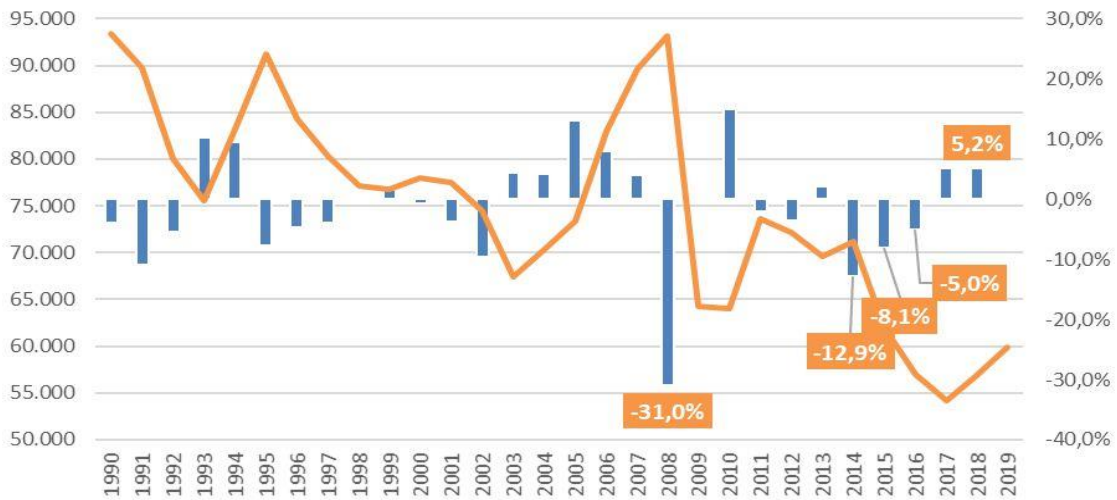


Figure 5. *Production of steel castings*

(right axis: % var. in trends; left axis: volumes in tons)

Source: CSA analysis of ISTAT data and Assofond sample surveys

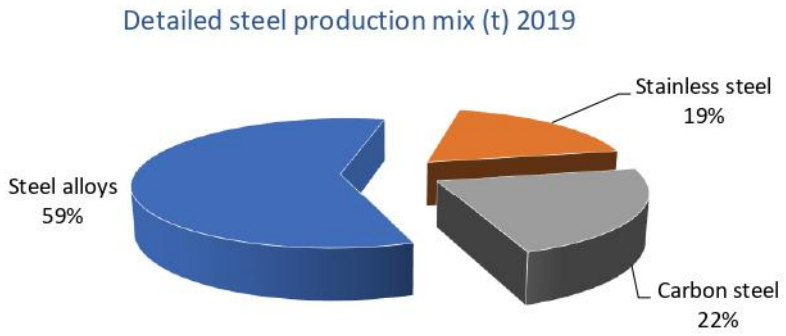


Figure 6. *Detailed production steel*

A highly fragmented picture emerges from the production result broken down by steel type.

Last year, **carbon steels** showed a very impressive ability to grow (**+22.5%**), which meant the segment registered around **13,000 tons** and increased its contribution to the total steel castings category by a full three percentage points (**22%** compared to **19%** in 2018).

Stainless steel also displayed a trend towards growth (up **+5.2%**), which took its volumes above **11,000 tons** and maintained its share of the total at **19%**.

Finally, volumes of **steel alloys** lost percentage points, despite maintaining the same production levels as 2018 of around **35,000 tons**. Its share was taken by carbon steels, and this sub-category now contributes **59%** of the total, compared to **62%** in 2018.

The extraordinary growth in the production of steel castings for the mechanical engineering industry (**+22%**) gave a significant boost to the overall result of the category.

The foundries that supply the industry produced **10,528 tons** of castings, equivalent to **18%** of the total. All production grouped under "mechanical engineering" saw significant expansion with double-digit rates of growth, albeit at different levels:

- castings for compressors and pumps (**+10%**);
- castings for steam and wind turbines (**+24%**);
- castings for the petrochemical industry (**+20%**);
- castings for valves (**+25%**).

Finally, castings for the electrical engineering industry closed 2019 at broadly the same level compared to the previous year.

Output at foundries producing castings for the mining industry, which includes castings for mining equipment, quarries and worksites, showed a downward trend of **-7%** compared to 2018.

Following a positive cycle in the transport industry and the beneficial effect on steel foundries, in 2019 the results of the contraction were reflected in the production of castings, which fell by **-5%** with a spike of **-10%** in applications for the automotive industry. The overall result for this industry was in part balanced out by the positive trend in production for other “motor industries” – marine and railway applications grew by **+11%** and **+5%** respectively.

The production of castings categorised as being for “steelmaking” was boosted by new investment in equipment for the steelmaking industries and metalworking in general, as well as for spare parts. In 2019, the output for this category maintained levels seen in the previous year (**1,306 tons at -0.2%**).

Castings for the construction industry go directly towards use in the building of public works. After years of worrying decline, 2019 production in this area saw a positive result, with growth of **+5.2%**, taking production levels above **11,000 tons**.

Investment castings: development in line with steel castings

In the category of ferrous castings, investment castings made using lost wax technology, together with steel castings, kept pace more effectively in 2019 than in 2018. An improving trend in volume terms showed growth of **+5.5%**, boosting overall output to **1,854 tons.**

By any measure – employee numbers, production or turnover – the Italian investment casting industry has a very high concentration of supply.

It also displays high levels of differentiation in production of ferrous and non-ferrous castings and superalloys. In terms of the mix of alloys produced, steel alloys maintain pole position relative to superalloys and non-ferrous alloy castings, and account for the largest share of production among firms that operate in this category.

As for target markets, the most significant contribution to growth came from the aerospace industry.

Automotive industry collapse in 2019 leads to 50,000 ton fall in castings for non-ferrous metal foundries

After four consistently positive years followed by a stable 2018, **non-ferrous castings** output ended 2019 with a fresh decline of **-4.9%**. The resulting loss of around **50,000 tons** drove output below the all-important threshold of one million tons per year (**959,000 tons**).

The category suffered the twin effects of a worsening in the economic climate for German car making and the fallout from trade disputes. The latter was not limited to the US and China, but spilled over into the EU and caused a significant downscaling in exports of non-ferrous castings, which are thought to account for between 50% and 60% of overall production.

The setback affected all non-ferrous metals, albeit to differing extents. The most significant contribution to the overall result, however, came from the production of aluminium castings, which accounts for **85%** of non-ferrous metals: it saw a drop of **-5.3%** compared to the previous year. The only segment to perform worse than aluminium was magnesium, with a decline of **-12%**.

Aluminium castings

In 2019, the production of aluminium castings fell to 810,647 tons. Compared to 2018, the average annual rate of decline was -5.3%. The percentage share of aluminium for total non-ferrous castings over the past 20 years has risen by 68% to the current figure of 84%.

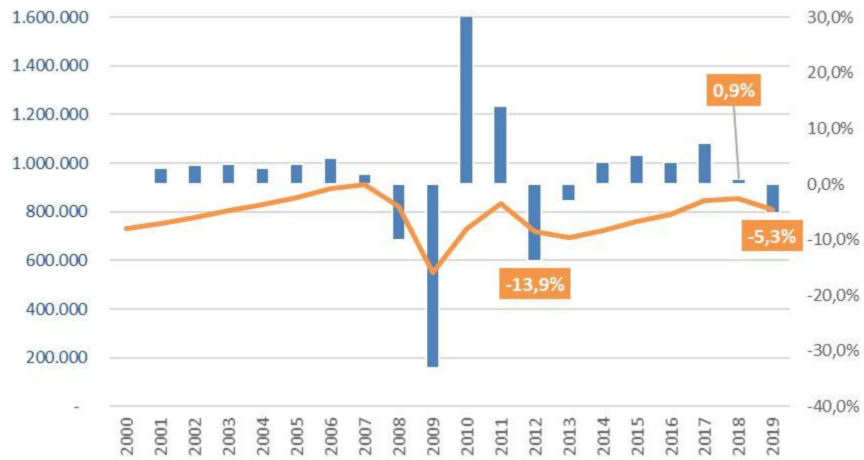


Figure 7. *Aluminium castings*
(right axis: % var. in trends; left axis: volumes in tons)

Zinc castings

Among non-ferrous alloys, 2019 was particularly significant for the development of the production of zinc alloys from die-casting (+1%, with volumes equivalent to 74,036 tons). This data should be viewed with a great deal of optimism; not only is it the one positive result, it also comes after the severe challenges that have beset the segment over the past 15 years – from the slowdown in domestic demand to the widespread delocalisation to Eastern Europe and Asia by many of the industries it serves.

Competition from companies in these countries is particularly apparent in large-scale production. Consequently, as a reaction to the economic challenges facing the segment, many Italian zamak foundries have implemented bold strategies in recent years that focus on medium-scale production, taking great pains to meet the more bespoke requirements of customers – and not only those related to the technical elements of casting.

A number of companies' operating models are designed to provide another layer of service to the customer, and no longer simply supply a raw part, but rather finished products that are chrome-plated, painted and assembled.

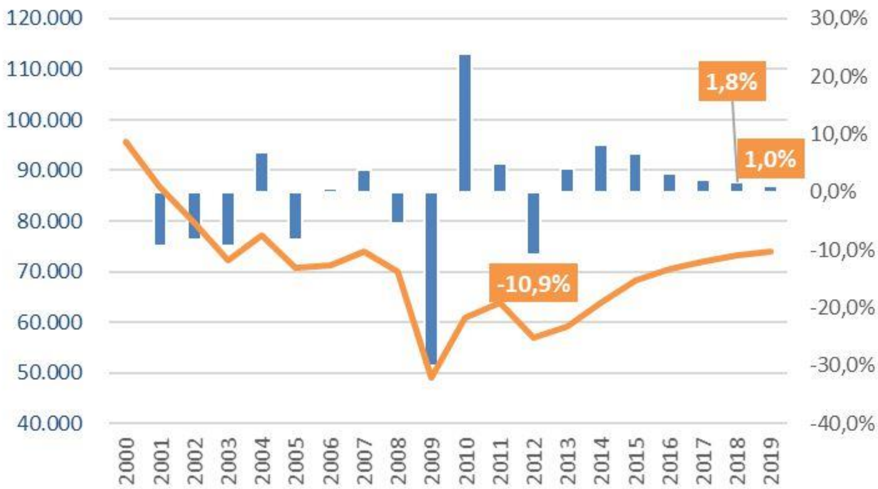


Figure 8. *Zinc castings*

(right axis: % var. in trends; left axis: volumes in tons)

Brass, bronze and copper castings

Copper-based metals also underwent a decline in 2019. Overall production of brass, bronze and copper castings fell by 66,438 tons (-4.7%). However, production in this segment – considered overall – has halved over the past 15 years, seeing a decline of around 60,000 tons. The issues that continue to influence the outlook for the segment include those common to other metals (high levels of competition from developing countries). Nevertheless, in the case of brass and bronze, they seem to have had a greater impact.

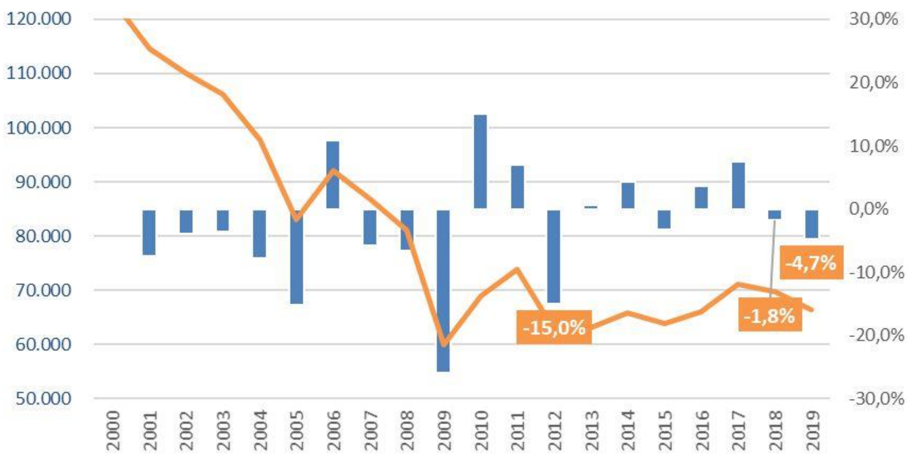


Figure 9. *Brass, bronze and copper castings*

(right axis: % var. in trends; left axis: volumes in tons)

Magnesium castings

As noted elsewhere, the increased delocalised of production on the part of companies making magnesium die-castings has led to a reduction in overall volumes. These have now been stable for several years at around 7,000 tons (7,097 tons in 2019 with a decline, in double digits this time, of -12% compared to 2018). This segment also suffered last year from the negative impact caused by the slowdown in the automotive sector.

Figure 10. *Magnesium castings*
(right axis: % var. in trends; left axis: volumes in tons)

Main markets

2019 confirmed the by-now familiar breakdown of non-ferrous castings sales to the five principal industries that make up the category's customer base. Ranked in order of importance: transport industry (**55%**), construction (**14%**), consumer durable goods (**8%**), electrical engineering (**11%**) and mechanical engineering (**9%**).

The Italian market for non-ferrous castings displays a very strong bent towards the transport industry, or more accurately the automotive industry, which accounted for **55%** of overall production in 2019, equivalent to **521,637 tons** – a downward trend of **-10%**, or a fall of more than **58,000 tons**. The industry's share fell by two percentage points compared to 2018.

The ability of the construction industry, the second largest market for non-ferrous castings, to make up the ground is in consistent decline. Its share of the total was **14%** in 2019, broadly in line with the previous year's result. Last year, volumes for the industry hit **137,454 tons**, a small increase of **+1%**.

The use of non-ferrous castings in the production of electrical engineering applications displayed a good rate of growth in 2019 (**+8.8%**), which meant volumes reached **104,197 tons**. This was mainly due to the effect of greater foreign demand, allowing foundries operating in this segment to grow export volumes.

2019 was not a positive year in terms of non-ferrous casting applications for the mechanical engineering industry. The production of castings for this industry fell by **5** percentage points, with a volume of **83,736 tons**.

Cost developments input materials

In 2019 the "**Raw Material Extra Charge**", used for inflation of the cost of ferrous foundry castings concerning the main raw material (pig iron and scrap) developed on data based respectively from the Italian market of raw materials. The value, expressed in euro/t, is related to different kind of metallic materials:

- Grey cast iron: Average Year 2019 /Average Year 2018 = **-7%**
- Ductile cast iron: Average Year 2019 /Average Year 2018 = **-7%**
- Steel castings: Average Year 2019 /Average Year 2018 = **-9%**

Regarding to the total **direct cost of raw materials** not considered in "Raw Material Extra Charge", as well as the cost of energy and of the auxiliary materials that are necessary to obtain the foundry casting, Italian Foundries in 2019 applied the "Direct Transformation Input" index. It is related to different kind of furnace:

- **DTI** for Foundries using electrical furnaces: Average Year 2019 /Average Year 2018 = **-1%**
- **DTI** for Foundries using cupola furnaces: Average Year 2019 /Average Year 2018 = **-1%**

Outlook 2020

If the Covid emergency does not worsen in the next months for Italian foundry production for 2020 it is expected a decline from **-20%** to **-30%**.

In the first quarter of the current year the total castings production (ferrous and non ferrous metals) declined by -17% compared to the same period in 2019: iron (-33%) and non ferrous (-16%).

In January-April we saw a larger decline of production: -29% (-42% iron castings and -32% non ferrous castings).

FOUNDRY PRODUCTION IN KOREA

National representation in the WFO:
KOREA FOUNDRY SOCIETY
WWW.KFS.OR.KR

The Status of the Korea Foundry Industry

The Korean domestic foundry is, currently, estimated to produce 2.4 million tons, consisting 0.7 million tons of larger companies' in-house production and 1.7 million tons of small and medium-sized foundries. Production by material is about 1.4 million tons of cast iron, 0.4 tons of cast steel and 0.6 tons of non-ferrous steel, respectively.

According the statistical data, the number of domestic foundries is estimated to be 1,300, consisting of cast iron, cast steel, non-ferrous and die-casting shops. However, 40% of the metal casting shops are small businesses with sales of less than 1 million dollars (less than 10 employees), therefore only about 780 shops are evaluated to have industrial impact and meaning. Of these, there are about 350 cast iron foundries, of which 216 are registered by the Korea Foundry Cooperative Association (KFCA).

Major Issues and Difficulties of the Korea Foundry Industry

Not enough orders from the buyer due to the continuous decrease in demand volumes and chicken games due to excessive competition are under pressure to continue to decrease in unit prices. There has been the so-called price reduction practice of 5-10% of the price desired by the supplier previously, but now the unit price is under pressure of cut-down of 10-15% because it is a way for the producer to bid directly for the estimate.

According to the analysis of the industry based on the working days and sales changes, the shipment of 50% automobiles and 40% of machinery and heavy equipment are reduced on average, and marine products such as LNG ships and vessels are not receiving orders at all compared to last year is reported. Government-grade orders are relatively good, showing a 10 percent decline.

In Daegu area, mid-southern part of Korea, where about 80 cast iron companies are gathered, they mainly produce heavy weight castings for automobiles under the Full Mold method, which uses Furan resin and styrofoam molds. Factory operation rate is 50 ~ 60%, and work is about 4 ~ 4.5 days. (Working hours are intentionally extended from 3 to about 4-4.5 days due to work or labor cost issues.) Prospects for future operation are also dim as the use of pig iron and resin has plummeted and prices of locally produced compressed iron have fallen, but have been in short supply.

The price fluctuation is believed to largely depend on the impact of Chinese situation. For instance, in areas where Chinese production is decreasing, there are some work with small amount of profit, but the price of items that show the tendency of Chinese production to increase are seriously falling or there is no supply at all. On the foundry field, they are experiencing difficulties enough to call it a future production panic.

Influences of COVID-19 pandemic towards the Korea Foundry Industry

Of the 216 paid members who joined the KFCA, 20 were found to be closed in 2020 and 25 dormant companies were found to be unable to close down owing to the debts. The other 170 foundries are currently operating production lines, and about 70 foundries are preparing further statistics.

The total number of employees is about 35,000, consisting of 10% of management and engineering staffs, 55% of technical workers, 15% of simple labor workers, and 20% of others. Due to the recent COVID-19 issue, it is estimated that the number of the illegal overseas workers (around 5 percent of the total employees (1,800 persons)) are consistently decreasing, resulted by successive escaping from Korea. The wage levels are investigated about 12% lower than those of other manufacturing industries.

FOUNDRY PRODUCTION IN MEXICO

National representation in the WFO:

SOCIEDAD MEXICANA DE FUNDIDORES

WWW.SMFAC.ORG.MX

SOCIEDAD MEXICANA DE FUNDIDORES, A.C.
MIEMBRO DE WORLD FOUNDRY ORGANIZATION

About Mexican Foundry Industry

It is one of the base industries throughout the production chain, the Mexican foundry industry closed in 2019 with approximately 8 billion US dollars, with production to 3 million metric tons (2019) generating more than48,000 employs direct and another 100 thousand indirect jobs that generate ferrous and non-ferrous products for various manufacturing sectors in the country such as: automotive, railway, aerospace, hydraulics, construction, manufacturing, mechanical metal, machinery, pumps, agriculture and mining, among others.

About MFS

Sociedad Mexicana de Fundidores AC (SMF) has been present in the industry for 75 years, bringing together the main Mexican foundry companies with the objectives of the sustained growth of the sector, generating and participating in the necessary actions to strengthen and position it more competitively. In addition to promoting the technological development of metalcasting companies, the SMF stimulates the debate on environmental, economic and social issues for the defense of the national sector and its commercial growth, as well as technical training within companies for their greater competitiveness.

Data Collection in 2019

Methodology by direct survey, they interviewed by telephone and direct mail to acquire information from 479 affiliated and non-affiliated companies of the association. After a census compared to 2017 statistical data, production trends, and other areas could be completed, it should also be noted that in 2018 we had no actions to collect data.

Metal Casting	Metric Tons 2017	Metric Tons 2019
Steel Casting	373,965	336,250
Ductil Iron	526,897	560,270
Gray Iron	892,188	816,160
Aluminum Alloys	817,911	832,770
Zinc Alloys	81,300	79,500
Cooper Alloys	217,200	215,500

Table 1. *Percentage of production of ferrous and non-ferrous castings in Mexico, Total in billions of metric tons*

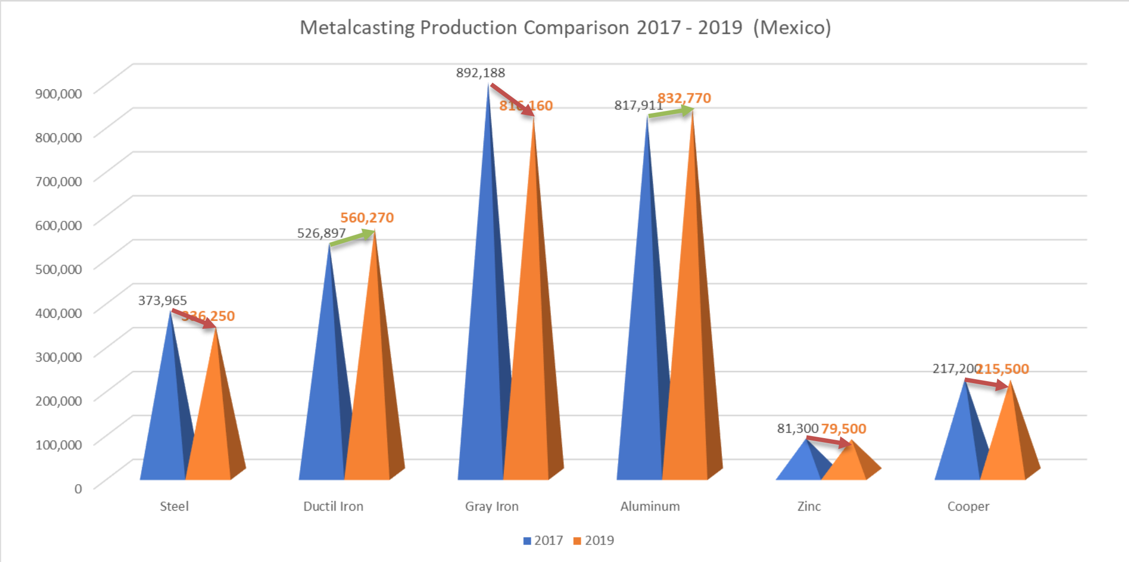


Figure 1. *Metalcasting production comparison*

There is currently a decline in small and medium-sized enterprises in our country, but since 2012 there has been growth of large companies or global industrial groups that have invested in the expansion of their plants, as well as domestic investment abroad, thereby increasing their installed production, as well as the installation of dozens of companies arriving from abroad with investment capital above MDD 700 between 2015 and 2016.

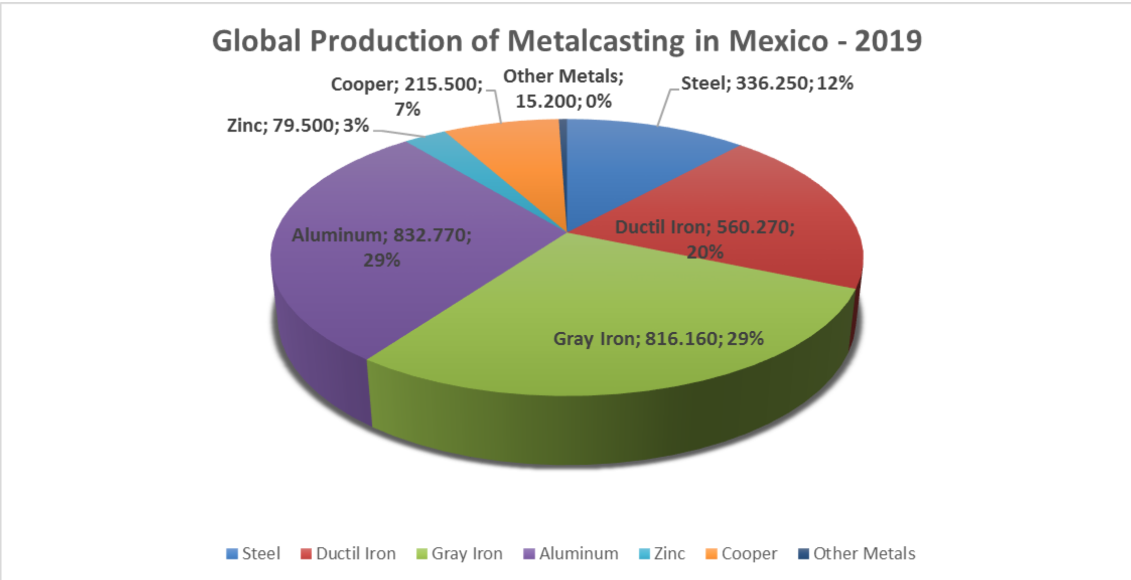


Figure 2. *Global production of metalcasting in Mexico 2019*

Most companies in Mexico offer additional services with machining workshops. SMF has around 80% of the smelter companies installed in our country registered. Direct employed personnel are about 52,000 workers (approximately 2016), and indirect staff approximately 100,000.

Today we have a strengthened industry, and with more competitive prices, competitive technology and energy cost is more stable, although the qualified workforce is skidding, but the cost is below the global average.

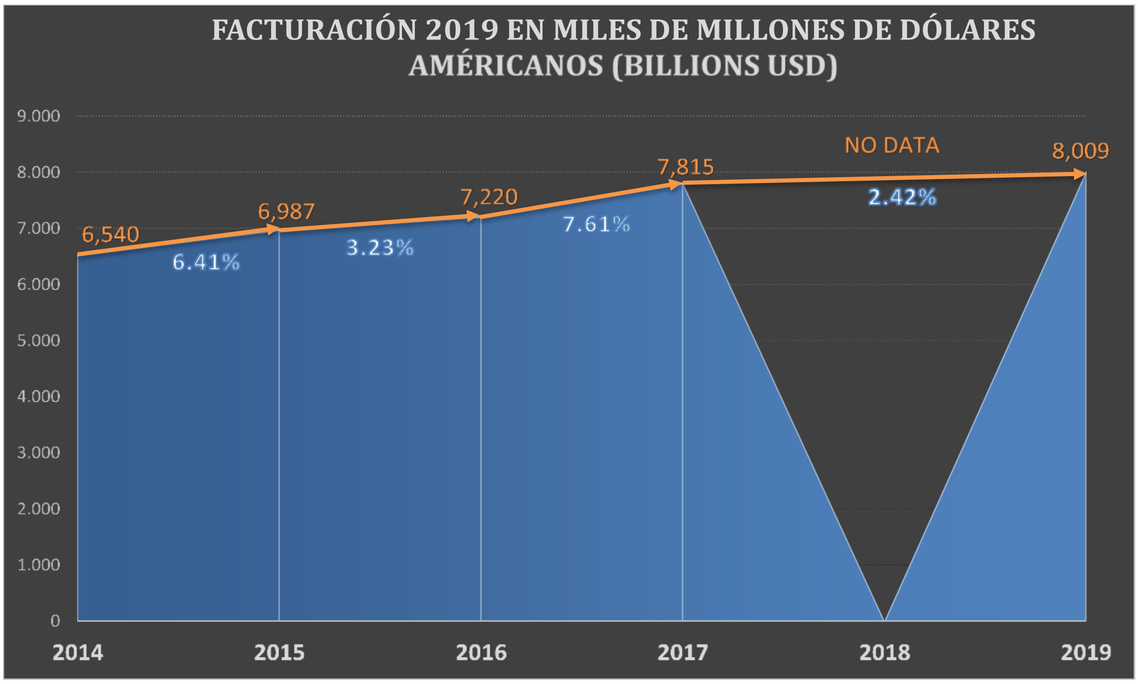


Figure 3. *Turnover 2019*

There is an average annual increase of 6% in National Turnover from 2014 to 2017, being in the period 2016 to 2017 with a record in sales growth, derived from the EXCHANGE rate MXN – USD.

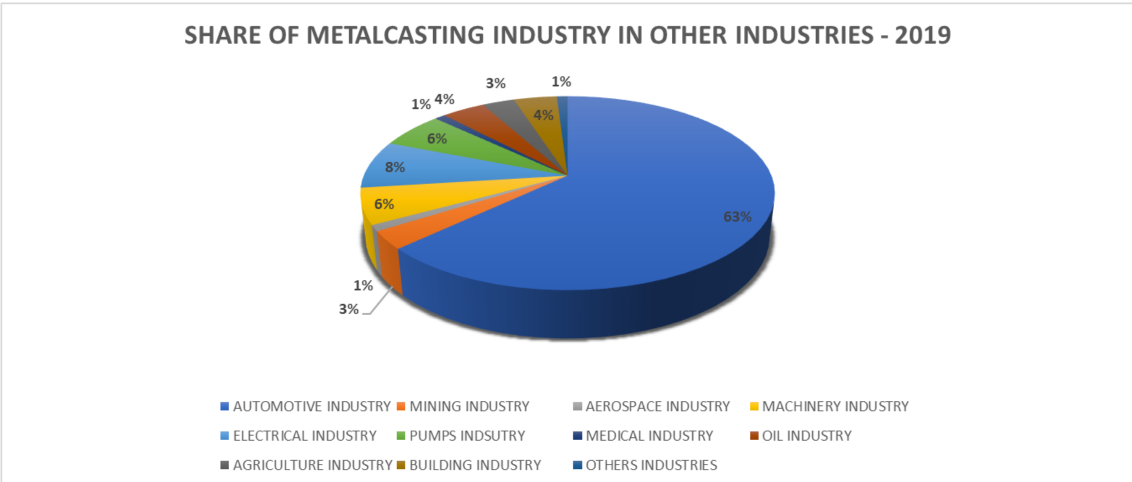


Figure 4. *Share of metalcasting industry*

63% of the production of the foundry industry is aimed at the automotive sector, and domestic consumption is around 54.5% and the rest is exported mainly to the US, Japan, Germany, Korea, Central America and the rest of Europe. Sectors with higher growth nodular iron, die casting aluminum. Mains areas with the greatest opportunity in the automotive and aerospace sector.

