SFSA CASTEEL REPORTER

Steel Founders' Society of America

a publication serving SFSA steel casting industry members

780 McArdle Drive Unit G, Crystal Lake IL 60014
Tel: 815-455-8240 Fax: 815-455-8241
http://www.sfsa.org

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Casteel Commentary

Where are we going to find the workers we need? Well, they don't exist, we stopped having enough children to supply our businesses. So, the Casteel Commentary shows that advanced manufacturing, especially automation is not just an option for improving our operation, it is a critical task to remain viable and prosperous.

Next Generation Manufacturing and Future Leaders Meeting

Please save the date for the second Next Generation Manufacturing (NGM) meeting, which will be held in Jonesboro, AR on November 12-13 and include a tour of Southern Cast Products. This meeting will be coupled again with a meeting for our Future Leaders Group (these attendees should plan to arrive on 11/11). Future Leaders will participate in a roundtable and a "what needs to go right to make a good casting" brainstorming event. The results of the brainstorming event will be used to kick-off the NGM meeting with a strategic planning session on Industry 4.0 technology for the job shop environment of a steel foundry. The NGM meeting will feature presentations by Jerry Thiel from UNI along with Doug Imrie from SCP. The tour of SCP will demonstrate the use of NGM technology through Robo Molding, printing sand, and the development of Robo-assisted manufacturing. Additional details for these meetings will be provided in the near future.

National Technical & Operating Conference

Make your plans now to attend the 2019 T&O in Chicago on December 11-14. The conference is the world's only event on steel casting technical and operating papers, mostly by fellow SFSA members. This year's conference will feature a session with topics related to Next Generation Manufacturing, pouring & gating innovations, and a continued discussion on remaining with silica sand along with lessons learned in ceramic sand. The workshop will feature two fundamental pouring & gating presentations by University of Iowa and University of Northern Iowa. One on filling effects based on rigging changes, and one on applying naturally pressurized gating practices. In addition, University of Alabama at Birmingham will provide a hands-on casting analysis activity that will help foundries perform their own assessments. A draft program and registration link will be made available soon.

SFSA Safety Awards

The steel foundry industry's safety record has improved significantly in recent years and SFSA would like to recognize members that have contributed to this ongoing improvement.

It is time to participate in our Safety Award Program! To be eligible for safety awards, participants must report a safety record DART for 2018 that is equal to or less than 2. This is the composite average for all manufacturing industries. We will be awarding "Perfect" and "Outstanding" awards. The formula used is as follows:

Days Away from work, Restricted, or job Transferred (DART) rate: This includes cases involving days away from work, restricted work activity, and transfers to another job. It is calculated based on (N / EH) x (200,000) where N is the number of cases involving days away, and/or restricted work activity, and/or job transfer; EH is the total number of hours worked by all employees during the calendar year; and 200,000 is the base number of hours worked for 100 full-time equivalent employees.

For example: Employees of an establishment including management, temporary, and leased workers worked 645,089 hours at this worksite. There were 22 injury and illness cases involving days away and/or restricted work activity and/or job transfer from the OSHA 300 Log (total of column H plus column I). The DART rate would be (22 / 645,089) x (200,000) = 6.8.

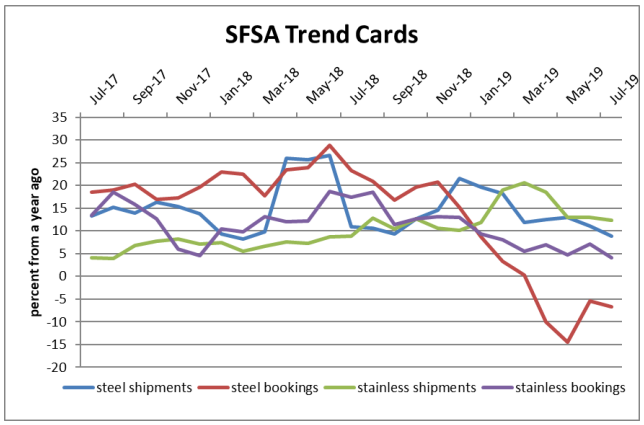
Remember, this is the previous year's data - 2018. You do not need to sign up for this program, you need only to fill out the application (https://www.sfsa.org/safety/) and return it to SFSA no later than October 15, 2019 to be eligible for a safety award. Member companies achieving a safety record less than or equal to 2 will receive a certificate; companies achieving a perfect record will receive a plaque. Safety awards will be presented at the SFSA T&O Conference in December.

Cast in Steel

After the success of the first ever Cast in Steel Competition, SFSA is pleased to announce the second Cast in Steel Competition for school year 2019-2020. This year's challenge is to cast a Bowie knife. Same as last year's, each team will work with a foundry partner. We plan to hold the testing and evaluation at the AFS Metalcasting Congress in Cleveland, OH on April 21-23, 2020. More information are available on https://www.sfsa.org/castinsteel

Market News

While business remains stable, some signs of slowing are clear. Our trends graph shown shows slowing rates of bookings and shipments with steel bookings falling below levels of a year ago. Backlogs for stainless steel castings remain stable at 10 weeks while steel casting backlogs have fallen below 10 weeks. This is still a relatively strong level.