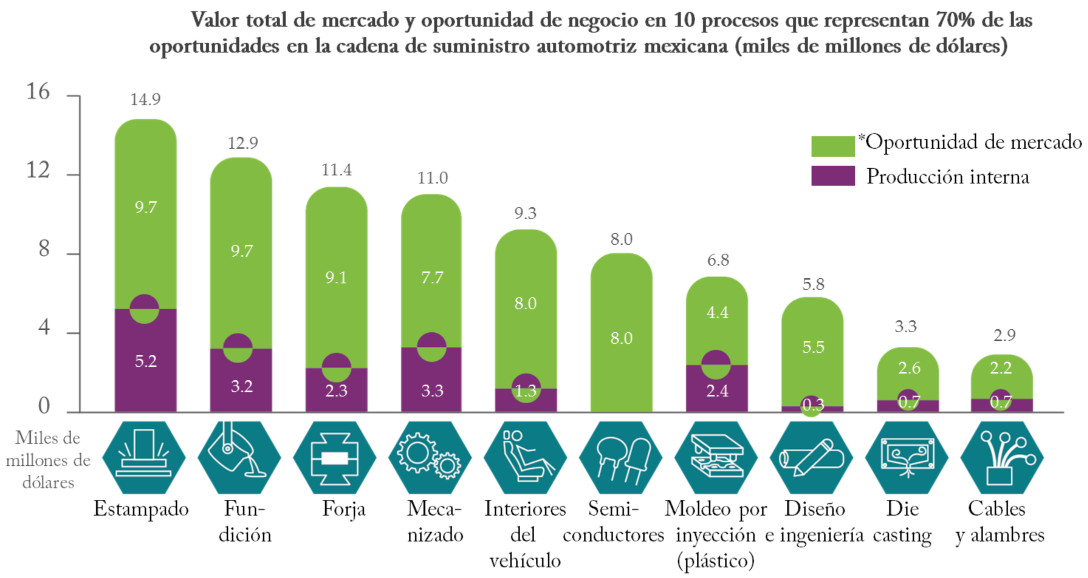


Figure 5. *Market total value and business opportunity*

Demand value Not produced in Mexico automotive cluster

The value of uns produced demand in the metals production market is estimated at around $50 billion, in the automotive cluster alone, the sectors with the highest consumption demand are, Die casting: 3.3 thousand mdd – Ferrous casting 9.7 thousand mdd – machining 7.7 thousand mdd – die casting and stamping 9.7 thousand mdd, forges 9.1 thousand mdd.

FOUNDRY PRODUCTION IN NORWAY

National representation in the WFO:

NORWEGIAN FOUNDRY TECHNICAL ASSOCIATION

WWW.STOPERI.ORG

Norwegian foundry industry overview

There are 13 Foundries – with a total of 974 employees.

There are 7 non-ferrous foundries with 398 employees. These foundries produce castings for various customer markets, only one foundry supplies the automotive sector.

There are 6 ferrous foundries (1 steel foundry). These foundries produce castings for various customer markets. The main markets for iron castings are road/drainage and domestic goods/furnaces.

We have an annual foundry congress, but in 2020 (which was also our 100th anniversary) we had to cancel the congress due to the corona pandemic.

We will try to have a new congress in May 2021.

FOUNDRY PRODUCTION IN POLAND

National representation in the WFO:
POLISH FOUNDRYMEN'S ASSOCIATION
WWW.STOWARZYSZENIE-STOP.PL

Poland's macroeconomic performance in 2018-2019

Indicator	Units	2018	2019
GDP	dynamics	105,1	104,0
Gross capital formation	dynamics	109,2	103,0
Price index of consumer goods and services (CPI)	dynamics	101,6	102,3
Price index of sold production of industry (PPI)	dynamics	102,1	101,2
Sold production of industry	dynamics	105,8	104,0
Average wages and salaries in the national economy - enterprise sector	PLN	4 852	5 169
Average employment in enterprise sector	thous.pers.	6 230	6 395
Unemployment rate (as of the end of the period)	%	5,8	5,2

Table 1. *Main macroeconomic indicators*

Polish foundry industry

The Polish foundry industry is created by about 455 foundries. The highest percentage of them are non-ferrous foundries (240). The rest of foundries are 180 iron foundries and 35 steel foundries.

The foundry sector is formed mainly by small and medium-sized enterprises (SMEs), which employ up to 250 employees. Despite the fragmentation of the foundry branch, foundries belonging to SMEs play an important part in total casting production, producing about 40 % of it.

In 2019 total casting production accounted for 1 011 500 tons incl. 655 000 tons of ferrous castings, which is 65% of total casting production. Production of nonferrous casting was on a lower level of 356 500 tons but we are still observing an increase in that area.

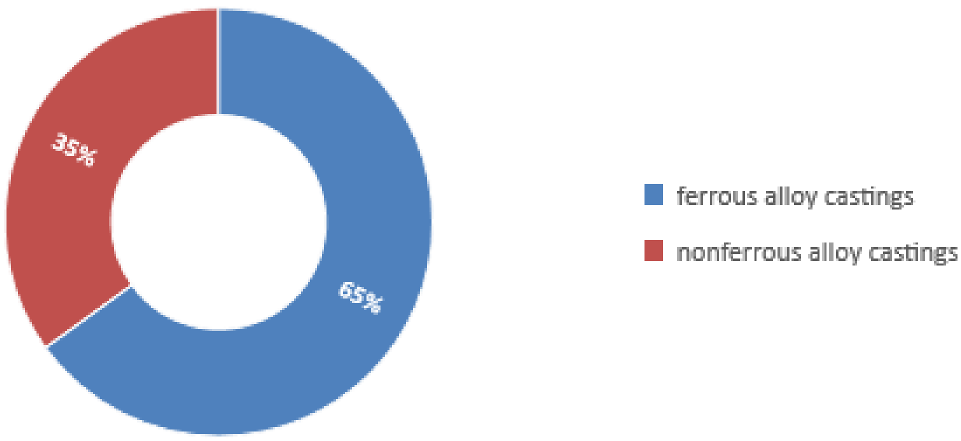


Figure 1. *General structure of casting production*

Material	Output [T] 2018	Output [T] 2019 /estimated/
Total iron castings	480 000	450 000
Total nodural iron castings	160 000	155 000
Steel castings	50 000	50 000
Total ferrous alloy castings	**690 000**	**655 000**
Copper alloys castings	6 100	6 000
Aluminium alloys castings	330 000	340 000
Zinc alloys castings	7 500	7 500
Other nonferrous alloys castings	2 900	3 000
Total nonferrous alloy castings	**346 000**	**356 500**
Total ferrous and nonferrous castings	**1 036 500**	**1 011 500**

Table 2. *Total Polish output*

Structure of casting production by materials used in total production:

- 44,5% - iron castings;
- 15,3% - nodular iron castings;
- 4,9% - steel castings;
- 33,6% - aluminium alloys;
- 1,7% - other nonferrous alloys.

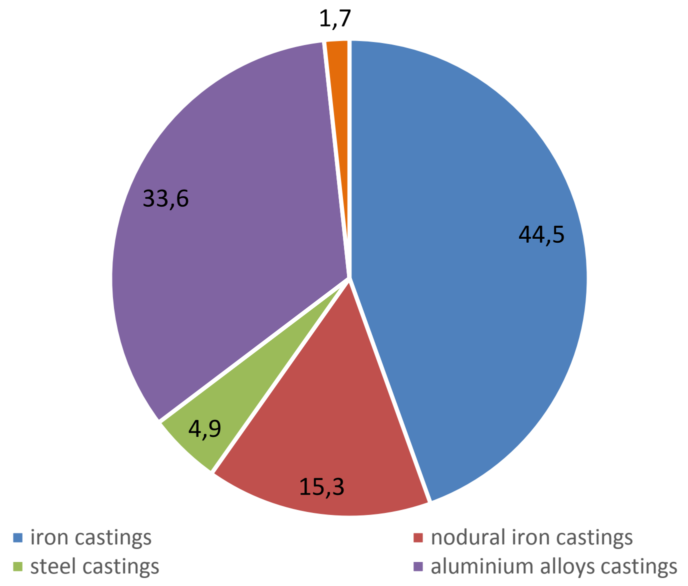


Figure 2. *Structure of casting production in total casting production in 2019 (estimated)*

Total casting production in 2019 was lower by 2,4% than in the previous year. The fall was caused mainly by a decrease of ferrous alloy casting production. According to the present trend and high demand for casting in the automotive industry, we observed an increase of nonferrous alloy castings production especially aluminum casting production. Polish foundries produced castings mainly for the automotive industry, construction industry and machine industry.

The foundry industry in Poland was still export-oriented. About 60% of total production was dedicated to export and the main recipients were Germany, Italy, France, Czech Republic and the United Kingdom.

The employment in foundry industry is estimated at the same level as in previous years. Total employment was 24 300 employees, incl. 8300 employees in non-ferrous foundries, 12500 employees in iron foundries and 3500 employees in steel foundries. More than 50% of total employment concerns SMEs sector. Polish foundry industry still had a huge problem with recruiting professional employees especially blue-collar employees with professional foundry qualifications.

Trends and forecasts

The year 2020 will bring changes to the foundry industry. Unexpected Coronavirus pandemic caused a decrease in the number of orders and a disruption of the supply chain. It is expected that the production volume in the first part of the year in foundries dropped by 30% on average, which translates into a decrease in sales volume. That situation also affects the level of employment in foundries. A lot of companies will decide to reduce the number of employees. It is worth emphasizing that the biggest challenge for many foundries will be also to maintain financial flow.

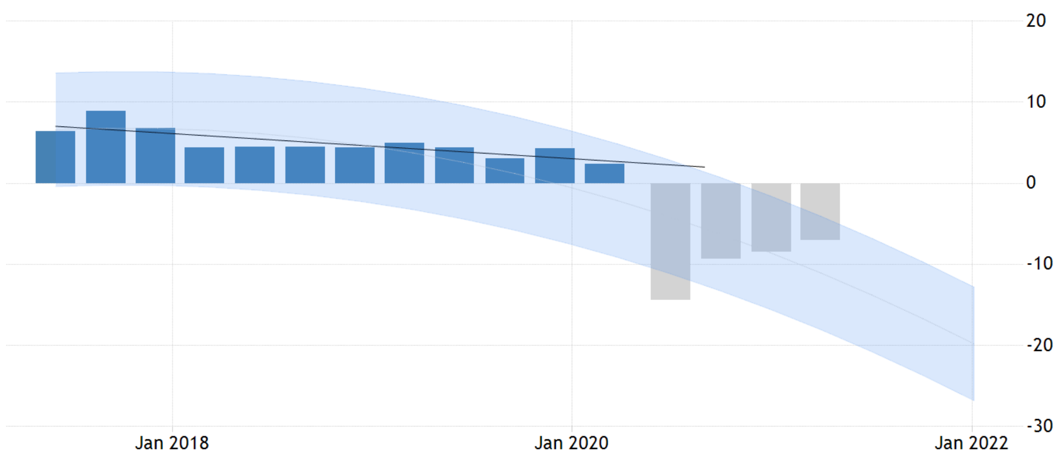
FOUNDRY PRODUCTION IN ROMANIA

National representation in the WFO:
ASOCIATIA TEHNICA DE TURNATORIE DIN ROMANIA
ROMANIAN TECHNICAL FOUNDRY ASSOCIATION
WWW.FOUNDRY-ATTR.RO

General Overview

Romania GDP Forecast 2018-2022

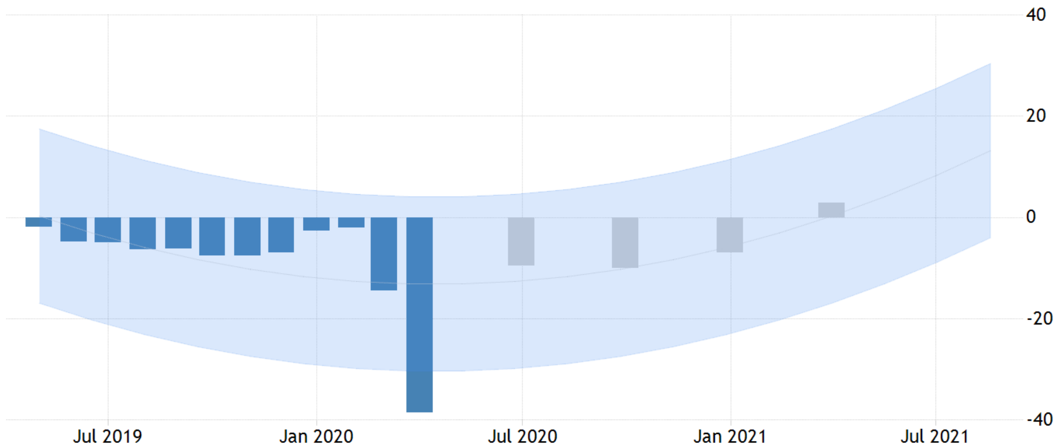
GDP Annual Growth Rate in Romania is expected to be -14.40 percent by the end of this quarter, according to Trading Economics global macro models and analysts' expectations. Looking forward, we estimate GDP Annual Growth Rate in Romania to stand at -7.00 in 12 months' time. In the long-term, the Romania GDP Annual Growth Rate is projected to trend around 8.80 percent in 2021 and 3.80 percent in 2022, according to our econometric models.



SOURCE: TRADINGECONOMICS.COM | INSTITUTUL NATIONAL DE STATISTICA

Forecast Industrial Production

Industrial Production in Romania is expected to be -9.50 percent by the end of this quarter, according to Trading Economics global macro models and analysts' expectations. Looking forward, we estimate Industrial Production in Romania to stand at 2.90 in 12 months' time. In the long-term, the Romania Industrial Production is projected to trend around 5.50 percent in 2021 and 3.50 percent in 2022, according to our econometric models.



SOURCE: TRADINGECONOMICS.COM | INSTITUTUL NATIONAL DE STATISTICA

Romanian Metal Casting Industry

About 80 foundries are now acting in Romania, with high diverted range of turnover. Range of castings starts from magnesium parts for automotive industry, with weights of grams and ends to steel castings designated to constructions, with weights up to 3 tones. Over the last years the metal casting production structural changes are visible: non-ferrous increasing while iron alloys decrees.

A general view of the Romanian metal casting industry, reveals two main directions:

- Automotive industry, with aluminium and magnesium castings manufactured in high serial processes; leader Dacia (Group Renault-Nissan) followed by Altur;
- Hand moulding parts, designated to machine building, energy, transportation, with castings produced in grey or ductile iron, as well as in steel.

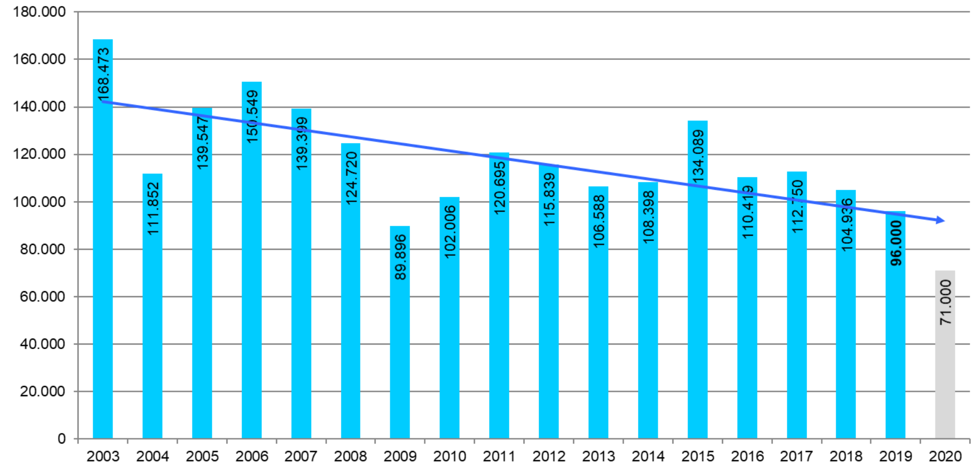
Most relevant technologies used in Romanian foundries:

- Hand moulding NO BAKE process (NBFA);
- Full mould process (also NBFA);
- Gravity Die Casting for aluminium alloys;
- High Pressure Die Casting for aluminium or magnesium alloys;
- Centrifugal Casting / Ferrous and Non-ferrous alloys;
- Investment Casting.

Main Foundries:

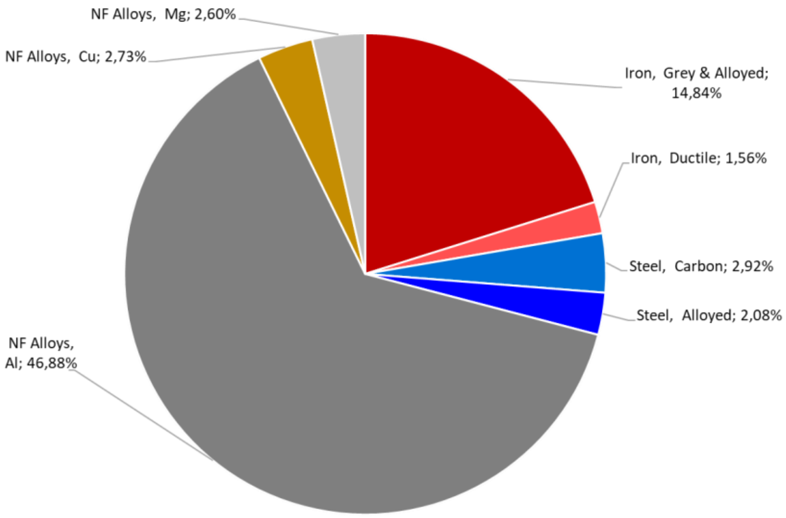
- SATURN Alba Iulia: 15.000 t / year / iron
- Automobile Dacia Pitesti: > 27.000 t / year / aluminium HPDC

Casting Production 2003 - 2019, [t]



Distribution of Casted Alloys:

Distribution of main Casted Alloys
Quantity Estimation for 2020, [%]

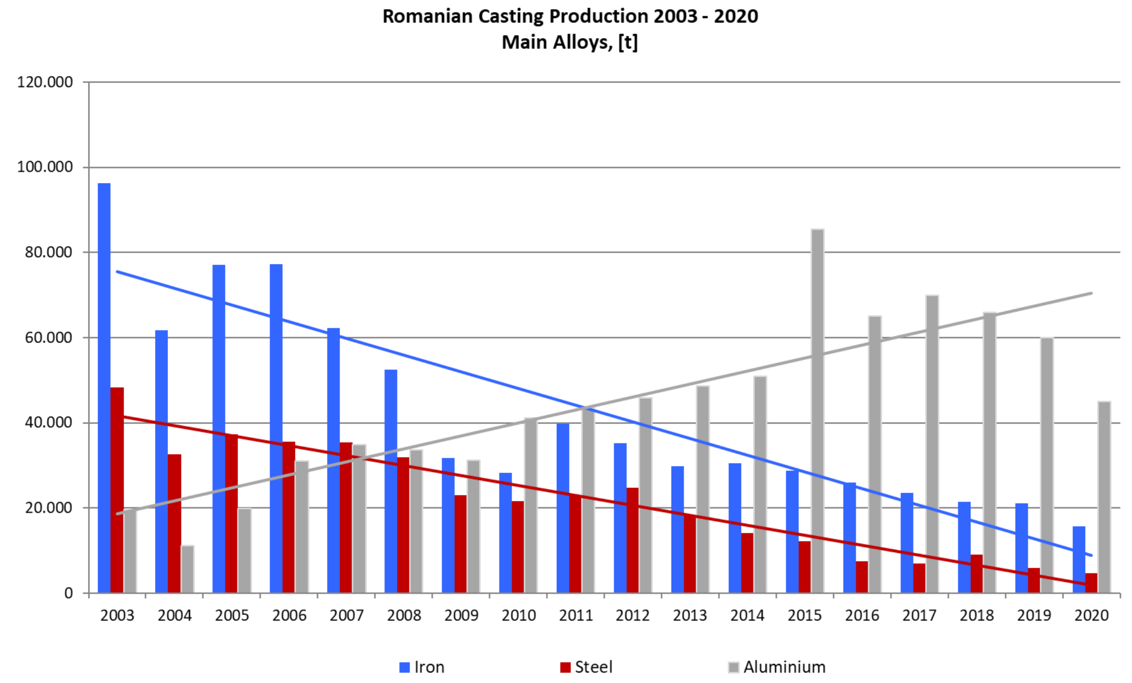


2020 Previsioned	Alloy	Iron,			Steel,		NF Alloys,				
		Grey & Alloyed	Ductile	Malleable	Carbon	Alloyed	Al	Cu	Mg	Zn	Other
	[%]	14,84%	1,56%	0,00%	2,92%	2,08%	46,88%	2,73%	2,60%	0,29%	0,10%
	[t]	14.250	1.500	0	2.800	2.000	45.000	2.625	2.500	280	100
		15.750			4.800		50.505				
	TOTAL Previsioned 2020, [t]: 71.055										

A detailed view of the last years' production may be observed in the following chart:

Year	Iron			Steel		Non Ferrous Alloys				
	Grey & Alloyed	Ductile	Malleable	Carbon	Alloyed	Cu	Al	Mg	Zn	Other
2003	77.531	16.774	2.014	24.595	23.797	2.906	19.535	6	594	721
	96.320			48.392		23.762				
	TOTAL 2003, [t]: 168.474									
2004	50.671	10.018	1.085	15.958	16.591	3.229	11.255	12	445	2.588
	61.774			32.549		17.529				
	TOTAL 2004, [t]: 111.852									
2005	64.464	11.604	1.114	15.991	21.352	4.439	19.899	1	679	4
	77.182			37.343		25.022				
	TOTAL 2005, [t]: 139.547									
2006	61.602	14.755	898	17.406	18.210	3.356	30.982	2.800	540	0
	77.255			35.616		37.680				
	TOTAL 2006, [t]: 150.551									
2007	54.521	6.903	793	18.513	16.935	3.841	34.811	2.805	244	33
	62.218			35.448		41.733				
	TOTAL 2007, [t]: 139.399									
2008	46.968	4.634	836	12.483	19.888	3.569	33.699	2.500	588	5
	52.439			32.371		40.360				
	TOTAL 2008, [t]: 124.720									
2009	29.485	1.471	712	10.141	12.814	1.814	31.163	1.750	535	9
	31.669			22.955		35.272				
	TOTAL 2009, [t]: 89.896									
2010	24.984	2.361	968	9.846	11.810	5.488	41.158	4.982	402	7
	28.313			21.656		52.037				
	TOTAL 2010, [t]: 102.006									
2011	36.812	2.075	927	15.332	7.779	6.168	43.499	8.000	83	19
	39.814			23.111		57.769				
	TOTAL 2011, [t]: 120.695									
2012	31.689	2.910	636	14.063	10.790	4.878	45.795	5.050	20	8
	35.235			24.853		55.751				
	TOTAL 2012, [t]: 115.839									
2013	25.645	3.332	875	9.874	8.507	4.216	48.745	5.050	174	170
	29.852			18.381		58.355				
	TOTAL 2013 [t]: 106.588									
2014	25.066	4.510	1.027	7.834	6.384	7.181	50.952	5.000	300	145
	30.603			14.218		63.578				
	TOTAL 2014, [t]: 108.398									
2015	24.186	3.924	685	7.153	5.059	2.569	85.417	5.003	26	66
	28.795			12.212		93.081				
	TOTAL 2015, [t]: 134.089									
2016	20.965	4.456	505	4.334	3.260	4.090	65.057	7.000	515	238
	25.926			7.593		76.900				
	TOTAL 2016, [t]: 110.419									
19500	20.000	3.500	0	8	3.000	4.500	70.000	7.000	500	250
	23.500			3.008		82.250				
	TOTAL 2017, [t]: 112.750									
2018	19.500	2.000	20	6.000	3.000	2.900	66.000	5.000	400	116
	21.520			9.000		74.416				
	TOTAL 2017, [t]: 104.936									
2019	19.000	2.000	50	3.500	2.500	3.500	60.000	5.000	350	100
	21.050			6.000		68.950				
	TOTAL 2020, [t]: 96.000									

Production trends:



Conclusions and predictions

The Romanian Technical Association estimates and predicts the metal casting production in our country as follows:

- The metal casting production in Romania stabilized at a very low level in 2019;
- For 2020 we estimate a general decrease in the casting production by 25-30% due mainly to the pandemic generated by coronavirus;
- Production of ferrous alloy decreased, resuming mainly to hand and mechanical moulding process in chemical bounded sands;
- Green sand moulding is still present in limited number of foundries;
- High Pressure Die Casting is the dominant process in non-ferrous casting production, followed by Gravity Die Casting; hand moulding of big castings;
- In 2020, we estimate that the increase trends will stop for aluminium HPD casting, in special for automotive industry.

FOUNDRY PRODUCTION IN SLOVENIA

National representation in the WFO:
SLOVENIAN FOUNDRYMEN SOCIETY
WWW.DRUSTVO-LIVARJEV.SI

Macroeconomic indicator and data on achieved foundry production in Slovenia for the year 2019 and forecast for 2020, in the light of coronavirus pandemic

After the relatively successful first half-year of 2019, the economic activity in Slovenia started to soothe down in the second half-year, because of the reduced demands from external markets. We detected these effects in the foundry industry, especially in foundries that are suppliers for the automobile industry. Therefore, the export in the last quarter increased only by 0,9% which is one of the lowest growths since 2010. The import in this period of time faced a 0,8% decline.

Spring forecast of economic trends for 2019 compared to 2018 data*			
GDP AND PRICES			
	2018	**2019**	**2020**
Gross domestic product (growth in %)	5.1	2.4	-7.6
Gross domestic product (in EUR mrd)	46.6	48.0	44.6
Gross domestic product per capita (in EUR)	22.563	22.983	21.592
Inflation	1.5%	1.6%	0.4%
LABOUR MARKET			
Employment (growth in %)	2.4	2.5	-2.3
Registered unemployed (rate in %)	8.0	7.7	9.8
EXTERNAL TRADE			
Exports (real growth in %)	9.2	4.4	-15.9
Imports (real growth in %)	9.3	4.2	-16.2

Table 1. *Economic trends*

Economic growth in Slovenia for 2019 by current prices was 48.0 mrd euros, which means real GDP increase of 2,4% (5,1% in 2018). Gross domestic product by capita is 22.983 EUR.

The growth of real export in 2019 was 4,4%, and the growth of real import was 4,2%. Inflation rate based on retail sales prices change in 2019 was 1,6%. The domestic consumption rate was more moderate than in 2018, and increased by 2,1%, while the total consumption increased by 2,7%.

Total employment in 2019 increased for 42.000 persons, which is 2,5% more. Registered unemployment in 2019 was 7,7%.

FOUNDRY PRODUCTION IN SLOVENIA IN 2019* (in tons)										
	Grey iron	Ductile iron	Mall. iron	Steel, Fe-granulate	Cu-alloys	Al-alloys	Mg-alloys	Zinc	Other nonf.	Total production of casting
2018	62.501	43.538	3.100	27.801	755	52.050	0	8.510	0	198.255
2019	58.281	43.867	3.200	25.099	872	54.625	0	9.665	0	195.609
INDEX 2019/ 2018	0.93	1.00	1.03	0.90	1.15	1.05	0	1.14	0	0.99

Table 2. *Foundry production*

**Statistical data acquired from Slovenian Foundrymen Society and Chamber of Commerce and Industry Slovenia*

In the table above showing achieved foundry production in 2019 in comparison to 2018:

- 58.281 tons of Grey iron (7% decrease);
- 43.867 tons of Ductile iron (on the same level as in 2018);
- 3.200 tons of Malleable iron (3% increase);
- 25.099 tons of Steel with Fe-granulate (10% decrease);
- 872 tons of Cu-alloys (15% increase);
- 54.625 tons of Al-alloys (5% increase);
- 9.665 tons of Zinc (14% increase).

Despite the obvious signs of coming recession in the second half-year of last year, the financial year 2019 was still relatively good for most Slovenian foundries. Influence of the recession in 2019 that was present in other European countries already in Autumn last year, Slovenian foundry industry haven't felt yet.

Conditions in Slovenian foundries after the COVID-19 pandemic in March this year changed drastically. Level of pandemic effect was different by individual foundries. It depended mostly on the chain that individual foundry is included in, and the country they supply. Slovenian foundries are mainly included in automobile, glass, railway and metal industry, agricultural machinery and heavy machinery.

In the first weeks of the crisis, all foundries took a stand to not stop production. They quickly organized to ensure high standard safety measures for all employees (Temperature measurements of 100% all people and visitors, wearing of masks mandatory for all employees, shifts don 't meet during a shift change, no warm meals supplied etc.). Many technical cadres and administration overnight organized "home offices" and continued the work from home. It is surprising and probably worth the praise that even in bigger foundries (where there are over 2000 employees) we didn't have a single coronavirus case.

In March production was still working in all our foundries so the first-quarter business results for most foundries were relatively good – sales approximately on last year's level or even better. In April the situation for foundries that are suppliers for the automobile industry got significantly worse. An important part of Slovenian foundry is bound to the German automobile industry, so after stopping their industry, the sales for this market lowered for 60 – 80%. Some foundries from this segment had to close down the production for a few weeks. After the relaunch of automobile industries in May, the production slowly restored. Our biggest foundries from automobile industry segment reached above 70% production before the pandemic, by the end of June. Regarding the orders, they could reach 90% by September. If car sales strengthen by the end of the year, we expect the fall of this year's production and sales to be around 8%.

Completely different is the situation for foundries that have more diverse sales market or are suppliers for railway and metal industry, agricultural machinery and heavy machinery. In this group positively stand out foundries that are a part of the critical supply chain. Those are foundries for the glass industry, in relation with the pharmacy and food industry. All these foundries have enough or even more orders and production compared to last year.

Slovenian Government so far took four measures packages for help and alleviation of negative effects of COVID-19 pandemic for economy and population. The first package of measures from March includes concern for social security for all population and especially economy, with emphasis on preserving workplaces. The second package refers to ensuring liquidity for companies and brings a consumable scheme for new bank loans. The third package brings the introduction of short-time work and extended country's subsidizing for workers on temporary lay-offs.

We estimate that despite the hard times that COVID-19 brought to our economy and population, Slovenia dealt with it relatively good with taking many safety measures. In the foreground, our goal was to preserve the production and workplaces. I think that this goal was quietly well fulfilled.

FOUNDRY PRODUCTION IN SOUTH AFRICA

National representation in the WFO:

NATIONAL FOUNDRY TECHNOLOGY NETWORK (NFTN)

WWW.NFTN.CO.ZA

Overview

The **National Foundry Technology Network (NFTN)** is an initiative of the Department of Trade, Industry and Competition (**thedtic**) and managed by the Council for Scientific and Industrial Research (CSIR). The NFTN has a mandate to manage, coordinate and facilitate transformation and development in the casting industry sub-segment through focused interventions designed to enable local South African foundries to become more competitive.

Situation

The current COVID -19 pandemic and lockdown regulations since March has negatively impacted the economic conditions in the Country. The current lockdown allows the manufacturing industry to operate at 30% staff to minimize the spread of the virus. For industry such as foundries 30% staff is not conducive since majority of the foundries are operating manually and requires the labor force to operate optimally. As a result the foundry industry has been extensively impacted. Overall manufacturing industry production has decreased by 49.4% YoY in April. The South African economy is expected to contract by 7.2% in the 2020 financial year.

General Industry Structure

The South African foundry industry is diverse in line with other global counterparts, 47% of this manufactures ferrous castings while 32% manufactures non-ferrous and the balance manufactures both ferrous and non ferrous castings. The industry produces castings is various process. The primary process in casting finished products are as follows.

- Sand Casting;
- Gravity Die Casting;
- High Pressure Die Casting;
- Investment Casting;
- Low Pressure Die Casting.

The recent study commissioned by the NFTN has shown that the South African foundry industry has approximately 134 foundries. The results have shown significant decrease as compared to the last study published by SAIF in 2016 where total number of foundries were 170. The overall production of the South African foundries is approximately 792 metric tons. 18% of this amount is exported. Overall the foundry industry employs about 11 390 people directly. The table 1 below depicts the number of foundries over the specified period.

Province	Number of Foundries			
	2003	2007	2015	2020
Gauteng	143	141	114	93
KwaZulu-Natal	26	25	20	17
Western Cape	33	32	14	11
Eastern Cape	20	20	8	4
Free State	13	13	5	5
North West	13	13	4	1
Northern Cape	7	6	3	3
Mpumalanga	15	15	2	1
TOTALS	**270**	**265**	**170**	**135**

Table 1. *Number of foundries*

The South African foundry industry uses various sources of energy for production, 73% uses electricity, 22% uses gas in addition to the electricity, 2% uses fuel based energy and 3% augment electricity supply with renewable energy. Majority of foundries uses electricity as a primary source of energy and this contributes 21% of operating cost. The energy source is depicted below in figure 1.

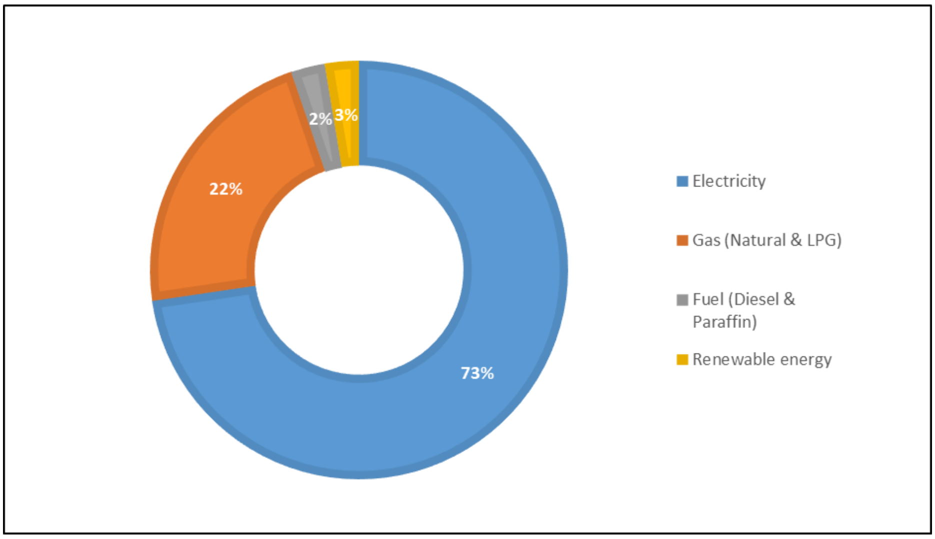


Figure 1. *Source - NFTN*

Energy and skills shortages are identified as some of the major challenges the foundry is facing. To mitigate against the skills shortages the NFTN in collaboration with industry stakeholders are developing youth in core foundry skills. Artisanship training in Moulding and Patternmaking are offered at College level to bridge the skills shortage.

Conclusion

The NFTN and other key stakeholders such as AFSA, SAIF etc, are continuing to support the industry to ensure long-term sustainability of the foundries. Engagements with Government are at an advance stage to ensure compliance of the industry with the Environmental legislations.

FOUNDRY PRODUCTION IN SPAIN

National representation in the WFO:
TABIRA FOUNDRY INSTITUTE
– INSTITUTO DE FUNDICIÓN TABIRA
WWW.IFTABIRA.ORG

Overall assessment

In Spain and during 2019, companies have had to adapt to an environment of demand that has been less buoyant than expected. The slowdown in the overall growth of the Spanish economy was driven by the fall in new orders, which fell irregularly during the year, in a context marked by difficulties in Automotive, in addition to more widespread political and economic instability.

Regarding Spanish foundries, they also faced an irregular 2019, with better production figures in the first part of the year, but with some drops in the production orders after summer in many companies linked to the Automotive sector (similar behavior than in 2018). Thus, the analysis of the year for foundries in Spain is fairly influenced by the evolution of Automotive demand in the same period. Despite the slowdown in production by the domestic car makers (the main metalcasting client sector in Spain), other sectors have offset this impact on different growth rates, maintaining the level of activity slightly similar to the one from 2018. Ferrous castings production dropped by more than 2%, while non-ferrous production saw a stabilization and a light growth in the production of Aluminum after the big drop experienced past year. Given the higher percentage of iron production within the Spanish global production figures, this has set the evolution for 2019. The sector has experienced a clear slowdown linked to the evolution of the Spanish exports and economy, that already felt in the last part of 2018 and consolidated this activity reduction in 2019.

Though for the beginning of 2020 it was expected a slow growth in the activity, the impact of the COVID19 crisis has changed all the forecasts for our foundry industry. Due to the specific economic and productive structure of Spain, with less specific weight from the industry and highly dependent on seasonal activities like Tourism and others like Retail trade, Transport, Accommodation & Food services (which were some of the most affected by this health crisis), the scenario for the country shows a very slow recovery, being among the countries in the Eurozone with one of the worst growth forecasts. Anyhow, the general expectation is that the industry will be one of the areas to recover better as soon as the COVID-19 allows a specific grade of normalization. The outlook for the next 3 years will be marked by containment, with production levels below the ones achieved in 2019 and a path of recovery is expected for the biennium 2022-2024 with the reactivation of sectors such as Automotive, Wind Energy, Chemical, Machine Tooling, Oil&Gas, among others.

General industry overview

2019 general economic and industrial highlights

The economic outlook for the coming years is of deep concern about the impact of COVID19 pandemic and the uncertainties for the restoring of the global market activity, which is affecting all sectors. Geopolitical tensions that were previously present and which can complicate the necessary recovery, also continue. The industrial environment in which the Spanish metal casting industry is performing is very exposed to the international context, mostly European, which is our main market. The Eurozone in 2019 was already experiencing a slowdown in the economy, which will cause that several industrial sectors will not maintain the previous pace of growth. Despite this context, Spanish GDP grew by 2% in 2019, above the European average (1.2%) in the same time, although this is the lowest figure reached in the last 5 years. In 2018, the GDP was 1,244,757 million euros, and the absolute value of GDP in Spain grew by 42,564M. Spanish GDP per capita in 2019 was 26,430 euros, 660 euros higher than in 2018, which was 25,770 euros. The reported drop in the growth occurs when there were already known disrupting factors such as an uncertain Brexit, the Diesel effect, the impact of the electric car or the industrial slowdown itself in Europe.

In 2019, the Spanish industrial production increased by an average of 0.6%, slightly below from the 0.7% in 2018. Industrial production moderates so its growth after 0.7% in 2018, 2.9% in 2017, 1.6% in 2016, 3.3% in 2015 and 1.5% in 2014. This was driven past year by equipment goods (2.4%), and, to a lesser extent, consumer goods (1.5%). Intermediate goods production evolved down with a 0.8% decline, as did energy, which fell by 0.4%. The Industrial Order Reception Index in December 2019 showed a variation of -0.2% from the same month of the previous year, once seasonal and calendar effects have been corrected. In 2019 order entries were reduced by 1.0%.

The slowing of the Spanish economy throughout 2019 reduced its job creation at the lowest rate since the 2028 crisis, with 402,300 new jobs, 163,900 fewer than the previous year. It has been the sixth consecutive financial year in which employment is created, this year by 2.06%, advancing in the reduction of unemployment and managing to reduce it to 13.73%. In addition, the active labour force is close to the figure of 20 million, a level that was reached before the previous crisis but which is being difficult for the Spanish economy to reach again despite the growth rate of recent years, with employment growths that have been around 1/2 million jobs. Last year finished with 19,966,900 people employed, after 92,600 jobs were created between October and December, representing the best figure in the last quarter of the year since 2006. The working population grew over the past year by 1.2% to the barrier of 23 million people, namely 23,158,000 active workers. The evolution of the labour market reflected the uncertainty of economic activity, taking into account also the increase in labour costs, with a historic increase in the minimum wage and also increases in wages set by convention and social contributions, which discouraged also in some way job creation. Anyhow, unemployment in the metal industry reduced slightly (-0.2%).

By sector, agriculture alone suffered in 2019 from job destruction with 31,700 fewer workers, a drop of 3.84%, even though the last quarter had an uptick of 47,600 more people. Services, on the other hand, accounted for the majority of job creation for the financial year, with 374,600 more workers than in 2018, an improvement of 2.54%, albeit lower than in the previous year. The industry, which lost workers in 2018, now scores 55,400 up (2.05% more), and construction, another 4,000.

In 2019, exports in Spain grew by 1.5% compared to the previous year. Sales abroad accounted for 24% of its GDP. Regarding the metal industry, the production saw an increase close to 1% in the end of the year, with a similar growth in exports.

Impact of COVID19 in 2020 outlook

By 2020, the Spanish economy is expected to fall around 12%, which means continuing to be subjected to a major crisis in the near future, being aware that other countries are suffering the effects of the same situation. Despite the high level of uncertainty, for next year it is expected a partial recovery path of around a 6% or a 7% for the Spanish economy (figures are anyhow under constant review). The drop in foundry sales and production in April 2020 has been total for Automotive producers, with also large falls in other sectors. There is a shared pessimistic forecast of a decrease in accumulated sales for the end of this year. The recovery will be leaded by the activity of the OEMs, who estimate about 3-4 years to recover the previous demand levels. The Spanish metal sector does not generally show economic pathologies that aggravate liquidity problems.

An important factor is that the foundry industry from Spain is one of the largest exporters in the EU (it exports a volume close to 750 thousand Tn, 75% iron, mainly to the EU). This means that the improvement of the European market will set the path for our industry (EU GDP will be around -8% this year, expected a +5% in 2021).

Foundry Industry

According to the general economic situation in Spain and following the evolution of the production trends in relevant customer sectors, especially in the Automotive sector, the Spanish casting production remained in 2019 in a slowed down output curve, which was accelerated down in 2020 by the effect of the COVID-19 health crisis. Thus, the total casting production in Spain presents similar figures in 2019 compared to 2018, continuing with the positive trend predicted after the stabilization phase post-crisis, but with a slowdown in the growth curve. The perspectives were moderated in the end of 2019, waiting for a better condition in driving client sectors like Automotive, and improvement in sectors like Wind Energy, but the outlook changed abruptly with the outbreak of the new crisis in the first quarter of 2020. The split of the production figures from 2019 are shown in the Figure 1.

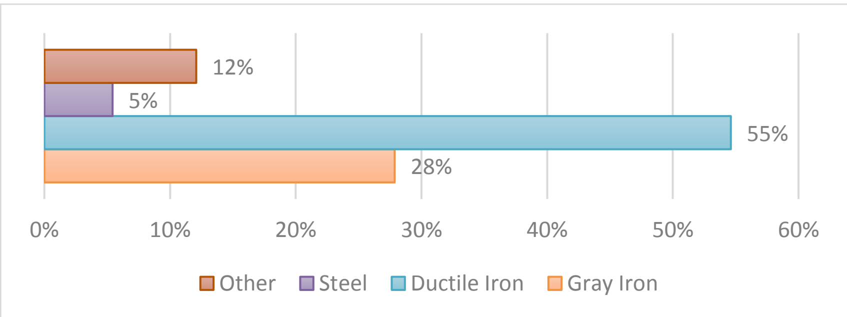


***Figure 1.** Spanish casting production figures from 2019*

More than half of the casting production in 2019 was on Ductile Iron (close to 0,7 million metric tons, with a decrease in the production level from the previous year close to 3%), followed by Gray Iron with nearly a 30% share (nearly 0,36 mil.t). Contrary to previous years' trend, there has been a reported better behavior in the production of Aluminum castings, mainly because of a partial improvement over the negative evolution of this market past year.

Ferrous castings represented nearly 88% of the total Spanish Foundry production during 2019, and non-ferrous materials got close to 12%. The trend in 2019 continued to be as in previous years, with a very similar split between these two groups, but showing a tendency to a drop in the production, as an impact of the slowdown in the markets. As it can be seen in Figure 2, the slowdown tendency in terms of production growth has evolved in 2019 to a decrease in production, which gets up to -2.2% in the ferrous materials.

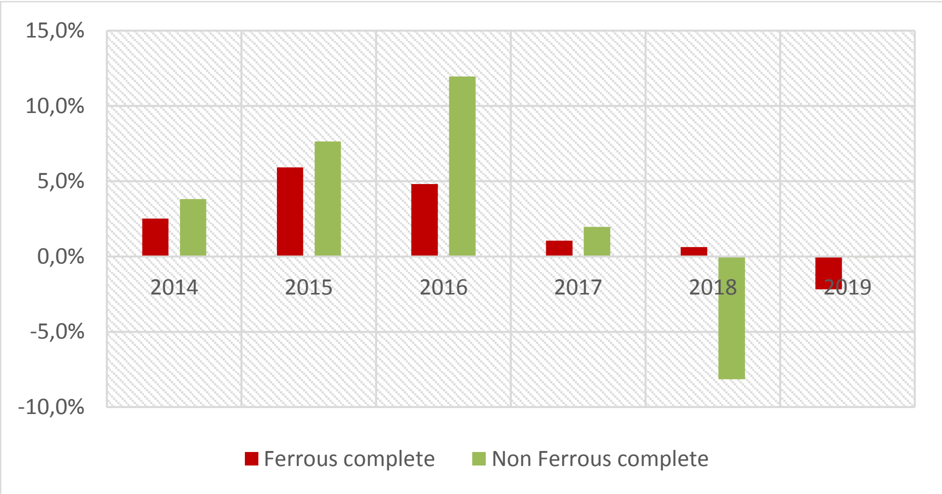


***Figure 2.** Production growth of Ferrous and Non-Ferrous castings*

As shown in Figure 3, Aluminum production growth rate has improved the slowdown showed in 2018 in comparison with the evolution for Ductile Iron and Gray Iron. As these last ones have been also showing a slowdown in their growth, the relative weight of Aluminum production kept a similar share, with a constant tendency during 2019.

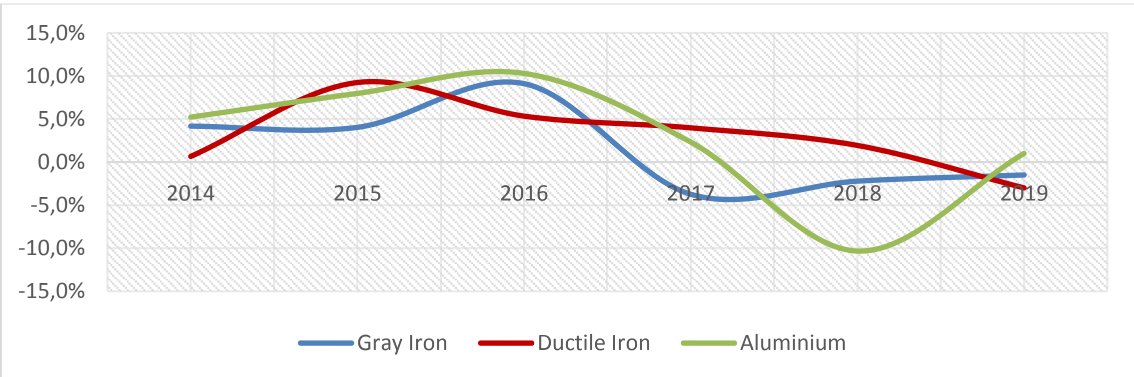


***Figure 3.** Evolution of annual production growths*

Despite the different circumstances and the recent economic crisis, the characterization of the Spanish production has remained in very similar levels, as can be seen in next figure, showing a mature and stable market.

The tendency of maintaining the specific weight of Iron castings is accompanied by a stabilization in the production of cast Steel (due to the better numbers in its production for 2019, more than 3% up in comparison with previous year) and a bigger presence of the Non-Ferrous materials.

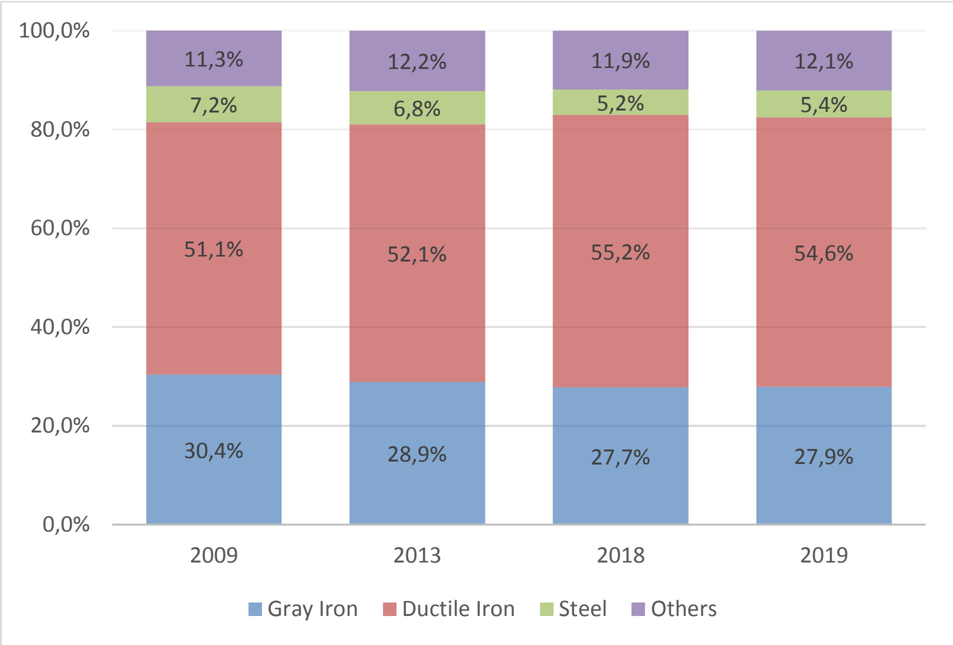


Figure 4. *Production share by materials*

Though close to 37% of the Foundry factories are Cast Iron Plants, they represent more than 50% of both turnover and labor market in the sector, as well as nearly 80% of the exports.

Main cost factors for Foundry plants are raw materials (an increased reported in sands for 2019), followed by workforce, representing both together more than 60% of the total cost.

The number of foundry plants remains quite constant, with a slight slowdown for 2019 in the efficiency and average production per plant provoked by the decrease in production and some plant restructuration.

Since 2003, some companies have suffered from restructuration or closure. For this reason, the number of facilities has had a significant reduction in the last 15 years. However, because of restructuring, modernization of facilities and efficiency improvements, the general production levels have remained positive.

In 2019, the average labor cost was over 40,000€, with direct labor over 65%, according to sectorial information. The number of employees has maintained some stability in 2019, close to 14,000, with a slight descend over 1%.

During the 2008 crisis, production figures dropped 30% from a total of 1.3 million metric tons. On the basis of the recovery started from 2013, a moderate increase in the annual production of castings was expected in Spain until 2020, up to the pre-crisis levels, and it was expected to keep on growing overcoming the 1.3 million tons by 2020. These expectations have been slightly reduced in 2019, with even a bigger decrease in production for 2020 because of the effect of the COVID19 pandemic, so that forecast won't be fulfilled as projected. The biggest production increase in 2019 has been in Steel (3%), with a slight decrease in Gray Iron and a wider one in Ductile Iron. Aluminum has stabilized the production after the big drop in previous year.

General production figures show a change in the growing tendency and the rising curve, with a decrease in ferrous materials (over -2%) and a better performance in the non-ferrous materials. The final outlook for 2020 is more pessimistic because of the impact of the global health crisis, with some forecasts announcing a drop between 8% and 12% in the production level, depending of the evolution and the measures to be taken to answer the pandemic impact.

Approaching the Spanish situation by sectors, we find an irregular response from casting plants producing for the Automotive industry, a continuing tendency from previous year. More than 60% of the total production is directed to the Automotive sector (in the Non-Ferrous materials, this figure goes up to almost 80%). In steel castings, Railway and Construction, as well as civil engineering are driving the production.

More than 80% of the production in Spain is exported. Though the manufacturing figures of cast components for the Automobile industry has increased in some cases (specially from July on), other have suffered a lower number of orders in the second part of the year. The stability in the industrial and commercial vehicle market is a key driver for Foundry companies in Spain, so the situation in this sector affects directly our national foundry industry.

The accumulated drops in the end of 2019 in the orders from customer sectors like Automotive, Machine Tool, Construction, Die Tooling or Agricultural, as well as some weakness in other sectors, confirmed the unstable trend value detected past year for the casting production.

There was a better evolution in others like Wind Power and Valves. The drop in the demand influenced the entire chain of molds, machine tool… that directly affects the casting industry. Sectors such as Aerospace, Railway, Paper, Oil and Gas or Mining do not show such a positive trend from the demand point of view.

In general, the prevailing feeling among Spanish Foundry managers about 2020 is pessimistic, because of the uncertainties in the global situation created by the impact of the Coronavirus crisis. Order drops are expected in the end of the year from all the main client industries. Overall production figures show a drop due to the overall slowdown in industrial sectors that see their development plans paralyzed as long as the effects of COVID last.

Everyone remains hopeful that from 2021 on, the production levels will be recovering little by little those in 2018.

General concerns

There are some main concerns in the Spanish Foundry industry which affect production costs and competitiveness, which we try to describe more into detail.

Market uncertainty

Although a slightly optimistic behavior was augured in the early 2020s, all forecasts have collapsed on the beginning of the COVID19 pandemic and the actual outlook identifies a setback that would take 3 to 4 years to recover.

The health crisis is also affecting the global foundry market and all its participants, so the new expected market shares and movements in the value chain is a concern for our managers.

Industrial and political uncertainties in the Covid19 era

The Spanish Foundry industry is highly linked to the Automotive sector and it is being affected by the impact of the production drop in the last years, so the Spanish Foundry managers are really concerned about the future evolution of this market. In addition to this, the political uncertainties around the future impact of Brexit in the European economy, plus the new tariffs and the trade tensions between the US and China and its possible effects, outline a complicated scenario where our industry faces new difficulties to establish the proper short-term strategies.

Energy costs

Though the manufacturing costs have remained similar in 2019 to the previous year, it remains as one of the most important concerns for the Spanish foundries, as oil, electricity and gas prices have experienced continuous rises in the last years. The EU has seen continued growths in electricity prices, being Spain one of the countries where more extra taxes are applied.

In the case of electricity and for the periods 2007-2009 and 2010-2014, Spain has moved from €113 / MWh to 140€ as average data. In comparison, there are exemptions in some EU countries, with final costs lower than Spanish industries.

The evolution of energy prices (electricity, gas and other fuels), has been accompanied, in the case of Spain, with a low relative increase in the prices of the products. The impact/effect of energy prices is remarkable in the sub-sectors related to foundry industry in this country. In short, the rate paid by Spain is 22% higher than the European average and reaches 30% on Germany.

Unemployment

The slowdown of the Spanish economy throughout 2019 reduced job creation to its lowest pace since the exit of the 2008-2012 crisis, with 402.300 new jobs, 163.900 fewer than the previous year.

It is the sixth consecutive year in which employment is created, this year by +2.06%, and the seventh in which the unemployment rate is reduced down to 13.73% of unemployment (still a very high figure), reducing the achieved 15% in 2018. The youth and women employment have been improved.

The evolution of the labour market reflects the evolution of the economic activity, swayed throughout 2019 by the global uncertainty of Brexit and trade wars.

The previous crisis forced to reduce labor in many foundries, and this meant as well the loss of experienced and skilled professionals. This effect has been increased by the health pandemic situation in 2020, especially during the lockdowns in the first quarters of the year. Spanish Foundry requires new qualified people, but it is necessary to carry out training programs to improve the knowledge in the companies.

Educational Centres are training professionals with the aim of improving the skills of the staff from the industry and bringing knowledge to the companies, with a special mention to the knowledge and skills required by the introduction of 4.0 technologies in the foundry industry.

More investment needed in R&D

The previous crisis affected unequally the different industrial sectors in Spain, maintaining in the metal industry a general trend of a lower investment in R&D activities. The following charts show the continuous R&D investment from the Automotive sector (1.37% of its business volume), compared to the decreasing metallurgical sector efforts that reached only a 0.27%. To be highlighted, the great momentum of the chemical sector regarding R&D, as with 1.5 billion euros has made an investment of 13.1%, 6 points more than the industrial average.

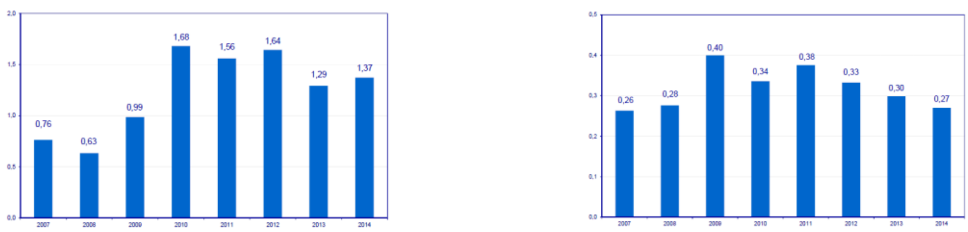


Figure 5. *R&D investment in Automotive*

Impact of Electromobility in Foundry

Electromobility is changing the Automotive industry (still at a low level) and in the near future it will also have a direct influence in the Foundry sector, with new power and transmission concepts in the future lightweight vehicles that will affect the demand of certain families of cast components. The outlook is quite ambitious, as by 2030 it is estimated that electric vehicles market can reach a quota of 24 million/vehicles per year. This logically means a change in vehicle designs and some parts replacement and will as well require adapting to new technologies.

Spanish Foundries are really interested in this topic and developing some initiatives to explore the impact and the new opportunities.

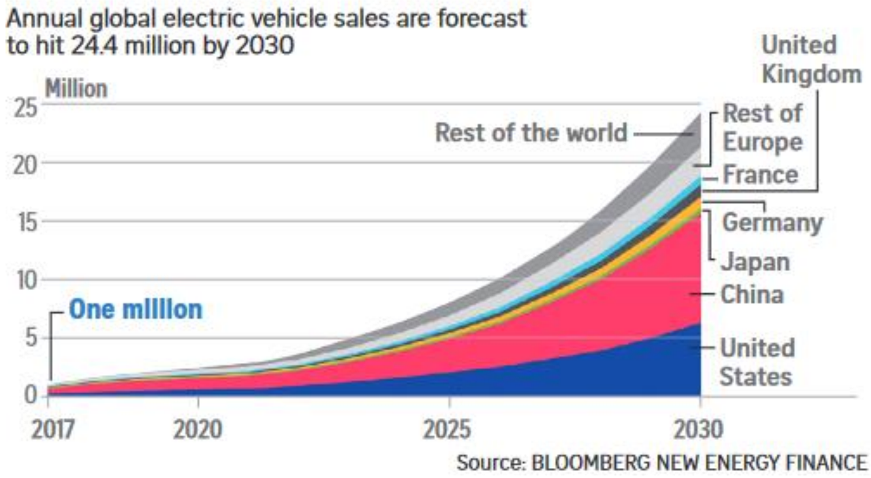


***Figure 6.** Annual global electric vehicle sales forecast 2030*

Challenges

The Spanish Foundry industry faces especially two main challenges linked to its efficiency: the digitalization and advanced management of the casting processes and the prediction and defect control on real time production. Thus, the sector is looking for the application of predictive control systems in the foundry shops and to the introduction of 4.0 technologies.

There are as well several additional challenges that the Spanish Foundry Sector identifies as a priority for next years:

- Access to advanced technical knowledge on international basis;
- Process automation;
- Attraction of new qualified professionals to the industry;
- New skills required linked to 4.0 technologies;
- Additive manufacturing;
- Advanced materials (optimization of mechanical properties, weight reduction ….)
- Good practices for a more efficient use of energy;
- Reduction of the environmental impact (emissions, silica quarz);
- Advanced reclaiming solutions for used sand;
- Increase in the proximity to the design of manufactured casting components.

Some of the new technologies and areas that the Spanish Foundry industry highlights with a higher impact on the most relevant challenges for its activity are:

- Artificial vision;
- Automatization and collaborative robots;
- Sensors;
- Automatic defect detection;
- Expert management systems.

FOUNDRY PRODUCTION IN SWEDEN

National representation in the WFO:
SWEDISH FOUNDRY ASSOCIATION
EN.GJUTERIFORENINGEN.SE

Report provided on their behalf by
RISE SWECAST AB
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Sweden - Economic situation and main indicators for 2019

Sweden now has about 10.3 million inhabitants, which is a steady growth. The unemployment rate at the end of the year was 6.8% in total, slightly higher than 2018. The Swedish economy has clearly entered a stagnation, which is normal after several years of an economic boom. This stagnation is furthered strengthened by the insecurities regarding Brexit and trade conflicts. Inflation in December 2019 amounted to about 1,7 %. The PMI index (Purchasing Managers Index) was during the first half of 2019 above 50 with indicates expansion, however from September to the end of 2019 the index was below 50, signaling a contraction.

General casting industrial structure

The number of foundries in Sweden is rather stable. Two HPDC foundries declared bankruptcy, but the production sites were taken over by two other HPDC foundries. This means that during 2019 we still had just less than 100 foundries (approximately 25 iron foundries, 11 steel foundries and some 60 metal foundries, mainly aluminum). As usual the customer side is dominated of the automotive sector, and nearly 70 % of the total production end up in the transport sector as components in trucks, light cars and construction equipment. The building of two new iron foundries, one at Scania and one at Volvo, which we mentioned in previous reports, has progressed according to plan in 2019.

Continued investments in automation have reduced the need for recruitment and the stagnation in the economy with higher unemployment figures have made it somewhat easier to recruit. The industry still has difficulties in recruiting younger and well-educated employees and further actions must be taken in order to make the industry more relevant. During 2019 a web-based distance education package for HPDC was launched as a result from a European project, see www.e-cast.eu

Production

The total foundry production has decreased with approximately 3 % between 2018 and 2019. The decrease is connected to the stagnation of the Swedish economy. This stagnation started in 2018 however was not as visible in the foundry industry at the time.

In table 1 below you can see the figures for the total production (tons).

Material	2019	2018	Diff (%)
Iron, total	216 900	225 700	-3,9
Steel	23 500	22 900	+2,8
Non-ferrous total *	65 100	67 270	-3,2
Total production, all materials	305 500	315 870	-3,2

Table 1. *Total foundry production in Sweden, 2018 and 2019*

** Al ~ 48 000, the rest is a mix of Cu, Zn and Mg*

Regarding Al we estimate that approx. 75 % is High pressure die casting (HPDC)

the rest, approx. 25 %, is a mix of Gravity casting and Sand casting.

During 2019 the Swedish foundry association along with RISE and Jönköping University presented a strategic agenda for the Swedish foundry industry in the perspective 2020 - 2035. The focus of the agenda is to realize a sustainable Swedish foundry industry. Three focus areas have been identified in order to fulfill the purpose namely: an attractive industry, advanced products and competitive and sustainable production.

Note: for 2020 a possible decline in the range of 30 – 50 % can be expected.

FOUNDRY PRODUCTION IN SWITZERLAND

National representation in the WFO:
GIESSEREI-VERBAND DER SCHWEIZ (GVS) – SWISS FOUNDRY ASSOCIATION
WWW.GIESSEREI-VERBAND.CH

Swiss foundry industry feels the economic downturn in 2019

Last year, the 45 companies merged in the Swiss Foundry Association (SFA) produced a volume of 42,160 tonnages delivered, in total nine per cent less than in the previous year. The interbranch organisation expects stabilisation on this lower level for the current year.

Thanks to outstanding innovative developments and the typically Swiss values in terms of quality, reliability, flexibility and punctuality of delivery, the Swiss foundry industry was also able to consolidate its good position in the international competition in 2019. In the first place, growth rates were achieved through new orders from the entire transport sector, especially from the automotive and commercial vehicle industry. Increasingly complex lightweight cast parts to reduce CO_2 emissions feature among the Swiss foundry industry's specialities. There was also an increasing number of orders received relating to e-mobility and from the entire environmental and energy sectors for new sustainable developments, including for drinking water supply and sanitation. The continuing boom in the building trade at home and abroad also ensured good utilisation of production capacity.

In the first half of 2019, the order situation in the Swiss foundry industry saw a stable upward trend – with continually moderate growth rates compared to 2018 in practically every user market. In the second half of the year, though, the growth momentum slowed down markedly; in some member companies of the SFA with losses in incoming orders and utilisation of production capacity of roughly 10 to 20 % towards the end of last year. Altogether, in 2019 the production volume of the 45 Swiss foundry companies merged in the interbranch organisation fell by approximately 9% on the previous year to 42,160 tonnages delivered. The drop in incoming orders reflects the downturn in the economy of the Swiss foundry industry's key export markets, which account for about 80% of the total business volume. The significant slowdown was caused by the trade dispute between the USA and China as well as the unresolved Brexit.

In this environment of economic uncertainty in 2019, it was primarily major corporations that made increasingly fewer investments. The customers from the automotive industry hugely stepped up the pressure again for price reductions to finance the upcoming investments in the new technologies like electromobility, autonomous and connected driving. Lightweight measures have become standard and a commodity. In addition to the global slump in business development, the falling margins due to the successively repeated strengthening of the Swiss franc against the euro also had a negative impact on the annual result.

FOUNDRY PRODUCTION IN TURKEY

National representation in the WFO:

TÜDÖKSAD – THE TURKISH FOUNDRY ASSOCIATION

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TÜRKİYE DÖKÜM SANAYİCİLERİ DERNEĞİ
THE TURKISH FOUNDRY ASSOCIATION

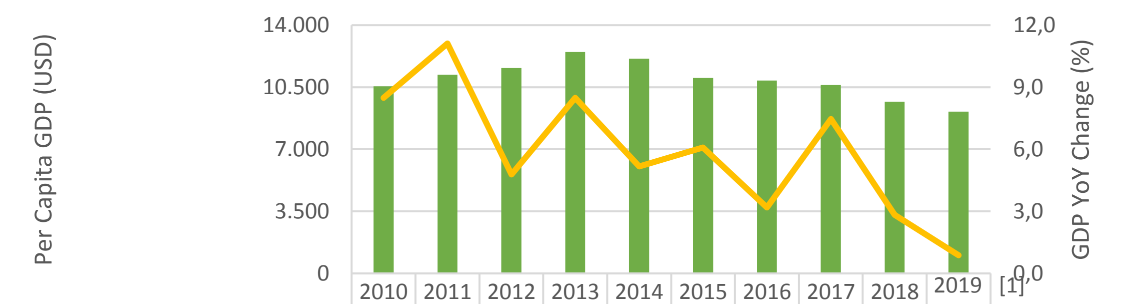
Macroeconomic Developments

2019 was the year of recovery for the Turkish economy after the negative macroeconomic developments, political tensions, geopolitical risks, and the changes in the global risk perception in 2018. After three consecutive quarters of year-on-year contraction, real GDP growth resumed in the third quarter of 2019 and strengthened in the fourth, bringing 2019 growth to 0.9 percent.

The central bank cut interest rates from 24 percent in June 2019 to 9.75 percent in March 2020. This rapid monetary easing stimulated domestic demand which strengthened notably in the final stages of 2019. This development, together with the supported exports due to currency depreciation aided the recovery in GDP.

With the government's reinforced focus on achieving high growth rates, lower borrowing rates and related regulations boosted private sector credit growth by 10 percent. On the other hand, the substantial minimum wage increase at the beginning of 2019, temporary indirect tax cuts and credit expansion by public banks accelerated private consumption, which grew 6.8 percent year-on-year.

Consequently, 6.0 percent year-on-year growth in the fourth quarter yielded a 0.9 percent economic growth in 2019. Due to the depreciation of the local currency by 13 percent, Per Capita GDP in USD kept contracted by 5.8 percent (Figure 1).



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019 [1]
Per Capita GDP (USD) [2]	10.560	11.205	11.588	12.480	12.112	11.019	10.883	10.616	9.693	9.127
GDP YoY (%) [3]	8,5	11,1	4,8	8,5	5,2	6,1	3,2	7,5	2,8	0,9

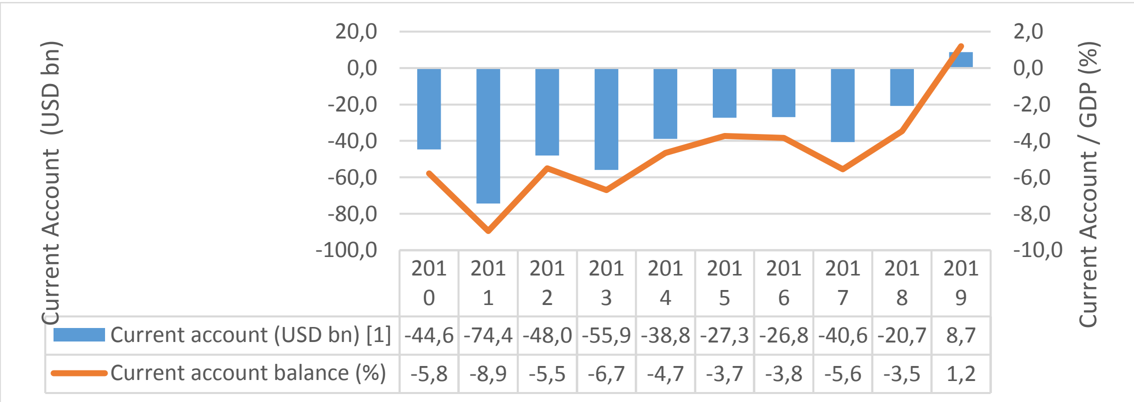
Figure 1. *Gross Domestic Product Growth and Per Capita Gross Domestic Product*

Source: TurkStat (Turkish Statistical Institute)
[1] 2019 figures are the sum of four quarters; subject to be revised when the annual figures published.
[2] Based on mid-year populations; the annual results of Address Based Population Registration System.
[3] Calculated by production approach in chain-linked volume percentage change [2009=100].

Households benefited from a relative reduction in the unemployment and inflation rates, especially during the last quarter, although both remained elevated nonetheless. Employment has declined through 2019, despite considerable additional job creation in public and social services, and the rate dropped from 46.2 in 2018 to 45.4 percent in 2019. Seasonally adjusted data shows that the unemployment and youth unemployment rates rose 0.2 points to 13 percent and 0.5 points to 23.9 percent relatively.

Strong domestic demand boosted import growth in the last quarter which grew 29.3 percent year-on-year during this period. But looking at 2019 as a whole, exchange rate depreciation delivered competitiveness gains, thus exports grew 2.1 percent year-on-year despite a 9.1 percent decrease in imports as compared to the previous year. Manufacturing export orders from the European market have contracted, but aggregate exports have remained positive, mainly due to tourism exports. As a result of export growth outpacing that of imports, the annual export to import ratio increased from 75.3 to 84.6 percent in 2019, which was the highest ratio in a decade.

The current account deficit which had recorded a surplus in the third and fourth quarters of 2008 shifted to surplus again in the second and third quarters of 2019 before returning to a deficit in the fourth quarter. Consequently, Turkey recorded a current account surplus in 2019 for the first time in just under two decades (Figure 2).



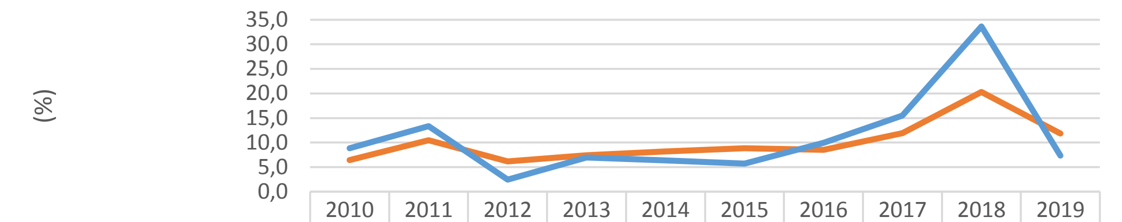
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Current account (USD bn) [1]	-44,6	-74,4	-48,0	-55,9	-38,8	-27,3	-26,8	-40,6	-20,7	8,7
Current account balance (%)	-5,8	-8,9	-5,5	-6,7	-4,7	-3,7	-3,8	-5,6	-3,5	1,2

Figure 2. *Current Account Balance*

Source: CBRT (Central Bank of the Republic of Turkey
[1] Balance of Payments statistics and the updated statistics for trade in goods item based on the General Trade System have been revised for the years 2013-2019.

Annual consumer price index inflation declined from its peak of 25 percent in October 2018 to 8.6 percent in October 2019, but it accelerated in the following months due to the higher seasonal factors and unfavorable base effects which led the annual CPI to end 2019 at 11.8 percent, down from 20.3% in 2018 (Figure 3).

After the sharp deceleration from 8.8 percent to 1.6 percent year-on-year rise in 2018, the industrial production fell by 0.7 percent year-on-year on a calendar-adjusted basis in 2019.



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CPI YoY (%) [1]	6,4	10,5	6,2	7,4	8,2	8,8	8,5	11,9	20,3	11,8
Dom. PPI YoY (%) [1]	8,9	13,3	2,5	7,0	6,4	5,7	9,9	15,5	33,6	7,4

Figure 3. *Consumer Price and Domestic Producer Price Indices Year-on-Year Changes*

Source: TurkStat - Turkish Statistical Institute
[1] 2003=100, End of Period, Annual Percentage Change

Except for September, the manufacturing purchasing managers' indices (PMI) stayed below the 50-threshold in 2019, which was the signal of annual contraction in industrial production. On the other hand, the index remained close to 50 during the last quarter, which showed the deterioration in the business conditions of the Turkish manufacturing-sector was pretty limited.

Furthermore, the continuous increase in the real sector confidence index in the last quarter reflected less pessimism regarding the total amount of current orders, while firms' views on output, employment, and export orders in the first quarter of 2020 were more positive. The index reached 108.7, which was 95.4 at the beginning of the year (Figure 4).

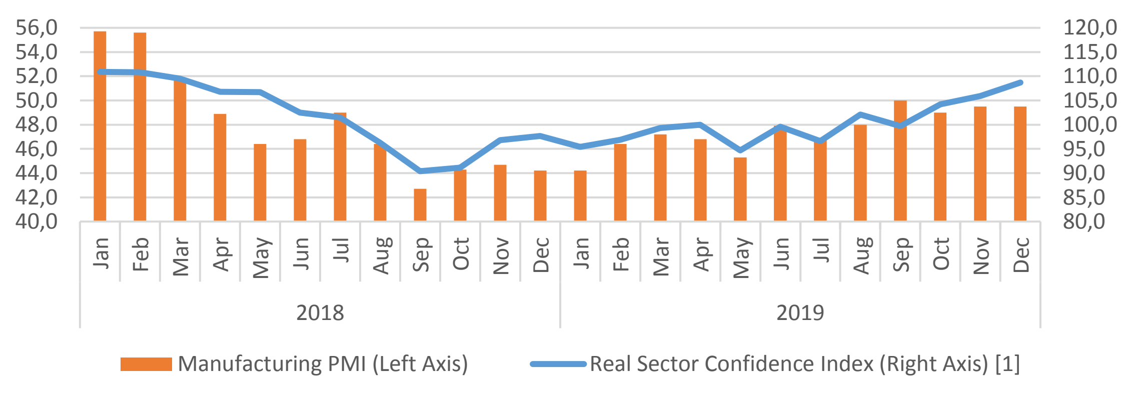


Figure 4. *Manufacturing Purchasing Managers' Index vs. Real Sector Confidence Index*

Source: TurkStat (Turkish Statistical Institute; CBRT (Central Bank of the Republic of Turkey); ICI (Istanbul Chamber of Industry) and IHS Markit
[1] Seasonally adjusted indices

The Situation in the Major Casting Customer Industries

In 2019, total motor vehicle production decreased by 6.5 percent and domestic sales by 35 percent year-on-year. The decrease in passenger car production and market (4.3 and 20.4 percent, respectively) were the main reasons for the decline in the vehicle industry. Commercial vehicle production fell by 8.6 percent, whilst tractor production by 36.6 percent.

The export volume of the general machinery industry increased by 4.2 percent, and to some extent compensated the loss in domestic demand. The export volume grew by nearly 10.3 percent in earth-moving machinery production where a 54.4 percent contraction was observed in the domestic market. The domestic sales in the tractor market were also reported to shrink by 45 percent, while there was a significant increase of 20 percent in the export numbers. Electricity motor and generator exports recorded an increase of 25.7 percent year-on-year in 2019.

Falling demand for housing deeply impacted the construction sector. The annual drop in building permit floor area reached 52.4 percent, and the total house sales fell by 1.9 percent. The annual production and domestic sales of the cement industry declined by 21.4 and 29.4, respectively, while the export volume increased by 48.8 percent.

Steel production dropped 9.6 percent as compared to the previous year.

The installed capacity in electricity production rose 2.3 percent in 2019, where the driving force was the investments in renewable energy resources.

Production in the white goods sector remained stable in 2019 which recorded a negligible decline of 1.1 percent, owing to the export volume.

Developments in the Foundry Industry

Industry Overview

According to the most recent statistics (i.e. AFS's 53rd Census of World Casting Production, which was published in December 2019), in terms of total casting production volume Turkey secured its position as being Europe's 3rd biggest producer; and in terms of ferrous casting production volume as being 2nd. The Turkish Foundry Industry sustained its growth and increased its share in the global casting production by 34 percent in the last five years to a 2 percent level (Figure 5).

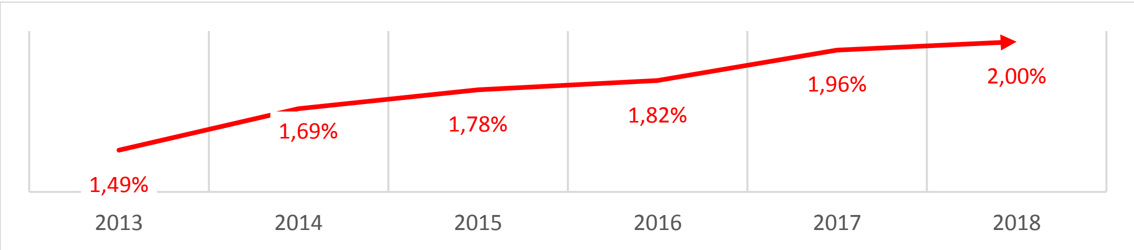


Figure 5. *Share of Turkey in Global Castıng Productıon*

Source: AFS 53rd Census, December 2019

In 2019 the total production of the Turkish Foundry Industry rose 2.6 percent year-on-year to 2.31 million tons, with an export volume of 1.48 million tons.

The recession in the economic activities that started in 2018 and continued in the first half of 2019 put pressure on domestic demand. However, the significant increase in the calendar-adjusted industrial production in the last quarter enabled the losses to be minimized in general, and the increase in total metal casting production continued in 2019, owing to the increase in exports despite the worldwide recession signals and trade war tensions (Figure 6).

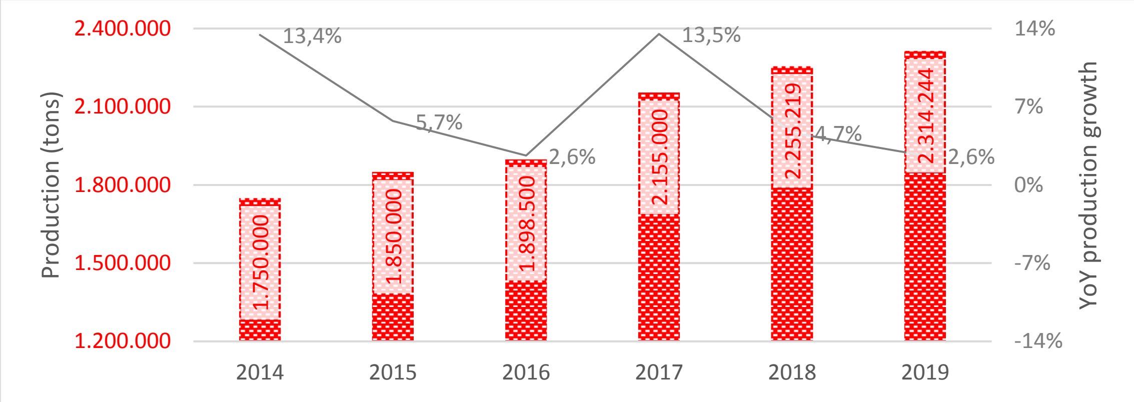


Figure 6. *Metal Casting Production*

Source: TÜDÖKSAD - Turkish Foundry Association

The deceleration is mainly due to the slowdown of the increase rate in nonferrous castings production, despite a stable trend in ferrous castings.

In 2019, the total production in iron foundries recorded a slight increase as compared to 2018 but in steel foundries, it remained stable. In total, ferrous castings production rose 1.9 percent to 1.74 million tons (Figure 7).

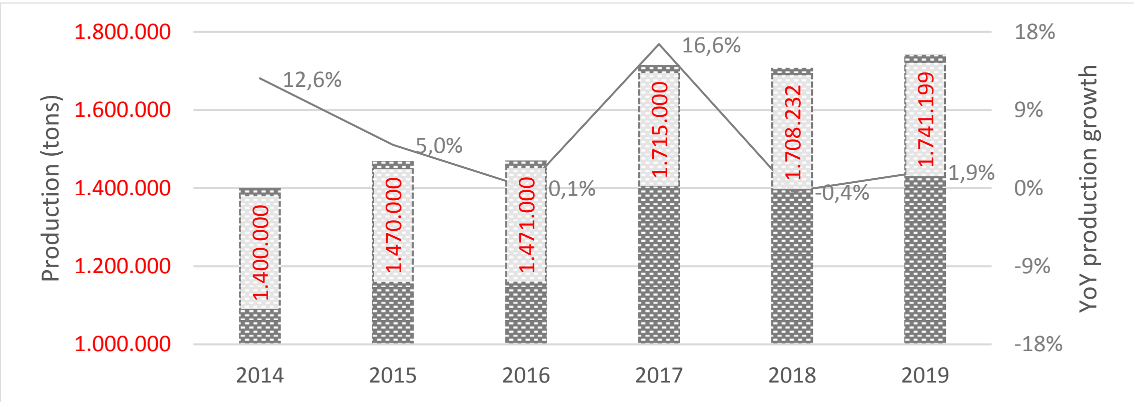


Figure 7. *Ferrous Casting Production*

Source: TÜDÖKSAD - Turkish Foundry Association

On the other hand, the production of non-ferrous foundries was up by 4.8 percent, which makes around 570 thousand tons of production in 2019. Nearly 90 percent of it was enrolled by aluminum foundries and the remaining was by the foundries producing other non-ferrous castings (Figure 8).

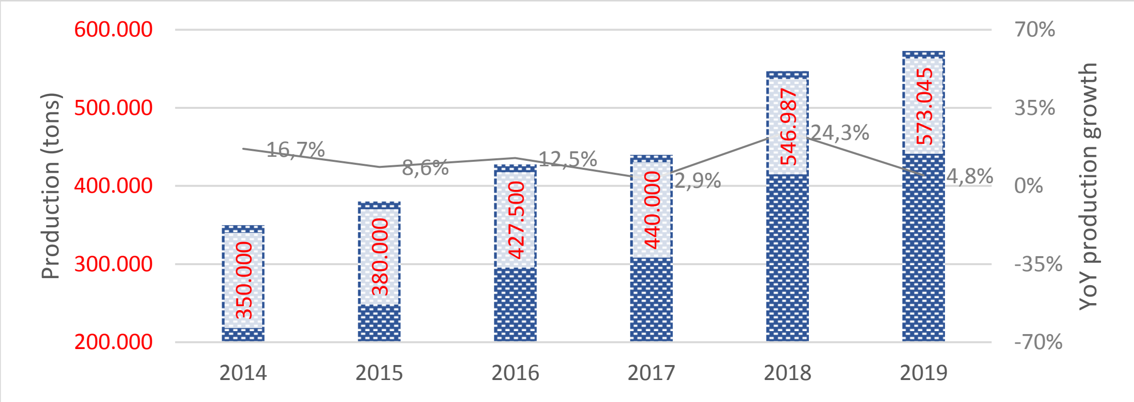


Figure 8. *Non-Ferrous Casting Production*

Source: TÜDÖKSAD - Turkish Foundry Association

However, the increase in the production value of metal castings against last year continued with a loss of acceleration in growth; thus the value increased by 4 percent to 5.32 billion Euros.Capacity utilization in ferrous foundries rose 1.46 points year-on-year to 66.6 percent in 2019. Whereas non-ferrous foundries reported a capacity utilization of 79 percent in 2019, down from 91.3 percent in 2018.

Investments

In line with the volatile macroeconomic conditions in 2019, the investment amount of the Turkish Foundry Industry declined to 102 million Euro with a significant, 41 percent decrease as compared to the previous year. A substantial part of the investments was put on hold and the actualized investments mainly aimed at increasing the productivity and maintaining automation of the processes.

The Situation in the Material Sectors

Iron Castings

After last year's sharp drop, grey iron castings grew 1.9 percent year-on-year in 2019. The annual increase in the nodular iron castings production was slightly higher, with a ratio of 2.4 percent. Consequently, the overall iron castings production volume reached 1.55 million tons with a 2.2 percent year-on-year increase.

While the pressure on domestic demand was the primary reason for this trend, the global economic situation, trade tensions, and the recent developments in the automotive industry were the other key factors. The share of iron castings in total metal castings production dropped from 67.2 to 66.9 percent in Turkey.

Iron foundries in total reported a capacity utilization of 66.6 percent, which was 64.3 percent for grey iron castings and 69.2 percent for nodular castings.

Steel Castings

The steel castings production volume remained almost stable at 193 thousand tons in 2019 with a capacity utilization of 66.6 percent.

Non-Ferrous Castings

The investments in capacity increase, especially in HPDC foundries had yielded a strong growth in aluminum castings for the past couple of years. In 2019, despite a decline in the growth rate, production volume reached 504 thousand tons, registering a 6 percent growth. Capacity utilization in aluminum foundries was 80.1 percent.

The production volume of other non-ferrous foundries dropped 3.2 percent to around 70 thousand tons with a capacity utilization ratio of 65.2 percent in 2019.

Cost Development

Manufacturing costs of foundries are mostly based on foreign exchange rates due to the import of raw materials. As compared to the significant increases in the previous year, exchange rates were stable in 2019, and relatively lower increase rates were recorded in the TL/USD and TL/EUR YoY exchange rates, 12.9 and 10.3 percent, respectively.

This upward trend, as well as the overall and casting industry domestic PPI year-on-year changes, had continued impacts on the production costs of the metal casting industry.

Energy

The sharp increase in both energy and gas prices sustained in 2019. In comparison with the previous year, the electricity and natural gas market prices for industrial facilities were up on Euro basis by 25.4 and 26.2 percent, respectively (Figure 9). The energy cost of foundries was reported to increase by 17.1% on the Euro basis in 2019.

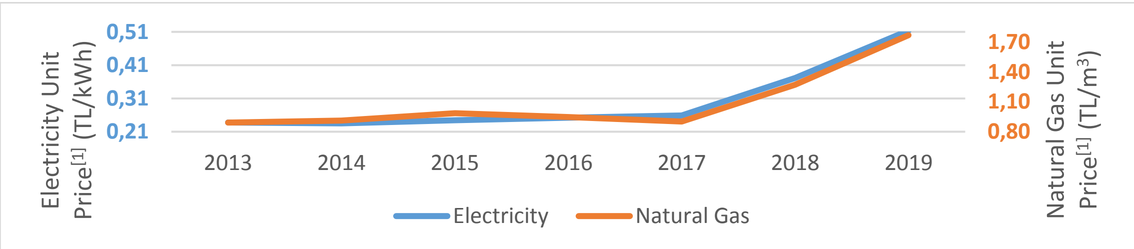


Figure 9. *Electricity and Natural Gas Prıce development*

Source: Turkish Statistical Institute
[1] Average prices paid by industrial consumers for 1 kWh electricity / 1 m3 natural gas including all taxes.

Raw Materials

The increase in the raw material prices sustained in 2019. More than 75 percent increase in local currency was observed in the past two years (Figure 10). Foundries reported a 17.1 percent increase in TLs and a 4.7 percent increase in Euros in total raw materials costs.

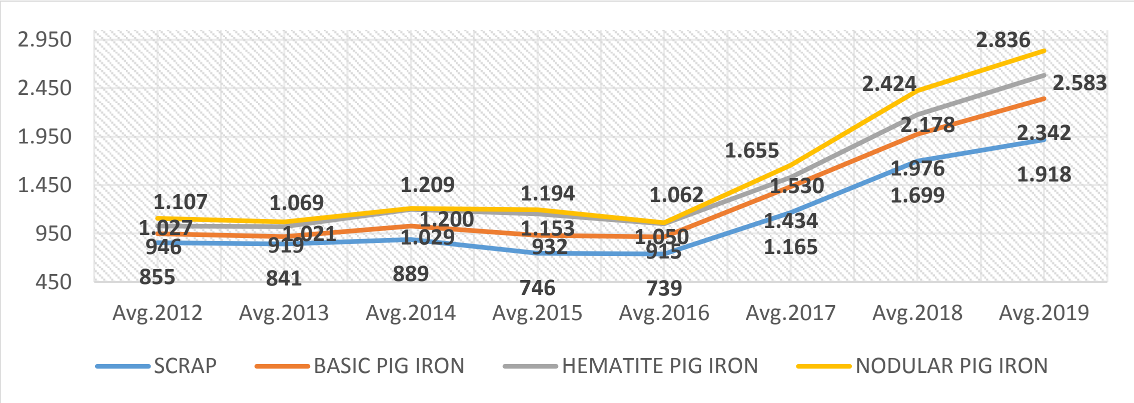


Figure 10. *Raw Materials Price Development*

Source: TÜDÖKSAD - Turkish Foundry Association

Wages

The year-on-year change in the industrial production hourly labor cost index which was below 10 percent in 2017, reached the highest level in ten years, 23.1 percent in 2019 (Figure 11). Foundries reported a 10.1 percent year-on-year increase on Euro basis in labor costs in 2019.

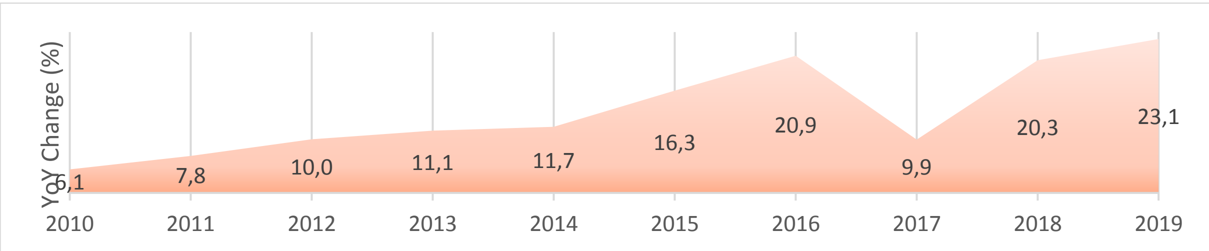


Figure 11. *Hourly Industrial Labour Cost Index Year Over Year Change*

Source: Turkish Statistical Institute
Labor cost is the cost incurred by the employer concerning employment as earnings and labor cost excluding earnings. Hourly labor cost is calculated by dividing the labor cost by the number of hours worked. The annual average of seasonally and calendar adjusted indices are used for calculation (2015=100).

FOUNDRY PRODUCTION IN UNITED KINGDOM

National representation in the WFO:
INSTITUTE OF CAST METALS ENGINEERS
WWW.ICME.ORG.UK

Report provided on their behalf by
the ***CAST METALS FEDERATION***
WWW.CASTMETALSFEDERATION.COM

Economic Background

UK gross domestic product (GDP) growth increased by 1.4% in 2019, compared with forecast growth of 1.2%, and growth of 1.3% during 2018. GDP was flat in Quarter 4 (Oct to Dec) 2019 with growth in both services and construction offset by a fall in production, which resulted in 0.0% GDP growth in the three months to December 2019. The rolling three-month growth weakened for the third month in a row in December 2019. UK manufacturing currently [(1)]:

- employs 2.7 million people – earning an average of £32,500;
- contributes 11% of GVA;
- accounts for 45% of total exports – totaling £275bn;
- represents 69% of business research and development (R&D);
- provides 13% of business investment.

Employment in the UK remained high during 2019 and fell to the lowest level for 45 years.

Political Uncertainty and its Effect on UK Manufacturing

The UK stopped being part of the EU on the 31st January 2020 but throughout 2019 negotiations and discussions were continuing on the withdrawal agreement leading to two extensions of the original exit deadline (of 31st March 2019), a change in the Prime Minister in the early summer and a general election in December. This led to considerable uncertainty throughout the year and this is reflected in some of the UK output figures for 2019, particularly for those from the manufacturing sector.

A UK Manufacturing Review of 2019/20[(2)] stated that "The past three years of navel-gazing self-indulgence by the political classes has been a severe hindrance to Britain's manufacturing base and its companies, of whatever size. Whatever one feels about the outcome of December's General Election, at least we have a Government with a majority big enough and stable enough to get its business through Parliament".

The uncertainty caused by the UK's negotiations for the departure from the EU can be seen from the following report which stated: "2019 was a particularly tumultuous year, as the first two quarters of the year saw stockpiling activities reach their highest level ever recorded anywhere in the G7 in anticipation of our original EU exit date of March 29th. Since then, output and order performance have suffered as a result as the early stockpiles have been gradually winding down"[(3)].

Even late in 2019, there was a lack of confidence in the economy as may be seen from the Purchasing Managers Index: "The weak PMI data in the closing months of 2019 pointed to one of the worst spells for the economy seen over the past decade, commensurate with GDP stagnating at best in the fourth quarter. Anecdotal evidence collected via the surveys revealed how companies blamed heightened Brexit-related uncertainty, exacerbated by political worries in the lead up to the December 12th general election, as having dampened spending by households and businesses alike"[(4)].

Manufacturing output also remained low (but with some notable but temporary fluctuations at certain points, driven by political decisions around Brexit) during the year.

Foundry Industry in the UK

In the ferrous sector, the first half of 2019 was generally strong for most iron foundries, with some companies reporting their best year for some years. There was however some softening into the second half of the year with most foundries experiencing some reduction in orders. Capacity utilisation levels remained generally high also with continued investment in plant and equipment.

For steel foundries, the first half of 2019 was fairly positive in the main, with most of the foundries reporting being busy with good levels of enquiries, many of which were translating into orders. Production capacity was high and many were anticipating production levels at or above those not seen for a long time in the industry. Admittedly this was in part due to a lowering of capacity in the UK, but there were also new projects starting with customers leading to increased levels of work and lengthening lead times. By contrast the second half of 2019 was poor when compared with the first six months, with some foundries experiencing reduced melting and casting days and considering some short time working into 2020. Enquiry levels were remaining good but were not translating into orders. It was clear that there had been some stockpiling by customers earlier in the year which was now resulting in these reduced order volumes and the end of the year was marked by limited visibility from their customers about future orders and new projects. This sector was also marked by continued downward pressure on prices in part due to some remaining overcapacity.

2019 began well for the non-ferrous sector, with several foundries reporting that business and production levels were at their highest, in part due to stock holding orders pre-Brexit. However, as the year progressed there was some slow-down reported by companies supplying the automotive sector with earlier and longer shutdown periods due to Brexit and the uncertainty and a slowdown across much of Europe was having a significant effect during the middle part of the year. Aside from the automotive sector, which continued to be affected by a number of issues, including declining sales in diesel vehicles, Brexit concerns and the transition towards electric vehicles, 2019 was generally been a good year for business but with some small reduction in production levels during the latter half of the year.

Investment casting foundries had benefited from a strong 2018 across all customer sectors, (with even the oil and gas sector having recovered to a degree and aerospace remaining buoyant, whilst some sectors – such as IGT and auto, including turbo-wheels - had slowed), and began 2019 with good order books. Into the summer foundries remained busy, in spite of fears that increasing orders to enable stock-holding in preparation for the UK leaving the EU at the end of March, might have contributed to a slowdown in Q2; there were new projects coming into production and orders being placed. The automotive market had slowed but the aerospace market was positive. Towards the end of the year business was reported as being steady; there had been some slowing from the earlier part of the year with the aerospace sector remaining busy with strong growth forecasts, and medical and commercial looking good, although auto and boat building had slowed, and IGT still showed little improvement. Foundries reported good order books for coming year and plenty of new design work in progress.

Employment in the UK Casting Sector

Many foundries reported that finding and retaining new staff continued to be a problem and that workers from overseas, typically eastern Europe, were less inclined to come to the UK. Several companies were taking on apprentices using the new foundry apprentice programmes – these are supported by national government funding through an industry levy charged on larger businesses. The apprentice training is then free for smaller companies with an annual wage bill of less than £3M per annum. Foundries seeking apprentice training were able to take advantage of the National Foundry Training Centre which opened its doors in late 2018/early 2019.

Closures and Consolidation

During 2019, despite the general stable situation for most foundries, some foundry closures and consolidations took place. One iron plus light alloy foundry group closed all of its three sites and a further steel foundry group went out of business leaving only one site sold and able to remain operational – work from these was transferred to other UK foundries in the main, plus one iron foundry also closed to make way for a change of business activity. A light alloy foundry consolidated by reduced from two to one manufacturing site and one diecasting facility closed.

Outlook for 2020

The industry outlook for 2020 remains uncertain due the global pandemic which has affected all sectors of the economy and all the main sectors that the UK industry supplies. In the short term some companies are busy supplying parts for the medical sector, including ventilator components, but this only applies to a small number of castings producers. Many car plants were taking extended closures around Easter 2020, with new car registration dropping by 97% in April 2020 compared with the April 2019 (5) and car showrooms closed. Light commercial vehicle registrations were also down over 86% in April compared with the same month the previous year[6]. At the same time the aerospace sector is facing unprecedented uncertainty with companies such as Airbus warning that the industry may take up to 5 years to recover[7]. The oil & gas sector is also dealing with a 20-year low in the oil price and a 14-year low for gas [8] as global demand has fallen. At present it is estimated that output for the year may be reduced by around 30 to 40% in the UK, but this depends on how quickly the economy is able to recover with some demand increases anticipated over the summer and into Q3 as the lockdown is eased.

Sources of Information:

1. *MAKE UK: https://www.makeuk.org/*
2. *UK Manufacturing Review:*

   https://ukmfgreview.com/uncategorized/editors-introduction/
3. *Source: Economic Monthly Brief, Make UK, Pub Dec 2019*

   file:///C:/Users/admin/Downloads/Monthly%20Bulletin%20-%20December%202019.pdf
4. *IHS Markit: https://ihsmarkit.com/research-analysis/uk-flash-pmi-signals-economic-rebound-as-uncertainty-lifts-Jan.html*
5. *SMMT News: www.smmt.co.uk/2020/05/record-97-3-fall-for-uk-new-car-market-in-april-as-coronavirus-shuts-showrooms/*
6. *SMMT News: www.smmt.co.uk/2020/05/coronavirus-shrinks-uk-new-van-market-as-registrations-plummet-86-2-in-april/*
7. *The Guardian: www.theguardian.com/business/2020/apr/29/airlines-may-not-recover-from-covid-19-crisis-for-five-years-says-airbus*
8. *OGUK: https://oilandgasuk.co.uk/call-for-three-stage-framework-to-help-head-off-thousands-of-job-losses-in-oil-and-gas-industry/*

FOUNDRY KNOWLEDGE LANDSCAPE

ANNUAL RESEARCH FIGURES IN FOUNDRY TECHNOLOGY

ACADEMIC RESEARCH OUTLOOK

Objective and methodology

This section highlights some of the actual figures and trends around the global academic research activity related to the fields of interest for the foundry technology. In addition to the activity of the WFO, its media partners and official journal as a major source of information, it is also relevant to check the specialized scientific production in specific search engines, such Web of Science (WoS). Thus, an analysis is made in a yearly basis for the Global Foundry Report based on WoS searches, to see the evolution in these trends.

The next summary has been focused on cast iron and has been kept to the period between 2015 and 2019 for general trends and to 2019 for specific ones.

Worldwide Foundry general research figures

The scientific production in the field of cast iron has been increasing in the period from 2015 to 2018 but has slightly dropped to 783 records in 2019 (according to records in WoS). Despite this small drop, it is a field with a strong research interest, and it is expected to be stabilized in 2020 despite the pandemic. In fact, the records are 579 for 2020 at the end of October 2020 and it is expected to raise up to 700 by the end of the year.

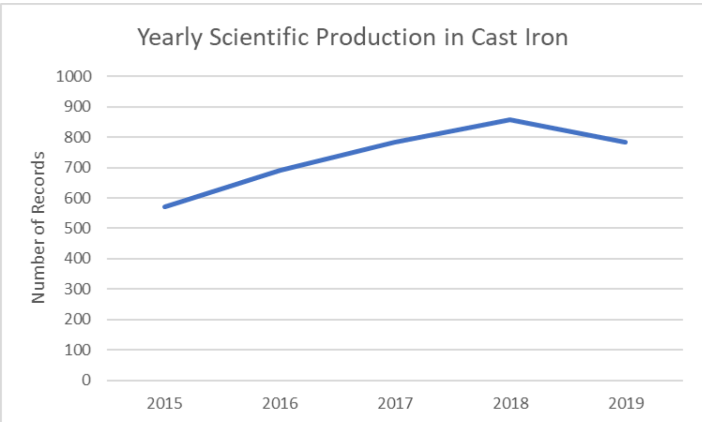


Figure 1. *Scientific production in the field of cast iron from 2015 to 2019 (source: WoS)*

In terms of the geographical distribution of this production, Figure 2 shows where the scientific production has been generated in the period from 2015 to 2019. China is the highest yield country followed by a group of high research output countries: Poland, USA, India, Russia, Germany, Italy and Japan.

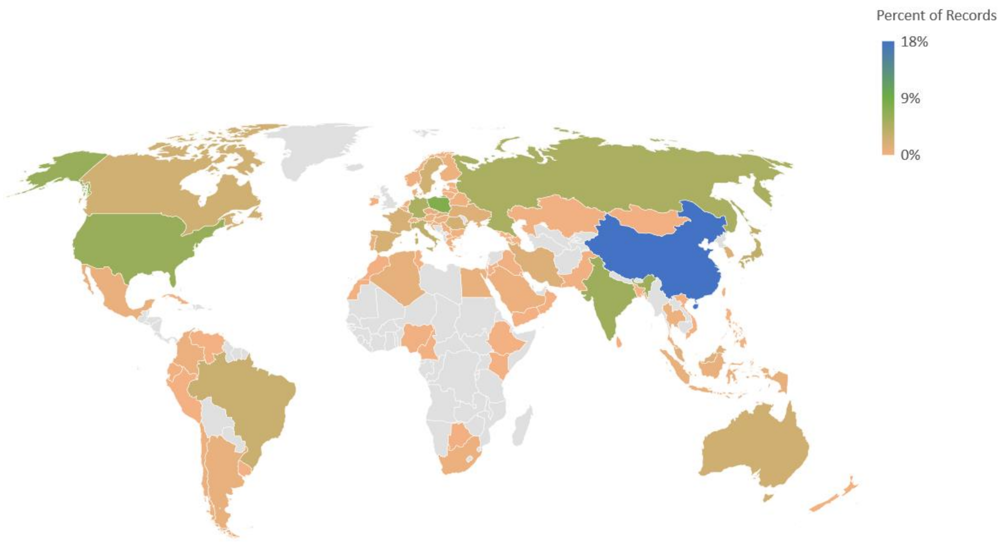


Figure 2. *Geographic distribution of the scientific production in the field of cast iron in the period from 2015 to 2019 (source: WoS)*

In terms of the production for 2019, Figures 3, 4 and 5 show the research publications distribution depending on the region. Starting with Asia as the highest output region (Figure 3), China is confirmed as the major producer and its records account for as much as the rest of the records of Asian countries altogether. India, Japan and South Korea show the next strongest research output summing up over 100 records, when their production is summed up. The records from Australia and New Zealand have been included in the Figure of Asia due to limitations in the automatic data processing system that has been employed to generate the maps. It is worth noting Australia is also a relevant country in the field of cast iron research, with 20 indexed documents published in 2019, despite the map of Oceania is not presented.

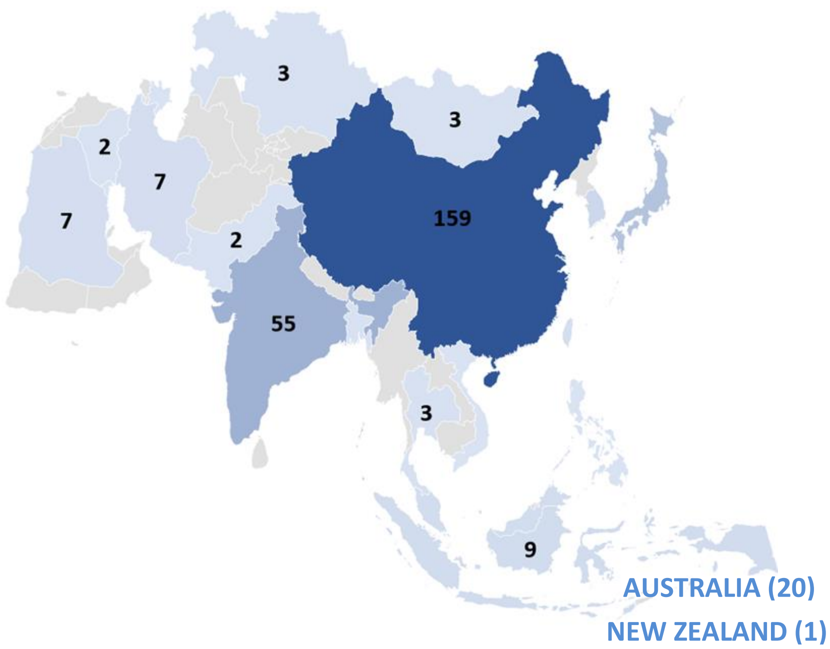


Figure 3. *Scientific output records in Asia in 2019 (source: WoS)*

Positioned in second place behind Asia, Europe shows a very distributed production with Russia, Poland and Germany as the leaders in the region. The three of them altogether nearly reach the yield of China. Italy, Romania and Turkey are second in the lead, accounting a few more records than India. This group is followed by Spain, Sweden, France and Ukraine, whose summed output is comparable to that of Japan and South Korea. Russia, Turkey and Israel don't appear in the map due to automatic data processing limitations. For this reason, their records have been included as text in the Figure.

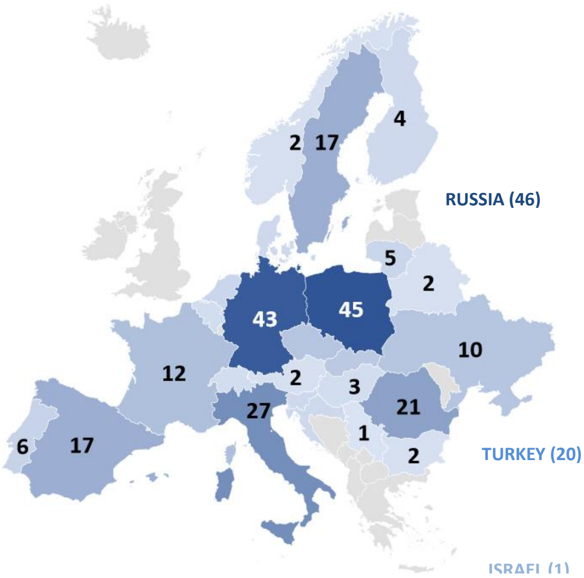


Figure 4. *Scientific output records in Europe in 2019 (source: WoS).*

Shifting to the American continent, USA is the major player with a scientific production in the range of India, Russia and Poland (50 ± 5 records). Afterwards, Brazil and Canada show a significant output, which is comparable to Spain or Romania. The whole continent scores over 100 indexed documents, what position the continent at the level of India+Japan+South Korea and Russia+Poland.

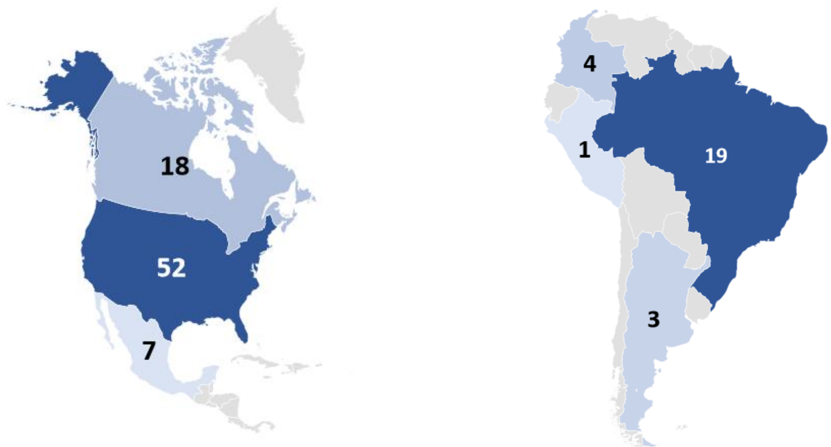


Figure 5. *Scientific output records in America in 2019 (source: WoS)*

SUMMARY. The research activity in the field of cast iron has been growing steadily in the last five years, but it seems to be coming to stagnation, partly due to the pandemic and partly due to natural fluctuations in the scientific output. The research effort in 2019, measured as number of indexed publications in WoS databases, is polarized towards Asia thanks to the weight of China, while Europe stands close with Russia, Poland and Germany together as the strongest core. The Americas stand close with a USA as the major player, which is slightly over the production level of each of the European leaders alone.

All the maps in this section have been drawn with Bing technology © GeoNames, Microsoft, NavInfo, TomTom, Wikipedia.

Highest publication count

When the attention is moved to the most prolific research areas (according to WoS) in the subjects related to cast iron, four agents appear repeatedly in the top eight. Fig 6 gathers the highest WoS indexed document producers in from 2015-2019, while Fig 7 shows the records for 2019 alone. It is noticeable that the rank in Fig 6 gathers only European and Chinese institutions and shows concentration of the activity per country. The top ranked institutes and universities account for, on average, over 20% of the scientific production of their country in cast iron.

POLITECHNIKA ŚLĄSKA	CHINESE ACADEMY OF SCIENCES	RWTH AACHEN UNIVERSITY	cnrs CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE
65 RECORDS	**62 RECORDS**	**62 RECORDS**	**56 RECORDS**
Российская Академия Наук	XI'AN JIAOTONG UNIVERSITY 1896	JILIN UNIVERSITY-CHINA 1946	JÖNKÖPING UNIVERSITY
44 RECORDS	**43 RECORD**	**40 RECORDS**	**38 RECORDS**

Figure 6. *Highest Output Institutions from 2015 to 2019 (source: WoS)*

Regarding the institutions that are repeated in Figures 6 and 7, this is the Russian Academy of Sciences, the RWTH Aachen University, the Chinese Academy of Sciences and the Silesian University of Technology, it is noticeable that they show approximately one fifth of the production from the interval 2015-2019 on the year 2019. This indicates a steady yearly production and the existence of well stablished R&D teams on cast iron technology.

Российская Академия Наук	XUT 1949 XI'AN UNIVERSITY OF TECHNOLOGY	RWTH AACHEN UNIVERSITY	CHINESE ACADEMY OF SCIENCES
12 RECORDS	**12 RECORDS**	**10 RECORDS**	**9 RECORDS**
KUNMING UNIVERSITY OF SCIENCE AND TECHNOLOGY	UNIVERSITY POLITEHNICA OF BUCHAREST 200 anniversary 1818	POLITECHNIKA ŚLĄSKA	University of Alabama System
9 RECORDS	**9 RECORD**	**9 RECORDS**	**9 RECORDS**

Figure 7. *Highest Output Institutions in 2019 (source: WoS)*

Regarding the highest output of indexed meetings and journals in concordance with WoS, cast iron related works are published mainly in foundry specialized journals and two tribology-surface engineering related journals. More general metallurgy, materials and process engineering related publications fill up the rest of the top sources with the highest number of records. The strong interest of wear and pipeline applications of cast iron is also noticeable.

MAIN TRENDS IN INDUSTRIAL FOUNDRY RESEARCH

The world is changing very quickly and the way we communicate, move and relate, too.

Our thinking is adapting to this new way of life and the needs of a mobility being responsible with the environment and sustainability occupy an important part of our attention. Consumer goods manufacturers try to respond to these new needs as quickly as possible and demand in turn an innovation flexibility and speed from their suppliers not known years ago.

It is no longer enough to be an efficient and competitive supplier, as to continue to succeed there is a constant need to add value. Only those foundries capable of producing components with high added value and with innovative and difficult-to-copy technologies that also invest in qualified people capable of directing their companies in new directions will succeed.

To answer to today's technological challenges, a number of well-known research trends are proposed in the industry, having the vast majority of them still not reached the optimum level of mastery of the technique.

The most relevant challenge currently faced by foundries around the world regardless of the type of product they manufacture is **environmental**. Foundries are considered to be among the most energy-demanding industries. There are multiple trends that are being worked on from this area to minimize the environmental impact of these industries. The use of more efficient castings capable of reducing raw material requirements, more efficient furnaces to reduce energy requirements, optimized manufacturing systems that reduce the volume of waste generated, recycling of materials with ISO quality, reuse of return sands within the casting process itself and in alternative external systems, energy storage of excess heat in recycled materials, minimizing emissions and omissions and predicting environmental quality within companies are some of the topics that seem most relevant for years to come.

In addition, the need to produce more complex and lightweighted parts remains one of the top priorities of all engineers and designers around the world. To meet these needs, the Foundry world is making very significant advances in molten **materials**, providing them with improved mechanical characteristics that are obtained by working on the material, by designing new and innovative alloys, on the solidification process, generating phases and structures with better properties, or through optimized and disruptive manufacturing processes.

Not only the bulk materials will experience significant modifications in the future, but also the coatings or surface layers will be capable of generating functionality not demanded up to this point, either by deposition or addition or by chemical or thermochemical transformation or modification of the surface layer.

It will also be relevant to respond to specific functionalities in partly or all of the parts the use of casted or generated multimaterials during the solidification process.

Both materials and processes will be called upon to erase borders and reflect on complementary materials or processes: associate casting and forging processes, associate diverse metals or metals and composites, etc.

Without a doubt, **predictive calculation tools** will be vital to support this type of transformation, minimizing experimental testing costs and reducing the time required to obtain results, based on theoretical scientific knowledge that allows us to extrapolate to industrial realities.

These technological challenges will in the future mean a growing investment in R&D as well as an improvement in the dialogue between foundry staff and team designers in order to collaborate from the conceptual stage of the components.

Traceability and connectivity are revealed as the big tools capable of linking all data flows to achieve the quality, productivity and efficiency goals required to situate in the market in a dominant position. Sensors, connected machines, and intelligent controls make it easy to detect real-time errors and make adjustments to operating procedures. However, the true value of this type of tools (Industry 4.0) lies not in themselves, but in the information they provide so that through the expert knowledge of the processes we can program Predictive Control Models that bring us closer to the Zero Defects.

Real-time prediction and integrated calculation systems to predict the quality and health of parts before they are manufactured will be basic production tools in the future and we will become familiar with their presence in production plants, not just engineering studies. People's capabilities will also be modified and will go from performing quality checks on already casted parts to making pre-manufacturing process predictions.

Another important technological challenge is based on the need to make manufacturing systems more flexible, reducing the delivery time of parts, manufacturing tools in short time, manufacturing molds or cores of very complex geometries and difficult to obtain through conventional systems. **Additive manufacturing** has come into the metalcasting world to respond not only to the needs of standalone parts, small series or spare parts, but can be considered a replacement technology for other conventional processes for the manufacture of molds, tools, etc...

The casting process is considered technologically very complex as a wide variety of individual factors exerts mutual influence, and extensive experience is required in the fields of mechanical engineering, metallurgy, chemistry and process technology to ensure optimal products.

Today's most successful approach to generating innovative advances is early collaboration between foundries, industrial equipment manufacturers, consumable suppliers, and universities or technology centers, so that a simultaneous approach can help reducing the time required for product and process innovations. Engaging all parties from the start, and working simultaneously on different aspects of a solution, leads to faster and better results.

Article	Citations
Modeling of thermal behavior and mass transport in multi-layer laser additive manufacturing of Ni-based alloy on cast iron	17,00
Braking pad-disc system: Wear mechanisms and formation of wear fragments	11,30
Materials in machine tool structures	10,33
Role of the friction layer in the high-temperature pin-on-disc study of a brake material	12,20
Fiber laser cladding of nickel-based alloy on cast iron	11,80
Micromechanisms of fracture in nodular cast iron: From experimental findings towards modeling strategies - A review	9,50
Effect of surface texturing on cast iron reciprocating against steel under starved lubrication conditions: A parametric study	9,30
THERMAL ANALYSIS-THEORY AND APPLICATIONS IN METALCASTING	8,00
LCA as a decision support tool for evaluation of best available techniques (BATs) for cleaner production of iron casting	7,50
An investigation on the stability of austenite in Austempered Ductile Cast Iron (ADI)	6,67

Table 1. *Article top citations in 2015-2019 (Source: WoS). Right column states citations by year.*

Article	Citations
Effect of coating thickness on the tool wear performance of low stress TiAlN PVD coating during turning of compacted graphite iron (CGI)	7,50
Structural evolution of directionally freeze-cast iron foams during oxidation/reduction cycles	6,50
Microstructure and tribological evolution during laser alloying WC-12%Co and Cr3C2 - 25%NiCr powders on nodular iron surface	6,00
Microstructure characteristics and mechanical properties of new-type FeNiCr laser cladding alloy coating on nodular cast iron	5,50
Microstructure and properties of NiCrBSi coating by plasma cladding on gray cast iron	5,50
Fatigue crack propagation and damaging micromechanisms in Ductile Cast Irons	5,00
Microstructure and residual elastic strain at graphite nodules in ductile cast iron analyzed by synchrotron X-ray microdiffraction	5,00
Predicting the Tensile Behaviour of Cast Alloys by a Pattern Recognition Analysis on Experimental Data	4,50
Elimination of voids by laser remelting during laser cladding Ni based alloy on gray cast iron	4,50
Revisiting the graphite nodule in ductile iron	4,50

Table 2. *Article top citations in 2019 (Source: WoS). Right column states citations by year.*

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SELECTED TECHNICAL CONTENTS

One of the main functions of the WFO is to unite the industry and disseminate appropriate information in a standardised and systemised manner at an annual event. To this end, the World Foundry Congress and the World Foundry Summit are held bi-annually for the presentation of technical and strategic papers and providing an adequate networking opportunity for those wishing to have a thorough understanding of the latest strategies, research and developments in the cast metals industry.

In this section of the Global Foundry Report you can find some Full Papers corresponding to the last 73rd World Foundry Congress, as well as a presentation originally planned for the World Foundry Summit 2020:

World Foundry Summit Paper

"The future is NOW – challenges and opportunities for successful manufacturing"

Donald L Huizenga, United States

73rd World Foundry Congress Paper

"Easy knock-out moulding and core sands – the future for metal casting"

Artur Bobrowski, Dariusz Drożyński, Beata Grabowska, Karolina Kaczmarska – AGH University of Science and Technology, Faculty of Foundry Engineering, Poland

73rd World Foundry Congress Paper

"Investigation and characterisation of inclusions in aluminium cast alloys for the automotive industry"

Onur Özaydın, Alper Kaya and Elvan Armakan, Cevher Wheels – R&D Department, Izmir, Turkey; Tuğçe Yağcı and Osman Çulha – Manisa Celal Bayar University, Engineering Faculty, Department of Metallurgical and Materials Engineering, Manisa, Turkey

73rd World Foundry Congress Paper

"Digital transformation to Foundry 4.0"

N Gramegna, F Greggio – EnginSoft SpA, Padova, Italy; F Bonollo – Università di Padova, DTG, Italy

73rd World Foundry Congress Paper

"Optimisation and automation of chemical control of alloys in smart Foundry 4.0"

Alberto Montenegro Correa, David Casasnovas González – AMV Soluciones, Spain

The future is NOW - Challenges and opportunities for successful manufacturing

Don Huizenga, United States.

The following is a paper that was due to be presented at the WFO World Foundry Summit in May. It was written prior to the current global pandemic crisis and its content is all the more poignant because of this. Rescheduled until 2021, the WFO World Foundry Summit will provide inspiration and high level debate around how to maintain successful businesses in a changing business climate. In the meantime, this is a taster of the calibre of presentations to be expected.

ABSTRACT

The paper focuses on the toolbox of leadership skills the industry needs to acquire to deal with the transformational global events that will occur. There are two overarching areas of change to focus on – political and governance structures with the societal disruptions that will happen, and the enormity of analytic technology that is inevitable and happening in exponential increases.

A WALK DOWN MEMORY LANE

Let's consider our past life in the 1980s – no mobile phones, no worldwide web, no cable TV? It was the age of mainframe computers, most still requiring data entry (key punch cards), and the beginning of strategic plans to guide our business.

In 2000, we survived the much globally hyped millennium or Y2K 'forecasted disaster' and we moved peacefully into the next century. Subsequently our world was turned upside down on 9/11; we no longer felt safe in our cities, and believed our governments could no longer protect us. Next, much of the world suffered from the toxic paper financial crisis that brought down institutions that we had grown up believing were pillars of our economy and highly revered, leaving us in a state of shock. The world's manufacturing capacity continued to move to China, India, and to Eastern Europe, the rules were changing. Politics was becoming highly partisan, ideologies prevailed over compromise, stubbornness was the norm, military conflicts continued in regions where people were born, raised, and died without ever knowing peace. How do we morally justify these conditions as leaders of industry and government?

THE FUTURE CHANGE

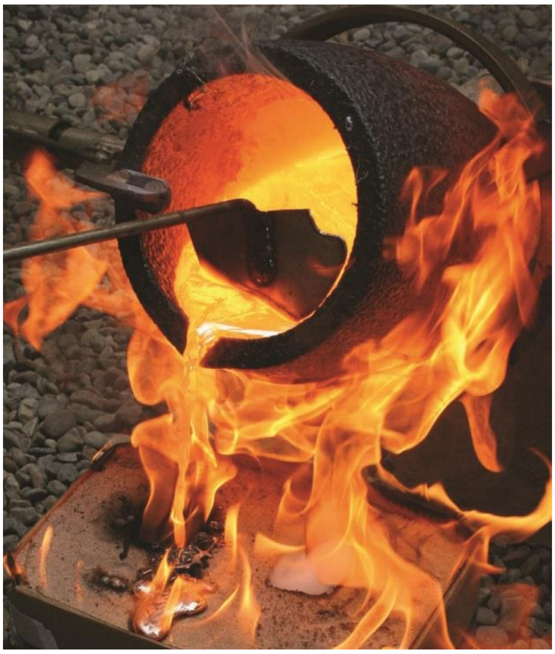
So, what does tomorrow bring? More misery, hope, or real change brought about by technology that today we don't quite understand or grasp, but it is already around us. Most people are familiar with the phrase "if you can dream it, it can happen", which is closer to reality then we realise.

This is the time to change the way we think and the way we process information, we need to change the way we approach business, because most of us are captive or guided by our past. Our past practices will not work in the future. Thus, it's time to consider if you are good at dealing with change.

A test is to try sleeping on the side of the bed you wouldn't normally sleep on, the reaction of your spouse will probably be: "what are you doing on my side of the bed?" Could you persuade them to accept the situation? Are you a change agent, or at least an ineffective communicator on the need for change?

ENERGY

Let us begin with energy, which has become a societal and a political issue. It is a critical component and a major operating expense for all manufacturing, and perhaps more pertinent for the foundry industry than any other expense. How will you cope with a political and public groundswell that is demanding power plants to use alternative energy sources such as wind and solar, in addition to discontinuing our reliance on fossil fuel?



Nuclear energy is clean, but in the eyes of the public, potentially very dangerous. The costs escalate rapidly for alternative sources and they are very geographical in their location, which is dependent either on a large amount of sun exposure or predictable and consistent wind currents. Our current grid system is not designed to transport energy over large geographic areas, and foundries find it difficult to be in hot, arid, or windy climates. Can we make nuclear power plants safer with the fourth and fifth generation reactors? The answer is: yes. Is it possible to employ another method of capturing the wind, without using wind turbines that have restrictions such as Betz law, which defines the amount of output they are capable of producing, and they must be shut down if the winds are over 22 knots(EST)? The answer is: yes. There are other models that can work, but often, politics determines the method employed, not science! Is it worthwhile to upgrade the grid system to store more, or transport it further? The answer is: yes, but there may be another option. There are plans underway for building a power plant that will be able to transport energy wirelessly via gravitational waves, where distance or a grid system is not an issue. It will be capable of providing energy to areas once considered too remote. Ponder the benefits of that in your future business model. There is debate whether the price points of such quantum mechanics of an untested theory will indeed work, but it is in the process of discovery.

Since our industry is a large user of energy, we need to be aware and educate ourselves on climate change and the importance of understanding if this is a normal and/or an historical weather pattern, or if this current cycle is caused entirely by mankind. There are experts on both sides with compelling arguments that are biased, confusing, misleading, factual, and perhaps a little melodramatic. In September 2019 *Time* magazine published an entire issue entitled: *'2050, how earth survived'*. It featured futuristic articles by leading proponents of manmade climate change and the dramatic changes that were hypothetically installed to slow down the temperature rise. They presented a draconian and bleak outcome if these changes 'had' not occurred. The politics surrounding climate change is astounding and I believe today's politicians are hypocritical on the subject, but it is tomorrow's leaders we need to watch. They have been educated with the doctrine of climate change, history revisions, and socialism. They are the true believers and they are disgusted with our generation's perceived disinterest in the environmental issues of the day. When they start running for office in the local, state, and federal governments they will be in the position to enact the very legislation and regulations that we scoff at today and I believe they will not stop with legislation. They have been raised and educated in our universities for activism. Let's look at an example. Some years ago, California passed Prop 65 – a law that required every building or structure in the state to post a warning sign if carcinogenic materials were used in the construction. Sounds like a noble endeavour, but of course nearly everything has cancer causing potential if experienced at certain levels, so the result of this law is that every building and structure in California and most products sold in California carry warnings about the risk of cancer – and most people ignore them because there is nothing that can be done about it – next time you board an aeroplane in a California airport note the Prop 65 sign at the end of the gateway as you enter the plane because jet fuel fumes are cancerous....but, will that sign stop you from boarding?

However, tomorrow's activists won't just post signs. A case in point is a recent action by a newly hired millennial of a company in Iowa. She became aware that the Federal manganese emission level for welders is set at 5mg of manganese per cubic metre of air surrounding the welding stick, but California just changed its law from 5mg to 0.02mg per cubic metre – so she notified OSHA that the company she was hired by in Iowa has a cancer-causing practice of welding in their plants and now OSHA has opened an investigation into the health of the company's employees. That's the difference between legislation and activism.

American environmentalist and author Bill McKibben points out the movement keen to reduce carbon dioxide levels to 350ppm in the atmosphere. The current level is estimated at 425ppm and to achieve the goal of 350, fossil fuel usage must be reduced by a factor of 20, to attain a level of 5% of today's usage. The following is an illustration of what must happen to comply.

Current global hydrocarbon consumption is approximately 225 million barrels of oil equivalent energy a day. The breakdown is as follows:

(a) 90 million barrels of oil.

(b) 75 million barrels of oil equivalent from coal.

(c) 60 million barrels of oil equivalent from natural gas.

A factor of 20 would result in reduction of daily oil equivalent usage to 11 million barrels or the amount consumed by India where 400 million people lack consistent electricity.

The demand for electricity is growing at 450 terawatt-hours a year (1 terawatt is 1 million megawatts). If we are forced to abandon fossil fuel and switch to alternative sourcing, consider that Germany, a country with the most progressive and committed solar industry, has a solar capacity of 33,000 megawatts which produces 28 terawatts yearly. The world would have to produce 16 times Germany's installed base every year. Wind energy would have to install 280,000 megawatts each year, and that footprint of new towers would be about the geographical size of Italy.

Consider the power density of different sources of electricity; wind produces 1 watt per square metre, nuclear produces 50 watts per square metre, and oil and gas wells produce 30 watts per square metre. Note, the average background levels of naturally produced carbon dioxide is around 280-300ppm.

This will continue to be a much debated and a thorny issue for our governments, our politicians, the business world, and the leadership of our global manufacturing community, to realistically understand the limitations of what solar and wind power can provide with their high costs of generating 'physics based' energy and balance that with the reduction of fossil fuel energy and the impact that will have on us economically.

FOURTH GENERATION MANUFACTURING

Now to the subject of fourth generation manufacturing. We are all hearing about it, but what does it all mean and how will it affect you? As a reminder, the First Industrial Revolution featured the arrival of the steam engine. It fundamentally changed the impact and importance of direct labour in the manufacturing process by reducing the need to rely on manpower. The Second Revolution was the science of mass production that aligned the workflow, which significantly improved efficiency and reduced cost; think of Ford's car production line. The Third Revolution was the advent of computational technology or the digital age; think personal computers, IPads and mobile smartphones. Today we are entering the Fourth Revolution, with the complete revitalisation of manufacturing, and moving into the *analytical age* with the artificial intelligence (AI) integration with computers, and taking machine learning to a new level, again at the probable disruption of the workforce.

The best companies are revamping their models with the realisation that business is operating in an age of digital transformation and soon will be on real time. During the next decade, we will all have to move quicker than before. We will look at *eliminating*, not reducing operating inefficiencies incrementally. Let's think about zero emissions, zero scrap, 100% on time delivery with no inventory, computer data interaction with suppliers and customers, elimination of sales calls, clean in-house environments, continuous pouring without ladles, elimination of cores by integrating with 3D printing, and the removal of shot blasting and shakeout from the process, coupled with an increasing consciousness of corporate sustainability, both from a moral and legal obligation. Our industry is currently in the stage of measuring and developing better metrics to provide consistency and reliability in our manufacturing. Why not devote the time and energy, the science and technology, to eliminate as much as possible from our non-productive and non-value added operational processes? We need to find solutions for problems we will have to face, but perhaps have not yet identified. If it is possible to dream about a foundry in terms of only moulding, pouring, and shipping – no sales function, no quality department, no maintenance department, a dramatically reduced labour function……would our lives be simpler?

This is a mindset change, we have to look at *technology* driving our business models. On the horizon, will be the quantum computer. Google recently announced completing on a quantum computer, a calculation that would take 10,000 years on today's most powerful supercomputers… they did it in only 200 seconds. While not yet ready for commercial application, the implications are mind boggling to bring about change. The future will bring about dynamic innovations in technology that we cannot yet envisage, but we need to prepare ourselves.

Let us consider the political landscape and the role governments will play in what has been called Industrial Revolution 4.0. Historically, governments have tried to prevent companies from eliminating labour savings through technology innovations and as a result they were keen to prevent riots and public disturbances such as the violent protests from professional writers in Germany, Italy, Augsburg, and France in the 1470s because of Gutenburg's printing press; or the prohibition of the gin mill in Britain in 1551, because two boys could do the work of 18 men; the prohibition of the labour saving stocking-frame knitting machine in 1589 in Britain. Then there was the protest in 1768, which resulted in the first steam powered sawmill being burned to the ground by 500 sawyers who claimed it took their jobs.

History shows that innovation and inventions create the seeds of discontent that can turn violent. Today, we are seeing public sentiment to go 'Green', to reduce fossil fuel usage, to reduce CO_2 emissions, restrict job loss due to the integration of AI and automation via machine learning. Higher technology will not be embraced by all people; it will disrupt lives, create permanent and temporary unemployment, eliminate entire job classifications (remember the key punch operators?), forcing people to learn other skills, perhaps at lower wages.

A recent Wall Street Journal article indicated 52% of Americans believe computers and robots will in the future do much of the work undertaken by humans, and 38% believe the work they currently do will be in jeopardy.

We have been saying for years we need to communicate with our legislators and understand the positions they take and the reasons behind the decisions. Considering the global economic powerhouses of the last two decades, it would be the United States and Europe, with Russia, India, Japan, Brazil and China trailing significantly. Today, it is much different, China is one of the economic powerhouses with the US and Europe. China has attained that position faster than any other nation in history. We are truly in a global economy and our politics needs to adjust.

Protectionism has lost its effectiveness, trade wars need to end, we cannot protect industries or products that are produced and priced due to our various nations' inefficiencies and/or rely on trade tariffs to survive. We need to work together for the benefit of all to bring enhanced and integrated technology into our manufacturing, which will be key for survival and a path to a more robust and competitive marketplace. We should be concerned with our election processes and the people we elect. We, the people, need to steer the ship rather than allow partisan ideologies to prevail. The United States is leaning to socialism, trying to re-balance the economic wealth and power of our citizenry, China is trying to hold on to its doctrines while perhaps morphing into socialism. The world's countries might intersect politically in the next decade. My point is, that everyone should care about what happens, it effects our businesses, our lives, and our children's future.

In the United States, politicians cannot make the world fair or make life risk-free through legislation, cannot make the Constitution a living document, people's voices must be heard. Remember, throughout history, the radical or a well-organised minority gets agendas passed due to the ambivalence of a disinterested majority.

A nation's economic and political power started with the foundry manufacturing engine that built the infrastructure, created wealth, made the castings for products that make our daily life more comfortable, also the weapons of war, and medical devices for implants into the body. We are eclectic and necessary for continued economic viability, in short, we need to find ways of remaining relevant to our society.

The First Industrial Revolution used machinery for the first time to create goods and products making England the most powerful economic engine in the world, and the country's footprint was seen throughout the globe. As we mentioned, those were difficult times, with the balancing of the workforce being forced out of their accustomed jobs, and the introduction of machinery that could make large multiples of pieces more consistently and far cheaper. As a result, often violence occurred. Today we face the same dilemma. The leaders of the First Industrial Revolution found a way to achieve harmony and balance. Our industry leaders need to utilise the technologies of AI and the speed of 5G, or wireless applications, and integrate them into our manufacturing, which will revolutionise our world. We cannot do anything incrementally when a sweeping change is required. A good example of that thinking which was visionary and unfortunately too far ahead of its time was a project called Saugus 2 developed by Denny Dotson. A bold concept, but we need more innovative thinking like this to be relevant(1). Maybe it is time for Saugus 3 or 4?

SINGULARITY

We are entering into an era of a technological explosion. It is called singularity and it will be at a speed and a volume of change that nobody has ever experienced. As defined by Wikipedia it: *"is the hypothetical point in the future when the technological growth becomes uncontrollable and irreversible, resulting in unfathomable changes to human civilisation." Novelist Vernor Vinge wrote: "The Singularity is a point where our old models must be discarded and a new reality rules. As we move closer to this point, it will loom vaster and vaster over human affairs…. Yet when it finally happens it may still be a great surprise and a greater unknown. We are on the edge of change comparable to the rise of human life on Earth. The precise cause of this change is the imminent creation by technology of entities with greater than human intelligence."*

Ray Kurzweil is acknowledged as the father of Singularity(2). In his 2006 book *'The Singularity is Near'* Kurzweil stated: *"By 2050, one thousand dollars of computing will exceed the processing power of all human brains on Earth."* Scary thought.

The question, of course, is who will lead the way to the Singularity and what will we do when we suddenly have reached that point and it has passed us by?

The nations that are working the hardest on developing AI are China, the United States, and the European countries. But China in particular may be leading the way in the practical experimentation illustrated by the following example.

China is experimenting with school children wearing headbands equipped with sensors that measure brainwaves to determine level of focus and concentration levels in the desire to enhance learning and give immediate feedback to teachers. The results have been encouraging showing meaningful improvement in learning and subsequent retention.

So, where and how do we start? AI has been a cocktail conversation, where we imagine humanoids and robots running around, taking over the world. We understand that 'machine learning' is progressing and algorithms freed from human programmers are training themselves on massive data sets (bit coin mining is a good example, where there are huge warehouses full of connected computers working together). The Smithsonian reported that a computer Bot using AI and machine learning, created by Alibaba and by Microsoft, beat a team of human competitors in a Stanford reading comprehension test that covered a diverse series of questions. We now begin to realise that we need help to change.

THE FOUNDRY SECTOR'S RESPONSE

For those active in the foundry who are wondering how we proceed, my suggestion would be to create a totally separate or segregated department, hire new and young people from the computer science discipline, give them the task of defining *big data*, and the mining of that data along with utilising AI. This will be similar in concept to when the start of the IT function occurred 50 years ago. It must not be the research and development department; it must be a stand-alone department. This is not a quick fix, or a bandage, or an upgrade. This is a transforming event. This will be *analytics driven*, call it the AI College, the AI Academy, or the AI Centre, but they must be independent, preferably reporting to the board. It must be staffed with people that have a deep understanding of AI, how it needs to be integrated into a manufacturing plant, and how to educate people and truly transform their behaviour. Above all else, it unequivocally requires the 'buy in' of all the senior executive team.

The executive of tomorrow in the foundry or any industry will have to balance the political pressures I see forming in the environmental arena, to attain levels of compliance never before imagined, to understand, accept, and oversee the installation of the most comprehensive transformation the world has ever experienced. They will have to deal with a widening of the wealth gap (not only with the population, but between nations). If that is not enough, we are seeing what is called *'Capitalism in Crisis'* according to Darren Walker, president of the Ford Foundation who says: *"The US, the paragon of Capitalism, is experiencing crushing income inequality and struggling to provide affordable health care and childcare for working families, as well as unprecedented climate change threatening further disruption."* There will be political and societal pressure to cap salaries, connect more with philanthropy, reduce the salary gap, and create a 'new capitalism' that will partner with philanthropy to deal with the inequality and injustice often seen in the marketplace. A global issue we must address is the reality of providing energy to the world's poorest people. Bill Gates says: *"The challenge calls for a scientific miracle. These will emerge from basic research, not for subsidies from yesterday's technologies."* Look at history and it can be seen that transformational change only occurs when catastrophic events happen, generally war, economic depressions, or natural disasters. However, Artificial intelligence will BE the catastrophic event, that I believe will bring about that change which will impact every nation, every person in the world, in ways we struggle to even imagine today. So, how is your toolbox of skills looking right now?

THE ROLE OF ANALYTICS

In a macro analysis, every event brings challenges and opportunities. Focus on the opportunities, get prepared, be ready, and take charge. Our global history indicates there has been the need to form alliances for a variety of reasons, generally for protection against a common enemy.

Perhaps this is the time for governments to collaborate with their collective digital information to assure a peaceful and productive transition into the new age of digital transformation and not weaponise this discovery like we did with nuclear energy. We are and should be concerned about global warming, CO_2 emissions, the expanding gap in wealth distribution worldwide, and population growth (which contributes significantly to CO_2 emissions), but in my opinion, they pale in comparison to the impact on society that we will see in the age of analytics.

In a micro analysis, the foundry industry will continue to be compromised by advancement of 3D printers producing small sophisticated metal parts in a production environment, combustion engines will be in the museums – being replaced by electric, fuel cell, or electromagnetic propulsion vehicles. All the ancillary parts supporting combustible engines will be no longer needed. The heavy weapons of war, such as tanks, artillery, etc. are not needed. The new wars of the future may be cyber driven, or weaponised lasers being positioned within satellites in orbit around our earth. On the environmental side we will need to face the real possibility of ZERO plant emissions, how will we cope with that? Also, fossil fuel may no longer be accessible to plants and the industry will have to rely on alternative energy sources at a higher cost then can be imagined. There will be no credit offsets to use to balance CO_2 compliance, it again will be ZERO. The World Economic Council published a futuristic report in which the following paragraph illustrates what the industry will be up against.

They list as the drivers of change four specific technological advances: *"ubiquitous high-speed mobile internet; artificial intelligence; widespread adoption of big data analytics; and cloud technology – are set to dominate the 2018–2022 period as drivers positively affecting business growth. They are flanked by a range of socio-economic trends driving business opportunities in tandem with the spread of new technologies, such as national economic growth trajectories; expansion of education and the middle classes, in particular in developing economies; and the move towards a greener global economy through advances in new energy technologies."*

This is the wakeup call; the industry needs to start now and hire the people that understand the future of analytics and how to incorporate that into manufacturing. It might help to buy the book *'Who moved my cheese'* by Dr Spenser Johnson, a parable about change, it will help readers grasp the dilemmas faced.

A FINAL THOUGHT

Change is the essential process of all existence and we are entering a new frontier, never before charted, it will be up to those managing industry to meet the challenges and make this world we live in a better place for all, with the technology available to us tomorrow. Employ the brightest young people you can find and do it now, you cannot wait. I wish everyone prosperity in this new world we are entering, and I wish I was 20 years younger, what a ride it will be!!

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[1] Dotson Denny, www.dotson.com/saugus2/docs/saugus2phase2slides.pdf

[2] Kurzweil Ray, *The Singularity is Near*, 2005.

AUTHORS

Donald L Huizenga.

*This paper is an invited submission to **Foundry Trade Journal** selected from presentations to be made at the planned World Foundry Summit 2020, postponed to 2021. For details about the WFO World Foundry Summit 2021 and how to get involved contact the World Foundry Organization direct, email: andrew@thewfo.com*
web: www.thewfo.com

Easy knock-out moulding and core sands – the future for metal casting

Artur Bobrowski, Dariusz Drożyński, Beata Grabowska, Karolina Kaczmarska – AGH University of Science and Technology, Faculty of Foundry Engineering, Poland

ABSTRACT

The paper presents the results of research of moulding sands with the inorganic binder Geopol®, aimed at lowering the final strength and thus improving the casting knock-out. The applied relaxant additives significantly reduces the final strength and positively influences the knock-out property. At the same time, the tested sands showed similar mechanical and technological properties. The addition of additives does not have a negative impact on the ecological properties of the sands.

INTRODUCTION

In recent years, interest in moulding and core sands with inorganic binders is on the increase, which results mainly from the tightening regulations related to the emission of harmful chemicals into the environment. The degree of harmfulness of moulding and core sands to the environment is assessed on the basis of the compounds from the BTEX group (benzene, toluene, ethylbenzene, xylenes) and PAHs (polycyclic aromatic hydrocarbons) emission. This emission arises as a result of a thermal degradation of the binder under the influence of contact with high temperatures of liquid metals[1,2,3]. Good technological and mechanical properties, the possibility of obtaining high quality castings, and specifically minor harmfulness to the environment, means moulding sands with inorganic binders are becoming increasingly popular.

Until recently, the most widespread inorganic binder was hydrated sodium silicate (water glass). To meet the expectations of customers and increasing requirements in terms of reducing emissions of harmful substances to the environment[4], companies operating in the market of foundry binders offered several new inorganic binding systems. Cordis technology (Hüttenes-Albertus) and INOTEC (ASK) appeared. In 2003 at the *GIFA* trade fair, the inorganic binder system Hydrobond from MEG was presented for the first time. SAND-TEAM proposes replacing the water glass with the geopolymer binders Rudal A and Geopol® [5-7].

The main disadvantage of all moulding sands with inorganic binders is their strengthening caused by high temperatures of liquid metals (high final strength) and associated with it the difficult knock-out and poor susceptibility to the mechanical reclamation. The first strengthening is observed in the temperature range of 200-300°C (the so-called I maximum strength) and the second in the range of 600-800°C (the so-called II maximum strength)[8-11].

Sand	Quartz sand, part by mass	Binder Geopol®, part by mass	Hardener SA72, % for binder	Additive, part by mass
IMS	100	2.5	8	x
IMS + S1	100	2.5	8	2*
IMS + S2	100	2.5	8	1*

*Table 1 The composition of the tested moulding sands (*only for final compressive strength determination (fig.1), the additive was used in an amount of three parts by mass.)*

Difficulties with knock-out, together with a poor susceptibility to the mechanical reclamation and a lack of resistance to moisture, determine the limited use of moulding and core sands with inorganic binders in the foundry industry.

Various types of activities are undertaken to reduce these disadvantages, including physical and chemical modifications[12-17].

Taking the above into consideration, actions were undertaken to improve the properties of sands with inorganic binders, while maintaining the low emission of harmful compounds when moulds are poured with liquid metals.

MATERIALS AND RESEARCH METHODOLOGY

Modifications of the composition of moulding sands with inorganic binders (IMS) consisted of introducing the relaxation additive. Two additives, designated as S1 and S2, were used. The investigations of moulding sands of the composition given in Table 1, were carried out.

The determination of ultimate tensile strength and compression consisted of preparing sands with the assumed composition, from which standard samples were made in the form of octal or cylindrical shapes. The moulding sand portion was placed in a special die, coupled with the device for vibratory compaction of samples (LUZ-2e apparatus manufactured by the Multiserw Morek Company). The curing process was carried out 'in an open air' under constant laboratory conditions, at a relative humidity of 30-35% and a temperature of about 20-21°C. The samples, after 24 hours of curing, were then heated together with the furnace to a specific temperature within the range 100- 1000°C. In each case, the same heating rate was used – 10°C/min. After cooling (including the furnace) to the ambient temperature, the strength determination was carried out using the LRu-2 tester (Multiserw-Morek).

The determination of the free fluidity consisted of placing a loosely sifted moulding sand (150g) in the funnel tank and dropping it – from a height of three feet (0.914m) – onto a sieve with a mesh diameter of 8mm. The fluidity value is the amount of mass expressed in grams that passes through a sieve of a given mesh size[18].

INVESTIGATION RESULTS – IMPROVEMENT OF KNOCK-OUT

The results of the final compressive strength R_c^{Tk} determination for the moulding sand without the additive and moulding sands with the proposed relaxation additives is presented in fig.1. Both moulding sands with addition of S1 and S2 are characterised by several times lower final strength.

In order to confirm the results of the final strength tests, the knock-out test according to PN-85/11005 was also made (fig.2). Standard cylinder-shaped fittings Ø50x50mm placed in a mould cavity (b) were made by using the model (a). The mould was poured with liquid metal, and then the knocking-out process was conducted by using a cone-shaped mandrel (c). The measure of the sand's susceptibility to knocking-out is the work needed to remove the core (standard cylindershaped) from the casting, described as (1)[10]:

$L_W = 1.63 \bullet n$,J (1)

where:

1.63 – work of one stroke (weight of 3.3kg) falling from a height of 50mm above the core, J;n – the number of strokes of the sinker at the time of the core removal from the casting.

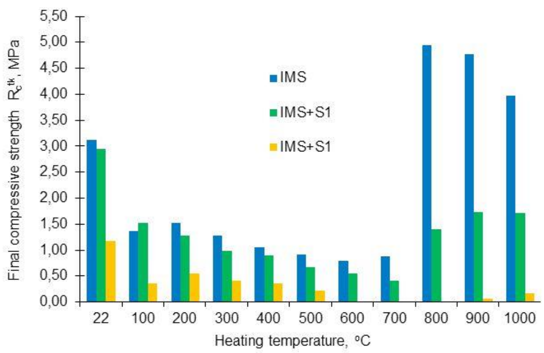

Fig.1 Final compressive strength of moulding sands with inorganic binder (IMS – without additive, IMS+S1, IMS+S2 – with relaxation additive)

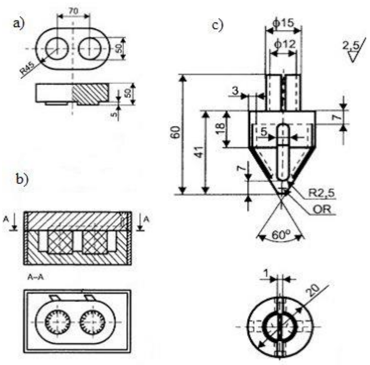

Fig.2 Model diagram (a) form, (b) conical stem, (c) for the knocking-out test by PN-85/11005(10)

The introduction of relaxation additions S1 and S2 significantly improves the knock-out of moulding sands with inorganic binders (all types (fig.3)), in relation to the moulding sand without additives (IMS). The work required to knock out the core clearly decreases.

The use of additives to moulding sands should not significantly reduce the properties of moulding and core sands. Therefore, tests were carried out to recognise the effect of relaxant additives (S1, S2) on the selected mechanical and technological parameters: tensile strength, free fluidity, permeability and abrasiveness.

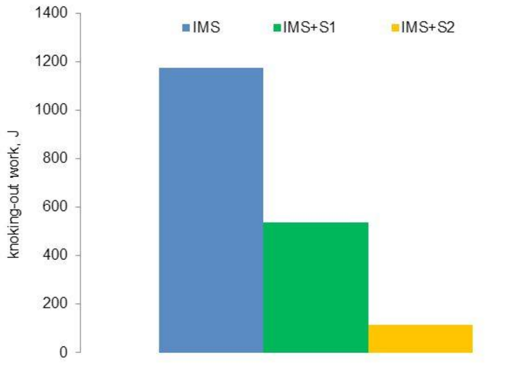

Fig.3 Results of the knock out test according to PN-85/11005

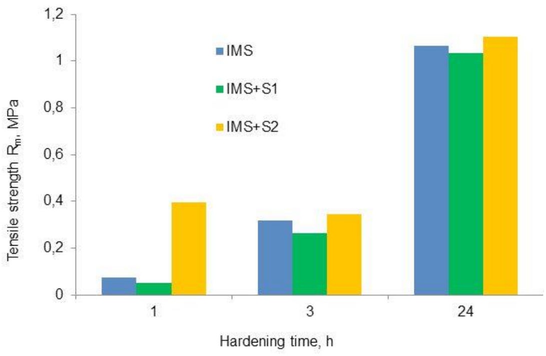

Fig.4 Dependence of the tensile strength of the Geopol® geopolymer binder, after curing, for sands with relaxation additives S1 and S2

Fig.5 Free fluidity of moulding sands with the Geopol® geopolymer binder and relaxation additives S1 and S2

Additives S1 and S2 are introduced into the moulding sand during the mixing process. As shown in fig.4, their introduction does not have the negative effect on the mechanical properties of the sands. After one and three hours of curing, all sands reach similar strength values in the range of 0.2-0.3MPa. After 24 hours of curing, the sands obtain the tensile strength of about 1.0MPa. The introduction of mineral additives

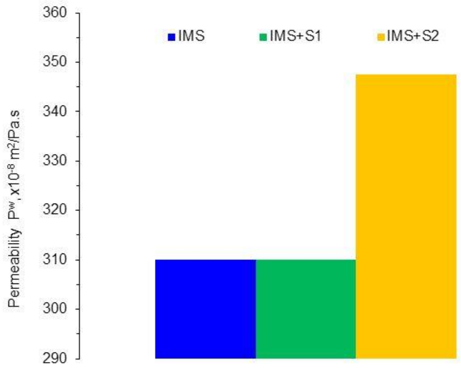

Fig.6 Permeability of moulding sands with the Geopol® geopolymer binder and relaxation additives S1 and S2

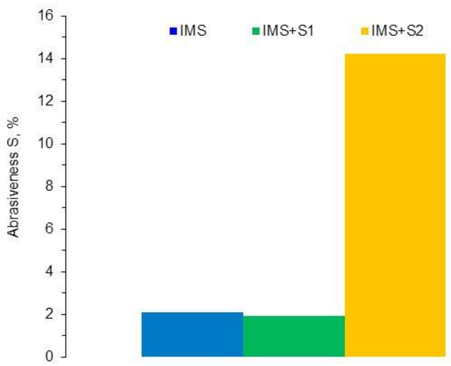

Fig.7 Abrasiveness of moulding sands with the Geopol® geopolymer binder and relaxation additives S1 and S2

does not have negative effects on the mechanical properties of the moulding sands, despite the fact that they are fine-grained materials, which increases the specific surface area of the sand.

The determination of free fluidity showed that the worst liquidity had the sand with the addition of S2 (fig.5). According to the guidelines presented in reference 18[18], all tested sands can be included in the moulding sands of a good fluidity group. The fluidity of sands is strongly associated with their ability for concentration, and consequently with the apparent density of the sample. The shown differences can cause the falsification of results.

The obtained results indicate that mineral relaxants do not have a significant impact on the sand's permeability (fig.6). The use of materials with a higher degree of fines results in the surface of the material being inundated, which leads to an increased consumption of the binder.

The moulding sands with relaxant additives are characterised by higher abrasiveness (fig.7), in particular the sand with the addition of S2, despite maintaining similar mechanical properties (fig.4).

Sand	Volume of gases, dm3/ kg of moulding sand	Emission of gases, mg/kg of moulding sand			
		B	T	E	X
IMS	14.0	25.1	0.0	0.0	0.0
IMS + S1	15.0	20.6	0.0	0.0	0.0
IMS + S2	13.5	15.6	0.00	0.0	0.0

Table 2 Emission of gases of the BTEX group (benzene, toluene, ethylbenzene, xylenes) from moulding sands with the geopolymer binder Geopol® containing relaxants materials

The gas-generation studies in terms of the total volume of gases released and the emission of compounds from the BTEX group in semi-industrial conditions were carried out on a patented research stand for determining the emission intensity and harmfulness of gases emanating from technological materials used in foundry and metallurgy processes (Patent PL 224705 B1)[19]. The measurement methodology consisted of preparing the sample of moulding sand of a cylindrical shape, size F50 × 50mm, of known mass. The sample was placed in a steel bell and fixed in a previously prepared mould cavity, and then poured with liquid metal of a temperature of 1350°C (grey cast iron). The gases formed as a result of a contact with liquid metal were adsorbed on the active carbon deposit, after drying, and then transported with the pipe system to the peristaltic pump and the electronic recorder[4]. The investigations were performed for the moulding sands about the composition given in Table 1.

The proposed additives do not cause the emission of harmful gaseous compounds during the casting process, cooling or knocking out. If used S2 even recorded a significant decrease emission of benzene. Preliminary studies also indicate that the proposed relaxant additives can have a positive effect on the mechanical reclamation process of used sands.

CONCLUSIONS

On the basis of the conducted research, the following conclusions were formulated:

1. The use of the proposed additions to moulding sand with an inorganic binder significantly lowers the final strength of the sands and thus positively influences their knock-out properties.

2. The introduction of additives does not have a negative impact on the process of making moulding sands, because the additives have a density similar to that of quartz sand.

3. The introduction of S1 and S2 additives does not affect the mechanical properties of moulding sands.

4. The greater abrasiveness of sand with the addition of S2 is associated with an increase in the specific surface area. In order to eliminate this phenomenon, it is recommended that a larger amount of the binder is introduced.

5. The moulding sands with S1 and S2 additives retain favourable ecological properties. The emission of gases from the BTEX group does not increase. There is even a reduction in emissions (additive S2) as compared to moulding sand without additives.

ACKNOWLEDGEMENTS

The research partially financed in the *'Incubator of Innovation +'* project is carried out by the consortium of the AGH University of Science and Technology in Krakow AGH Center for Technology Transfer and the Krakow Center for Innovative Technologies INNOAGH l l. Company in the non-competitive project *'Support for managing research and commercialization of research and development results in scientific units and enterprises'* implemented within POIR 2014-2020, Measure 4.4 - Increase of human potential R+D.

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AUTHOR CONTACT

Artur Bobrowski, Dariusz Drożyński, Beata Grabowska, Karolina Kaczmarska – AGH University of Science and Technology, Faculty of Foundry Engineering, Reymonta 23, 30 059 Kraków, Poland, email: arturb@agh.edu.pl

*This paper is an invited submission to **Foundry Trade Journal** selected from presentations at the 73rd World Foundry Congress, organised by the Polish Foundrymen's Association on 23rd to 27th September 2018 in Krakow, Poland, and has been expanded from the original presentation.*

Investigation and characterisation of inclusions in aluminium cast alloys for the automotive industry

Onur Özaydın, Alper Kaya and Elvan Armakan – Cevher Wheels, R&D Department, Izmir, Turkey; Tuğçe Yağcı and Osman Çulha – Manisa Celal Bayar University, Engineering Faculty, Department of Metallurgical and Materials Engineering, Manisa, Turkey

ABSTRACT

'Lightweight materials' are widely used in the automotive industry. Not only the demand for fuel efficiency, but also regulations mandating lower emission values lead automotive manufacturers to increase their use of lightweight materials. Considering the low density, better mechanical properties, easier machinability, corrosion resistance and recyclability, Al-Si based alloys are widely used in automotive components such as wheels. Beside these advantages, disadvantages such as impurities, porosity and grain size play a vital role in terms of mechanical properties and surface quality of aluminium alloys. In this study, inclusions were investigated. The SEM (scanning electron microscopy) and EDS (energy dispersive spectroscopy) analysis and elemental mapping methods are preferred in the investigation. All critical areas on the samples were defined and analysed by SEM & EDS methods.

INTRODUCTION

The concepts of sustainability and energy saving are crucial issues for the future of the world. Ecological concerns have led manufacturers to research and develop new materials and mass production processes. In the automotive industry, one way of reducing the strictly regulated CO_2 emission values is the reduction of fuel consumption which could be achieved by increasing the amount of light alloy components in a vehicle. For this reason, aluminium alloys are widely used in the automotive industry as lightweight materials(1). In comparison to other light alloys, aluminium alloys are also at the forefront in terms of high specific strength (strength/density) and visual quality. Aluminium (Al) cast alloys are the preferred material for critical automotive components such as cylinder heads, support brackets and wheels. Also, aluminium alloys enrich the vehicle visually(2).

All original equipment manufacturer (OEM) wheels must satisfy certain mechanical and metallurgical requirements and must have distinguishing visual characteristics to have a distinct impact on customers. Therefore, all manufacturing and testing steps during manufacturing processes must be well planned and controlled. The step by step production flow chart of aluminium alloy wheels produced by the low pressure diecasting (LPDC) method from raw material to shipment is shown in fig.1.

At the beginning of the manufacturing process the liquid material is analysed and grain refined with AlTi5B1 and then modified with strontium (Sr). Secondly, liquid material is again chemically analysed and if it is acceptable according to related standards and specifications, the liquid metal is transferred into a transfer ladle. After the transfer, nitrogen (N) is given into the liquid metal to remove the hydrogen (H) from the metal. A transfer ladle transports the liquid metal to a holding furnace to start the LPDC process. In this step, the liquid metal is chemically analysed again while the mould is being prepared. After clamping the mould to the LPDC machine the casting process begins.

After casting an x-ray inspection is a must for all cast Al alloy wheels. Then, according to material content, wheels may be heat treated or not. In wheel production AlSi7 is usually used in heat treated form while AlSi11 is not(4). After heat treatment, wheels are transferred to the machining line where hub, bolt and valve holes are drilled and spokes and rim section received in it's final form. All cast Al alloy wheels (100%) must also be checked for leakage by a He-Leakage test machine. If the wheel passes the leakage test it is transferred to the paint shop. After painting, there might be an additional process called 'diamond polishing'. Diamond polishing is a type of re-machining operation where the paint is removed from the top of the spokes by machining and the wheel front side receives a shiny appearance. After that the clear coating process must be repeated to prevent corrosion on the machined surfaces.

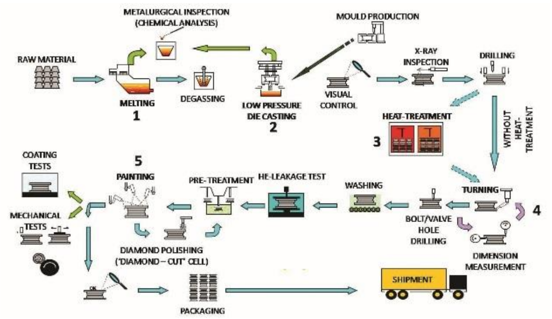

Fig.1 Production flow chart of aluminium alloy wheels[3]

Fig.2 Diamond cut wheel

Finally, paint and mechanical tests are carried out according to related standards and specifications, and if all checks are positive the wheel is ready for shipment[3].

In recent decades, the market share of re-machined wheels, also known as 'diamond cut wheels', is growing dramatically due to their very distinct appearance. A part of a diamond cut wheel product is shown in fig.2. However, a challenge is inherent in re-machined wheels – the machined surface must have a perfect appearance, even a very small defect may be deemed to be unacceptable by current automotive standards.

Fuel efficiency and emission value regulations have led to automotive manufacturers increasing their use of lightweight materials. Considering the low density, good mechanical properties and machinability, high corrosion resistance and recyclability, Al-Si based alloys are widely used in automotive components. In particular, AlSi7 and AlSi11 are the main materials used in wheel production[4]. However, flaws such as impurities and porosity play a vital role in terms of mechanical properties and surface quality of Al alloys.

In the literature, there are numerous studies about controlling the microstructural characteristics and enhancing the mechanical properties and machinability of Al cast alloys. Dispinar[5] noted that inclusions in Al alloys act as stress-raisers and thus may lead to a premature failure in the structure. The most common inclusions are oxide particles and films resulting from oxide skins on the surface of material to be melted. Zhao et al[6] studied the effects of inclusions on mechanical properties of die cast A356 alloy wheels. The SEM & EDS analyses indicated Al-Ti-B compound, α-phase (Al12FeSi), β-phase (Al9Fe2Si2) and Al_2O_3 in the structure. They showed that the rate of defects affects the mechanical properties directly. Tebaldini et al[7] investigated the effects of casting defects on A356/T6 fatigue limits. Impurities in the structure may act as fatigue crack initiators and affect fatigue life directly. After fatigue tests, they examined the structure of fracture initiation area with SEM and analysed the chemical composition with EDS. They noted non-metallic inclusions in microstructure. Navyanth[8] created a pareto chart of rejection of Al alloy wheels and shows that inclusion ratio is the reason for almost 10% of all cast wheel failures. It indicates that inclusion is one of the major problems of Al alloy wheels and there is a correlation between inclusion ratio and holding furnace cleaning frequency. According to Navyanth, inclusion ratio decreases dramatically with a higher holding furnace cleaning frequency.

Alloy	Si	Fe	Cu	Mn	Mg	Zn	Ti	Al
AlSi7	6.5-7.5	0.15	0.02	0.10	0.30-0.45	0.07	0.10-0.18	remained
AlSi11	10.0-11.8	0.15	0.02	0.05	0.1-0.45	0.07	0.15	remained

Table 1 Chemical composition limits of AlSi7 and AlSi11 alloys

Fig.3 Cast samples obtained from different steps of the production process of aluminium alloy

In this study, inclusions in Al cast alloys are divided into two groups – internal and external. 'Internals' may appear during melting, degassing and grain refinement processes. 'Externals' may be caused by holding furnace lining and/or transfer ladle lining and form during the re-melting process. Inclusions include different phases such as oxides (Al_2O_3, MgO, SiO_2), carbides (Al_4C_3, TiC, SiC), nitrides (AlN), borides (TiB_2, ALB_2), inter metallics and spinels ($MgAl_2O_4$). The main aim of this study is to find and analyse the structure of inclusions.

MATERIALS AND METHODS

As mentioned above, AlSi7 and AlSi11 are the most used materials in wheel production. Therefore, these two materials are investigated in this study. The chemical compositions of the studied AlSi7 and AlSi11 cast alloys are given in Table 1.

According to the literature on research conducted to determine theoretical root causes, the identification of a root cause is not always a straightforward process. Since there are multiple mechanisms for inclusion formation, occasionally the emergence of inclusions is a result of synergetic conditions[9-10].

Based on information from literature, the types of inclusions which may affect the surface quality directly are determined. To determine the effect of inclusions, different samples are taken from melting and holding furnaces at different steps during the wheel production process. Samples taken from molten aluminium alloy before and after degassing were also examined to decide the effects of degassing on formation of inclusions in the structure. Cast samples taken from different steps of the production process of Al alloy wheels are shown in fig.3.

Then, inclusions are analysed morphologically and chemically (wt.%) by using SEM technique with EDS. Elemental mapping technique was used for the determination of spatial distribution of the elements in the region containing inclusions. By means of these microstructural examinations, the structures of inclusions are clarified and linked with potential root causes.

RESULTS AND DISCUSSION

The identification and elimination of inclusions in the structure is extremely important in terms of the quality.

The determination of elemental composition of the samples taken from different steps in aluminium wheel production process is carried out by EDS technique used in SEM. The characteristics of x-ray emitted from the sample give information about which element atoms the sample contains. These x-rays, which are detected by electronic receivers, generate peaks in the computer monitor and perform elemental analyses. The peaks of the elements are proportional to the areas underneath. Based on this, the results of the SEM analyses of the inclusion studies on the samples taken from the five different steps of the production line are given in detail in this section.

The different regions where the EDS analysis of the same sample is performed are shown in fig.4. The detailed results of the SEM analyses of the carbide type inclusion on the surface of the diamond cut wheel are given in fig.5. According to the results of the EDS analyses, the inclusion is containing some oxides. Especially, the zone called ‘selected area 1’ contains aluminium oxides. There is no desired aluminium alloy in this region. Also, no inclusions were found in the structure in the ‘selected area 3’ region.

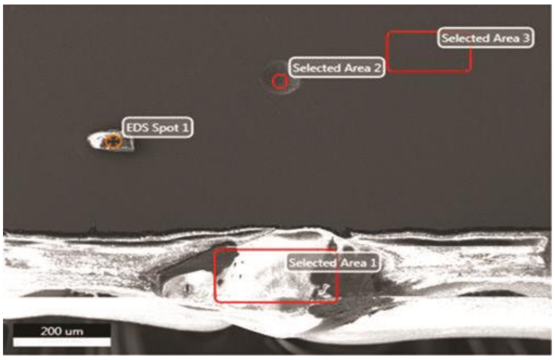

Fig.4 EDS analysis regions on the surface of diamond cut wheel (sample no:1)

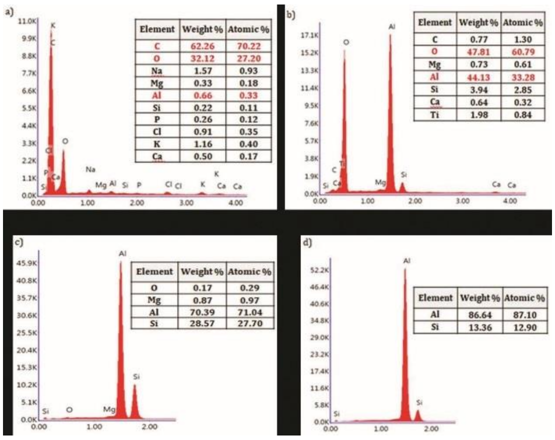

Fig.5 SEM-EDS results of the sample taken from the surface of diamond cut wheel (sample no:1): (a) EDS spot 1, (b) selected area 1, (c) selected area 2, (d) selected area 3

The same characterisation techniques were carried out for ‘sample 2’ and ‘sample 3’ taken from other regions of the wheel surface. The different regions of the specimen are shown in figs.6 and 8. The results of EDS analyses are also given in detail in figs.7 and 9.

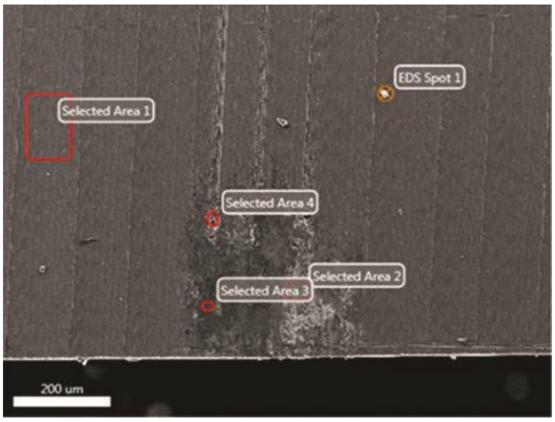

Fig.6 EDS analysis regions on the surface of diamond cut wheel (sample no:2)

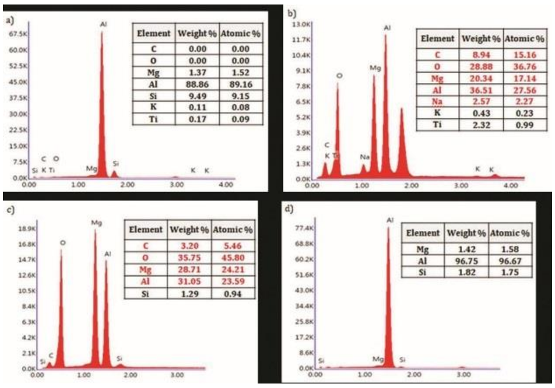

Fig.7 SEM-EDS results of the sample taken from the surface of diamond cut wheel (sample no:2): (a) selected area 1, (b) selected area 2, (c) selected area 3, (d) EDS spot 1

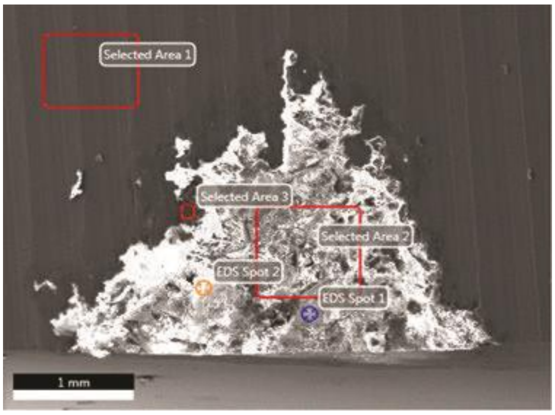

Fig.8 EDS analysis regions on the surface of diamond cut wheel (sample no:3)

The microstructural image of the complex oxide type inclusion is represented in fig.10. These type of inclusions, which contain aluminium magnesium oxides (solid solutions of $MgAl_2O_4$ and Al_2O_3), are called 'spinels' in literature[11]. As shown in fig.10, these FOUNDRY TRADE JOURNAL December 2019 343 spinels have an irregular shape. Their surface acts as a preferential site for crack initiation and propagation. During production, precautions must be taken against the occurrence of these inclusions.

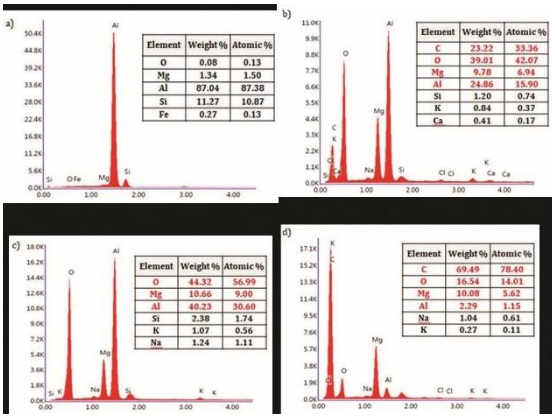

Fig.9 SEM-EDS results of the sample taken from the surface of diamond cut wheel (sample no:3): (a) selected area 1, (b) selected area 2, (c) EDS spot 1, (d) EDS spot 2

In addition to the qualitative and quantitative elemental analysis in the sample by SEM, distribution of elements was followed by mapping technique with EDX detector of the same equipment. Fig.10 shows the distribution of C, O, Mg, Al and Si elements around the inclusion zone in sample 2. According to the map, the inclusion is containing some oxides such as aluminium and magnesium oxides.

A considerable amount of work has been carried out on the effects of inclusions in Al cast alloys. Seniw et al (2000) investigated the effect of micro scaled inclusions, silicon segregation and their locations on the fatigue behaviour of A356 aluminium alloy. They showed that the amount and distribution of micropores, Al-Si eutectics and the inappropriate morphology of phases in the microstructure affects the solidification requirements and decreases the fatigue resistance of the samples[12]. On the other hand, there are many studies on the developing analysers to control liquid metal quality in a more practical, effectively and safe way. An analyser named as LiMCA (liquid metal cleanliness analyser) consisting of a probe, a current source and a signal processing system, was designed by Kahtani (2013) to measure the concentration and size distribution of inclusions and oxides in Al melt[13]. In addition, porous disc filtration analysis (PoDFA) method developed by Alcan is used to identify the size and number of inclusions in molten aluminium[14].

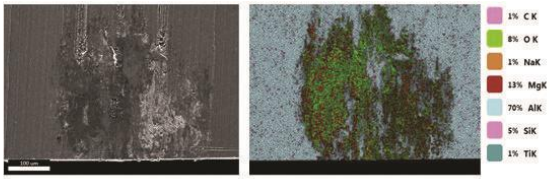

Fig.10 Elemental mapping results of 'sample 2' taken from the region of inclusions

CONCLUSION

In this study, information about the forms and contents of inclusions which can be formed in aluminium alloy wheel production by the low pressure diecasting method is given. It was shown that different types of inclusions can be observed in aluminium cast microstructures. The conclusions are:

1. Reaching the root causes of formation of undesirable inclusions in liquid aluminium is a challenging process since they do not always have a single root cause. To be able to take precautions against complex inclusions, which may appear because of a combination of many different reasons, having an accurate diagnosis of the cause of the problem first is extremely important.

2. The affinity of aluminium alloys for bonding with oxygen, hydrogen, silicon, alkali and alkaline earth elements, fluorine, hydroxide and phosphates is quite high. Therefore, the cleanliness of aluminium alloys during wheel production by the low pressure diecasting technique is critical to prevent the formation of inclusions.

3. Inclusions in molten aluminium alloys affect the mechanical properties and formability of wheels negatively.

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AUTHOR CONTACT

Onur Özaydın*[1], Tuğçe Yağcı[2], Alper Kaya[1], Osman Çulha[2], Elvan Armakan[1]

1 Cevher Wheels, R&D Department, Izmir, Turkey,

2 Manisa Celal Bayar University, Engineering Faculty, Department of Metallurgical and Materials Engineering, Manisa, Turkey,

email: oozaydin@cevherwheels.com

*This paper is an invited submission to **Foundry Trade Journal** selected from presentations at the 73rd World Foundry Congress, organised by the Polish Foundrymen's Association on 23rd to 27th September 2018 in Krakow, Poland, and has been expanded from the original presentation.*

Digital transformation to Foundry 4.0

N Gramegna, F Greggio – EnginSoft SpA, Padova, Italy; F Bonollo, Università di Padova – DTG, Italy

ABSTRACT

The competitiveness of the foundry sector is driven by innovation oriented to quality and production efficiency. The deeper knowledge of foundry process supports the introduction of optimal solutions to high quality products as requested from different global markets. The ability to manage all the stages of foundry production, based on advanced monitoring and cognitive platform, is fundamental to be able to react in real-time with a positive impact in terms of energy, environment and cost.

Nowadays, the challenge is the digitalisation of real processes introducing intelligent systems to control the stability and the efficiency of production lines, along with being able to enable quality assessment and predictive maintenance.

The application of the new ICT platform, Smart Prod ACTIVE, is oriented to zero defect manufacturing as demonstrated and validated at the foundry.

INTRODUCTION

Digital transformation is essential for an innovative foundry to comply with the Industry 4.0 paradigm and the application of enabling technologies similarly for automation in assembly. The maturity, transversal usability, and fast evolution of information and communications technology (ICT) is accelerating the application of cyber-physical system (CPS), Internet of Things (IoT) and artificial intelligence (AI) in existing foundry plants or at new production sites. The foundry and metallurgy sectors start this digital revolution by introducing advanced process simulation tools in the design and engineering departments of the supply chain. All equipment and processes are well designed and optimised by casting process simulation.

The 'smart manufacturing' strategy is in line with zero defects and system efficiency in a foundry with the support of new ICT platforms with full interoperability of systems, with flexibility for small or large factories, with optimal solutions for one size or serial production, improving the human machine interaction as well as sharing the information along the supply chain. All stakeholders in the foundry supply chain (material, implant and equipment suppliers, foundry user and the end-users of castings) are looking for a collaborative market place where quality, energy and cost models are key performance indicators (KPIs) of the decision support system (DSS).

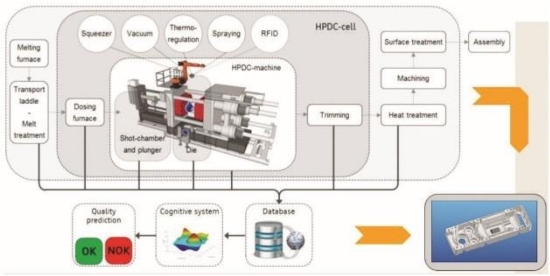

Fig.1 Multi-stage and devices of HPDC cell connectivity of ICT platform for smart monitoring of the process and quality predictive models

Foundry digitalisation is facing technological barriers, limits in people skills and opportunities for new business models. Intelligent control and energyaware agile manufacturing is providing a new age to the traditional multi-stages production of the smart foundry (ref. EU FP7-MUSIC project – (1-2)) in agreement with EU, national and regional strategies embraced by the Veneto Regional foundry network SINFONET (www. retesinfonet.org/).

INTELLIGENT PROCESS DATA MANAGEMENT

The 'zero defect' target is always the first priority of the digital approach in a foundry – to minimise the defects with real-time retrofit. The scrap rate reduction is focused on those defect factors mainly contributing to the overall quality requirements of the product. Energy consumption connected to the production rate, the cycle time optimisation (more pieces per hour) and improved management of energy-demanding devices all lead to cost reduction[7,8].

In the frame of foundry processes, a challenging issue is constituted by high pressure diecasting (HPDC). In the multi-stages of a HPDC production line (fig.1) there are different devices with various brands and controllers. The HPDC machine is a key element and typically it is well controlled via PLC, but the most important element of the process is the die because it is generating 60% of the defects (e.g. lamination, cold shots, flash, blister, soldering and incomplete casting) referred to the specific product[3,4]. The implemented sensors network[1] is acquiring the traditional data from machines including more advanced sensors in the die (e.g. metal contact pressure and temperature sensors) as well as sensors to monitor the process stability during the different phases of the process (e.g. filling, solidification, ejection, cooling, die opening, die spray and closing).

In general, foundry digitalisation requires the following elements (fig. 2):

1. *Remote control of multi-stage foundry processes* to verify the process stability; to monitor any stops and times. The control has to be applicable for existing or new production lines independently by the trademark. The *smart monitoring* module is collecting all process data in a server database (or cloud), via OPC_UA protocol, coming from all existing devices[2-3] and active sensors in the production line.

2. *Real time improvement of overall equipment effectiveness* (OEE), taking into account the availability (unplanned and planned stops), the performance (fast cycles and small stops) and quality (good parts produced). The KPIs of the OEE are immediately elaborated, monitoring the time of each stage in the cycle and predicting the defects by implementing the cognitive model.

3. *An increase in the knowledge of the process* from the data and re-use the best practice for the next batch or similar castings. The real-time visualisation of elaborated data, including warning and alarm messages and statistic production diagrams, can be customised for multiple users' interfaces as machine operator, production manager and plant director.

4. *Application of artificial intelligence to support the process optimisation* with proper suggested reactions. The smart web graphical user interface (GUI) visualises the data and deviation, shares and communicates the significant KPI to support the decision making with proper reactions in real-time.

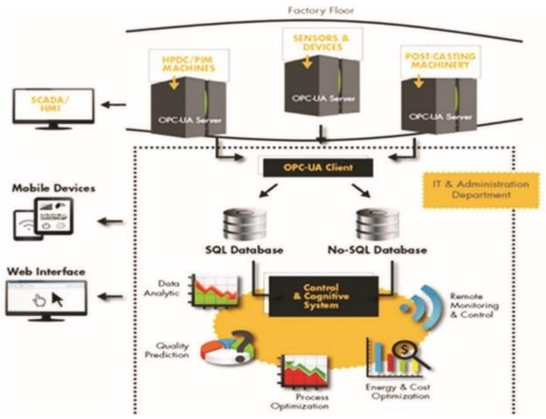

Fig.2 Connectivity and smart monitoring of the foundry process to elaborate OEE and apply quality predictive models

Based on these concepts, a *Smart ProdACTIVE platform* has been developed, and its application is shown in this paper. Those elements are available inside the Smart ProdACTIVE platform improving the user experience depending on his roles.

PREDICTIVE MODELS AND PROCESS OPTIMISATION

The standardisation of the quality classification and investigation methods[4-5], as well as the casting traceability, are fundamental to train the quality predictive model, guiding the minimisation of relevant indexes affecting the scrap rate.

All process parameters possibly affecting the quality of specific castings have been taken into account and used in the training stage of a meta-model – both virtual and real – correlating input process variables and data from sensors with quality indexes in the areas of interest. The model needs to be trained with reference to a specific product and process, because the quantification of correlations are unique and not generalised. The parallel chart (fig.3) is one method to visualise the dependency of quality indexes from process parameters and sensor

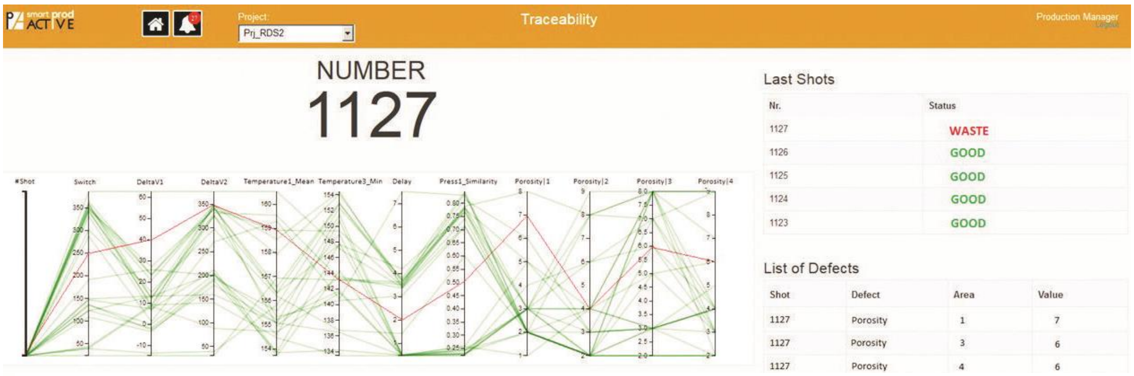

Fig.3 Parallel Chart: connection between process setup, sensor signals and quality indexes

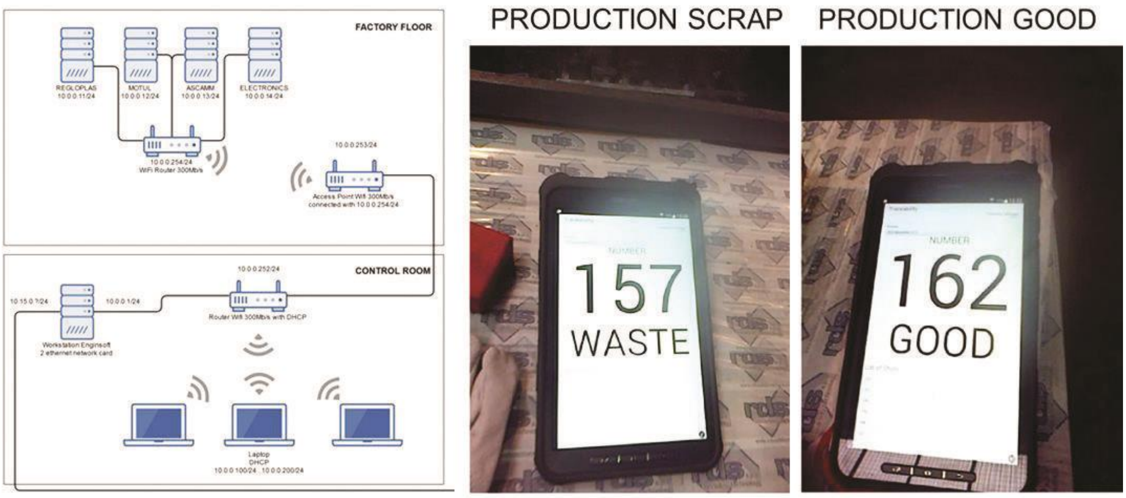

Fig.4 LAN network connection and real time prediction of waste and good castings

measurements. The met-model is trained from data with reference to specific quality index without a fixed threshold. The acceptability thresholds for each quality index (or classified defects) are applied by the user.

With this innovative approach, the sampling stage is used to train the model to understand the genesis of all possible defects. The traceability of the castings, during the training or during the production is a mandatory task. Any new data from the production line and quality laboratory is an input for the automatic re-training of meta-model, improving the accuracy day-by-day.

The production starts normally using the best process setup. The stability and repeatability of the best shot is monitored with real time comparison of reference curve previously selected and the instantaneous verification of thresholds satisfactions to quality prediction. The scrap castings or good castings, predicted by quality models, are visualised in PC, tablet (fig.4) or smart-phone with available web connection to the system. The example shown in fig.4 is the result of the optimisation procedure applied during the production – the scraps were expected during the warm-up of the die and good quality achieved at a thermal steady state; a 30-minute break generated some scraps at re-start (e.g. casting number 157) and good production after five castings (e.g. casting number 162) has been recovered.

COST MODEL AND FOUNDRY BENEFITS

The application of cost model approach in the high pressure die casting (HPDC) context has been investigated by defining parametric analysis to identify the main sources of costs and the related impacts on production processes to guarantee a real-time quality and cost management as well as a comparison of company past production data. The cost model is developed adopting a cost centres

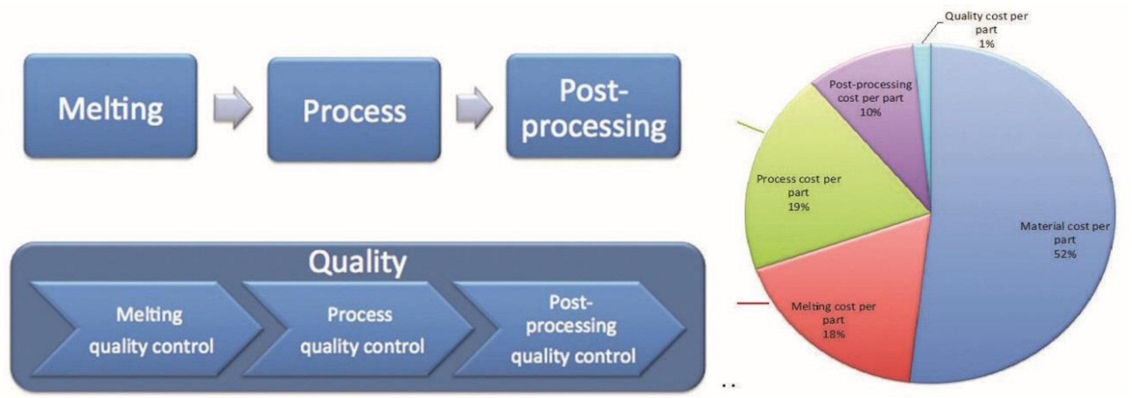

Fig.5 Cost centre approach for the diecasting process and example of cost model application

approach[2,7]. A cost centre can be defined as a productive area of a company (such as a division, department or unit) in which costs can be allocated. In fact, during the real production monitored by Smart ProdACTIVE, the unforeseen events (such as damages of equipment or production wastes) can negatively affect production costs with a consequent decrease of the production margin (phase of monitoring of final costs).

The Smart ProdACTIVE platform predicts the quality, energy and cost of the injection process in real-time, covering 100% of products, and suggests the appropriate reactions to adjust the process set-up and/or mechanism. The client-server connection works in combination with the real time monitoring system (the intelligent sensor network) to elaborate instantaneously the production data set with respect to quality/energy/cost prognosis.

The industrial demonstration projects validate the following potential benefits in best case scenario:

• 40% reduction in scrap rate for the involved HPDC foundry.

• Up to 40% decrease in the cost of quality control.

• 5-10% reduction in energy consumption, due to scrap reduction and increased production efficiency.

• Better knowledge and control of the process, resulting in time to market reduction and minimisation of trial and error approaches.

CONCLUSION

The foundry leadership integrating competences, products and services along the casting supply chain to support the innovation and knowledge transfer based on the twenty years of experience and synergy between university and industry[5-6] is more and more strategic. The foundry digital transformation is essential for the competitiveness, excellence, sustainability and profit. In agreement with the strategy of smart manufacturing, intelligent process data management, automation and artificial intelligence are connecting the real world with the virtual one.

The application of Smart ProdACTIVE has been demonstrated and validated at a foundry[1,2]. In the frame of the HPDC production process, operator and process manager take advantage by adopting a centralised remote control system supporting process monitoring and quality prediction in real time. The decision is supported by cause-effect correlations, and proper reactions suggested by a continuously updated meta-model.

The energy consumption connected to the production rate, the cycle time optimisation (more pieces per hour) and the improved management of energydemanding devices (furnace, thermo units, etc.) lead to cost reduction[7,8].

The extension of application to further multi-stages and multi-disciplinary production lines (e.g. sheet metal forming, forging, rolling, thermoforming, machining, welding, trimming, or the innovative additive manufacturing) is planned to exploit the same methodology in different industrial contexts. This activity will strongly involve SINFONET, the Innovative Foundry Network recently approved by Regione Veneto.

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Optimisation and automation of chemical control of alloys in smart Foundry 4.0

Alberto Montenegro Correa, David Casasnovas González – AMV Soluciones, Spain

INTRODUCTION

Optimisation of the casting process, whether for ferrous or non-ferrous materials, is determined by different factors that, as well as affecting the production costs and the quality of the alloy produced, directly influence the levels of rejected castings and are decisive in process efficiency and company competitiveness.

Chemistry is one of the key factors when it comes to achieving high quality castings. That's why the following points are a must for any foundry or melt shop that aspires to be competitive and ahead of the market:

1. Improve the chemical control of the alloys, achieving composition increasingly stable, according to the desired physical and mechanical properties.

2. Do it in the most efficient way possible by:

   (a) Optimising the use of raw material inventory, obtaining the necessary qualities at the least possible cost.

   (b) Minimising the number of steps necessary to achieve the desired chemistry, with the consequent reduction in energy and processing time.

3. Avoid human errors in the input of the different parameters that will determine the final chemistry of the casting.

4. Have complete traceability of the process and learn from data history to continuously improve results.

5. Combine all these factors in a reliable system that guarantees to the customer that their orders will be produced with maximum quality, optimising costs, minimising time and eliminating rejections.

How can we maintain control of such important points? Here are some important measures that need to be taken to achieve this:

1. Calculate furnace charges and adjustments using mathematical algorithms that guarantee the results are free of errors, considering chemistry, recovery, melting losses and material costs, ensuring accurate chemical results at minimum cost.

2. Integrating the different measurement and analysis devices (scales, spectrometers, thermal analysis systems, etc.), so that their results are automatically incorporated in the system, showing alarms if necessary and carrying out the following calculations based on those results:

   (a) Furnace adjustments, if required.

   (b) Ladle additions.

   (c) Applying linear regression techniques and, in general, big data analysis of the casting history and refining the input parameters from them, so that the actual chemical results are closer and closer to those calculated by the system.

Those techniques, which AMV has recently started to apply in several foundries of different countries, form the basis of the case study AMV is presenting together with United Cast Bar (UCB) – Chesterfield (UK), a worldclass producer of continuous cast iron bars, both in grey and ductile iron.

The study was conducted based on cumulative production results over eight months.

Mathematical model

For each chemical element, AMV used a multiple linear regression model:

$$Y = \beta_1 X_1 + \cdots + \beta_n X_n$$

Where:

• Vector **Y** represents the actual amount of the element, obtained by Fig.1 ALEA system implementation scheme multiplying the amount of liquid metal of the different heats by the chemical proportion read from the spectrometer (one component per heat).

• Vectors $\mathbf{X}_j$ represent the actual charged amounts of the raw material **j**, one component per heat, one vector per raw material in inventory.

• β_j refers to the parameters to be estimated, and represents the effective proportion of the chemical element in the material **j**.

• Assumptions made and calculations:

• Normal distribution of **Y**:

$$Y_i \in N(\Sigma^n_{j=1} \beta_j X^j_i, \sigma 2)\ i = 1, \ldots, m.$$

• Sample size greater than number of raw materials (m > n).

• $\beta_0 = 0$ (no amount of chemical element with no charged materials).

• Estimation of β_j using Least Squares Regression:

$$\hat{\beta} = [X'X]^{-1}X'Y$$

with distribution

$$\hat{\beta}_{i'} \in N(\beta, \sigma^2 q_{i,i})$$

where $q_{i,i}$ is the corresponding diagonal element of $[X'X]^{-1}$.

• Confidence Intervals:

$$CI_{1-a}(\beta_i) = [\hat{\beta}_i \pm t_{a/2,(m-n)} S_R \sqrt{q_{i,i}}]$$

CASE STUDY: United Cast Bar – Chesterfield: 'Right-First-Time Project'

United Cast Bar (UCB) produces cast iron bars in different qualities (ductile and grey) using the continuous casting process. UCB uses eight-ton induction melting furnaces and depending on the diameter, shape and length of the bars, several heats can be required for producing the same bar. Therefore, chemical consistency is critical to secure bars with stable composition throughout the length. Before starting this case, around 72% of heats required at least one chemical adjustment. The main goal for UCB was achieving a continuous progressive reduction of chemical adjustments and the improvement of chemical consistency. That's why they referred to this case from the very beginning as the *'Right-First-Time'* project.

The study was carried out through the implementation of the linear programming based system ALEA. The following describes how the system is being used:

The ALEA system was implemented in a local server of UCB, with PC terminals in different areas of the plant, including laboratory, crane cabin and furnace platforms. The system is used by the laboratory supervisors to calculate furnace charges and chemical adjustments.

The system works integrated with (fig.1):

(a) Spectrometer: chemical analysis can be imported into the system in real time and stored together with the heat number. If the heat is out of spec, ALEA calculates the optimal adjustment considering the genuine chemistry.

(b) Scales: one crane scale and two manual scales at the corresponding furnace platforms.

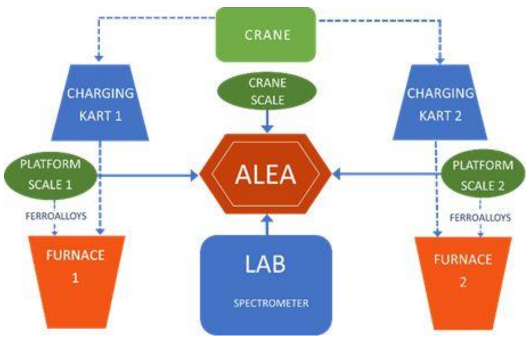

Fig.1 ALEA system implementation scheme

The operator reads on the ALEA screen the different materials to be charged, including amount and charging order. The system reads the charged weight from the scales and warns when it is within the admissible limits. The operator does not type any quantity but validates the actual values by pressing an industrial button under the screen when the system asks for confirmation.

Based on the chemical results of the heats prepared during the first week under the conditions described, a first review of the chemical composition of the raw materials was made, the C, Si, Mn, Cu and Cr content of scrap and returns. Also, the ranges of those elements used by ALEA for charge calculation were slightly narrowed.

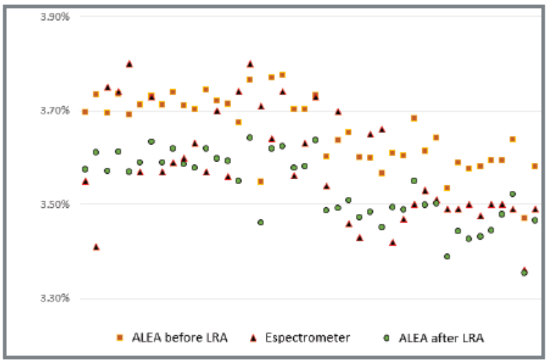

Fig.2. C% previous LRA / actual / after LRA

MATERIAL	Element	Previous %	CI 99%	Change to...
Pig Iron	C	4.30%	[4.04%, 4.23%]	**4.25%**

Table 1 CI and change for %C in pig iron 1

MATERIAL	Previous recovery	CI 99%	Change to...
Premium Graphite	88%	[74.51%, 84.10%]	**84.50%**

Table 2 CI and change for graphite recovery

Relative error: ALEA expected / spectrometer analysis		
	Carbon	Silicon
Before LRSA	2.52%	4.99%
After LRSA	1.12%	1.46%

Table 3 Relative error before and after LRSA

HEATS PER YEAR	5,000
AVERAGE EXTRA TIME PER ADJUSTMENT (min)	11
FURNACE POWER (kWatt)	3,500
ENERGY COST (£/kWh)	0.085

Table 4 Production parameters

After 30 days working under the above conditions, around 50% reduction in the number of melts requiring adjustment was observed, as well as a higher consistency of chemical analysis, with increasingly narrower chemical variation bands.

By the end of 2017, the heats requiring adjustment decreased from 72% to 36%. From January 2018 to June 2018 (included), the average value was 31%, with around 1% of heats requiring two corrections. At the end of June 2018, downloading the actual charge weights and chemistries of the last 504 heats, a linear regression and statistical analysis (LRSA) on that data was performed by AMV, with the aim of estimating actual recovery per chemical element and raw material (see previous section entitled mathematical model).

LRSA provided 99% confidence intervals (CI) for the effective proportion of each chemical element per raw material (including scrap, returns, pig iron and ferroalloys). For this case, only those with current values out of their CI were selected as candidates. For pure materials (ex. graphite), values were analysed in terms of global material recovery, for the rest, recovery is analysed by chemical element. Examples showing the proposed change for %C in pig iron and recovery of graphite can be seen in Tables 1 and 2.

Applying those changes (at test level), the new expected chemistry of 504 sample heats was calculated. A comparison between the chemistry expected by ALEA before and after applying the changes in the regression model, along with the values analysed with the spectrometer (silicon and carbon) are shown in fig.2 and Table 3. It can be observed that the new values predicted by ALEA are much closer to the real ones (read from spectrometer) than those anticipated before applying LRSA.

Results of LRSA were presented in UCB – Chesterfield in mid-July 2018 with proposed changes. Changes were approved by UCB and implemented in ALEA production environment, to start to be applied on 1st August 2018. Production results were collected and analysed on 31st August and 15th September 2018.

RESULTS

After 30 and 45 days of production applying the new chemical values obtained from LRSA, the number of heats requiring adjustment was measured, with very significant improvements – it decreased from an average value of 31% to 24.5% at the end of August and to 20.7% by mid-

September 2018. Even more significant: during the full period (45 days) there was not a single heat requiring a second adjustment. Figs.3, 4 and 5 present the evolution, highlighting two milestones:

• Before / after implementation of ALEA system (red line).

• Before / after recalibrating the system with LRSA results (green line).

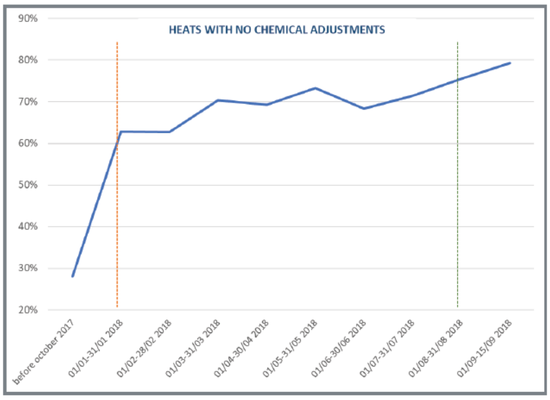

Fig.3. Heats % evolution with no adjustments

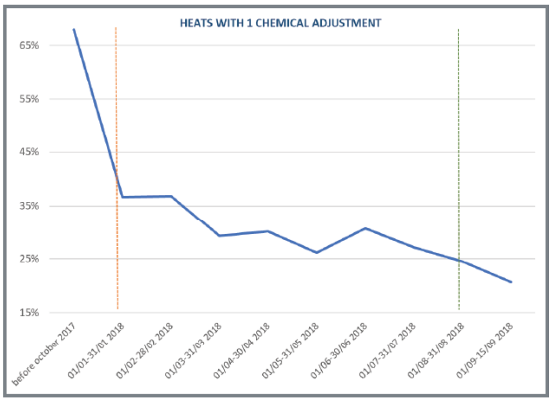

Fig.4. Heats % evolution with 1 adjustment

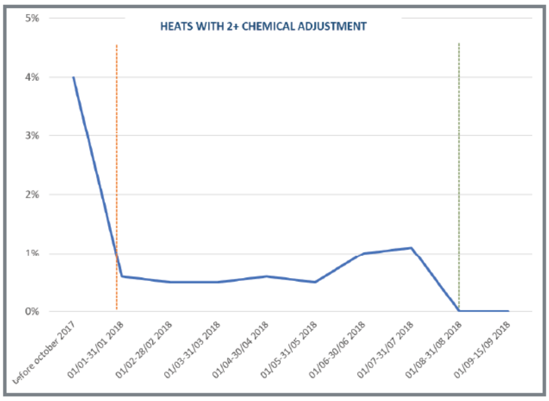

Fig.5. Heats % evolution with 2+ adjustments

COST AND PRODUCTIVITY IMPACT

To analyse the impact on energy savings and increase of productivity, production parameters were considered (currency: pound sterling), see Table 4.

Applied to results exposed in the previous section, the total melting time was reduced by 458 hours per year (376 hours as effect of system implementation and 83 hours because of applying LRSA), which represents a productivity increase of around 6.4% (4.2% ALEA implementation / 1.2% LRSA), see Table 5.

Energy savings, extrapolated to an entire year, are around 1.6 million kWh, which represents a cost reduction of more than £130,000 per year. Details are presented in Table 6.

CONCLUSIONS

To minimise the number of required heat adjustments, increase chemical consistency of the castings and reduce melting process time, the following points are critical:

1. The usage of a linear programming based system to calculate and optimise charges and chemical corrections, capable of setting recoveries per chemical element, raw material, furnace and process.

2. The integration of measurement tools (scales, spectrometers, thermal analysis…) to avoid human factor when entering actual values (charged weights, actual chemistries…).

3. The capability of the system to store actual chemistries linked to actual charged weights, including intermediate states (furnace heel + first charge + first analysis…).

4. The application of points 1, 2, 3 may reduce the need of adjustments in the order of 50%, also increasing chemical stability.

5. The periodic application of linear regression techniques and statistical analysis to last heat results is essential to maintain the updates of the actual recoveries of chemical elements per material, furnace and process, with the subsequent positive impact in chemical results.

No ADJUSTMENTS / No HEATS			TIME REDUCTION (hours / year)
0. BEFORE SYSTEM IMPLEMENTATION	72%		
1. AFTER SYSTEM IMPLEMENTATION (NO LRA)	31%	↓ 41%	376
2. AFTER SYSTEM IMPLEMENTATION + LRA	22%	↓ 9%	83
	TOTALS	↓ 50%	458

No ADJUSTMENTS / No HEATS			ENERGY REDUCTION (kWh / year)	ENERGY SAVINGS (£ / year)
0. BEFORE SYSTEM IMPLEMENTATION	72%			
1. AFTER SYSTEM IMPLEMENTATION (NO LRA)	31%	↓ 41%	1,315,417	111,810
2. AFTER SYSTEM IMPLEMENTATION + LRA	22%	↓ 9%	288,750	24,544
	TOTALS	↓ 50%	1,604,167	136,354

(Up) Table 5 Melting time reduction *(Below) Table 6 Energy savings and cost reduction*

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AUTHOR CONTACT

Alberto Montenegro Correa and David Casasnovas González, AMV Soluciones, Av. Madrid 40 36214 Vigo, Spain, email: alberto@amvsoluciones.com
david@amvsoluciones.com

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73rd WFC Paper publication

The Proceedings from the 73rd World Foundry Congress are available at:
http://www.thewfo.com/contentfiles/pdfs/160.pdf

After the Congress, the authors were encouraged to expand the two-page versions to become full-length papers and submit them directly to one of five journals listed below. More details about which 73rd WFC extended papers were published is available at the various journal's websites:

*1) **IJMC**: International Journal of Metalcasting – This is a publication of the American Foundry Society and The Official Research Journal of the World Foundry Organization*

https://link.springer.com/journal/volumesAndIssues/40962

*2) **FTJ**: Foundry Trade Journal - an international magazine for the global cast metals industry.*

http://www.foundrytradejournal.com/

*3) **JMEP**: Journal of Materials Engineering and Performance - This is a publication of ASM International, The Materials Information Society.*

http://www.springer.com/materials/characterization+%26+evaluation/journal/11665

*4) **AMM:** Archives of Metallurgy and Materials – The Journal of Institute of Metallurgy and Materials Science and Committee on Metallurgy of Polish Academy of Sciences*

https://www.degruyter.com/view/j/amm

*5) **AFE**: Archives of Foundry Engineering - Official journal of Polish Academy of Sciences, Foundry Commission*

https://www.degruyter.com/view/j/afe

*6) **JCME:** Journal of Casting & Materials Engineering - -Published as a quarterly in the open access system by the AGH University of Science and Technology in Kraków.*

https://journals.agh.edu.pl/jcme

FINAL REMARKS

The World Foundry Organization publishes and disseminates the Global Foundry Report on a yearly basis, providing a complete overview of the worldwide scenario linked to the casting industry.

The drafting of the WFO Global Foundry Report 2020 counts with the collaboration of 27 WFO Member Countries with the compilation and design work from the WFO Secretariat Team

All information contained in the WFO Global Foundry Report 2020 is provided by its Member Associations and relies on the cooperation compromise from all the involved parts.

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Save the dates

WFO World Foundry Summit

"CEOs Reshaping the Foundry Industry"

New date to be announced

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WFO 74th World Foundry Congress

"CAST THE FUTURE" October 16th-20th 2022

Bexco, Busan, Korea

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Contact details:

General Secretary: **Eur Ing Andrew Turner**

Offices: **Winton House, Lyonshall, Kington HR5 3JP United Kingdom**

Telephone: **+ 44 1544 340332**

Email: **andrew@thewfo.com**

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