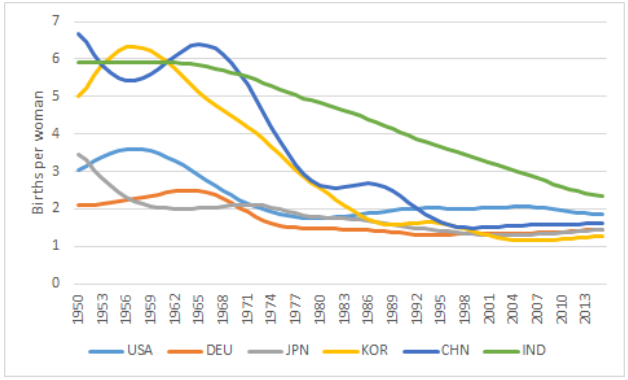
In the weekly reports posted each week, steel production and pricing have fallen over the past 6 months. Copper prices have also dropped and oil prices are lower and bouncing around. Commerce reports on iron and steel mill and casting shipments have dropped slightly.

New orders for Capital Goods are down slightly and shipments are increasing slowly.

The SFSA forecast presented at the Fall Leadership Meeting is here: https://www.sfsa.org/news/2019/2020%20SFSA%20Market%20Forecast.pdf. It anticipates a relatively flat market at least for the first half of 2020.

Casteel Commentary

Where are my needed workers? Why can't I staff up with good and talented people to meet my needs?



Many reasons are given for why we cannot find the people we need to work in our plants. We have not encouraged or trained young people to work. We have not taught the value and satisfaction of work. We are prosperous and young people do not feel the need to work. Parents indulge and support their kids without requiring that they work. We believe that manufacturing and ordinary work is not creative or rewarding. We think that any job that does not require college education is not able to pay enough to afford a good life. We encourage young people to find their passion rather than to use their energy and abilities to help others by doing valuable things in service. Business is good and unemployment is low so everyone that wants to work has already found work.

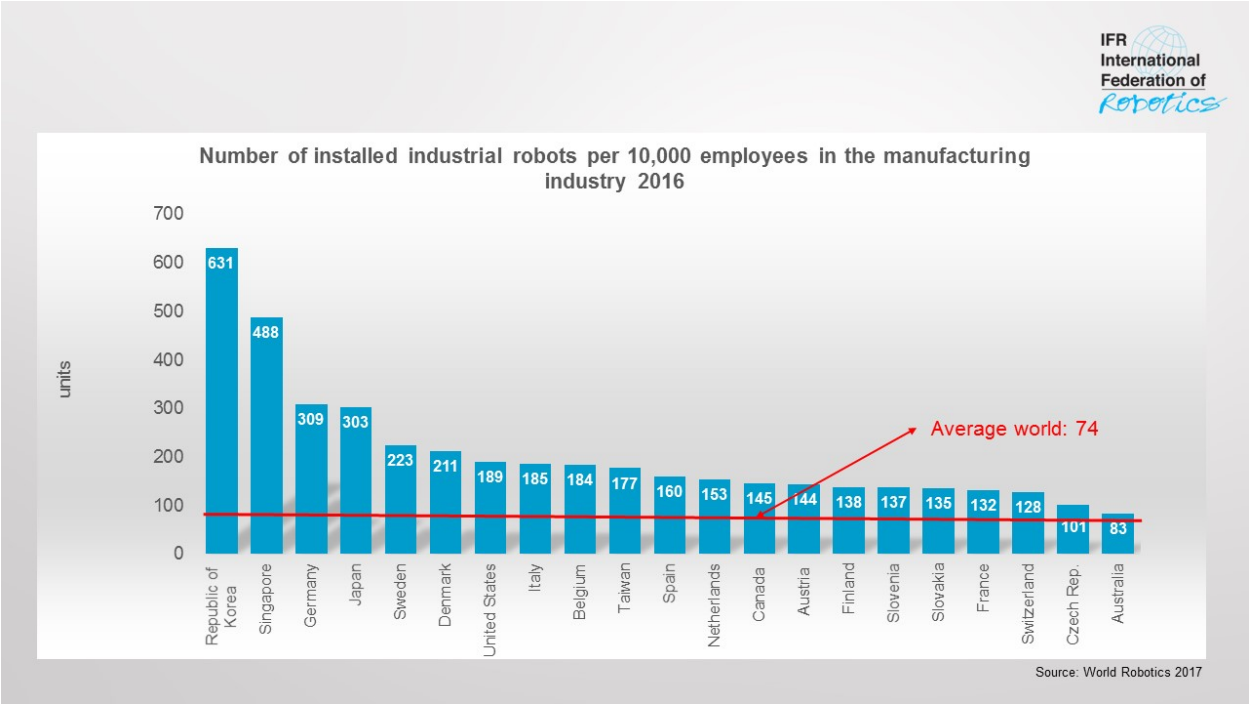
But…

We have other demographic and societal conditions that add to this problem and suggest that we will need to find ways to reduce the labor requirement in steel casting production.

One overlooked fact is that the industrialized, developed economies have had a dramatic but unappreciated shift, which is we no longer have as many children. For a population to be stable, the average number of children per woman in her life time has to be 2.1. Since some women do not have children for medical or other reasons, many families must have 3 children to get that result. Since the

development of modern birth control, the number of children per woman has fallen dramatically. Many women would want more, not fewer children but culturally and economically this is not possible. Our most industrialized competitors; Germany, Japan, South Korea and even China like us are at birth rates below replacement. (https://ourworldindata.org/fertility-rate) India is still growing but their rate is falling rapidly.

I have proposed for years that Japan's success at automation is not the result of clever business practices or cultural habits but is largely due to the lack of children. This seems to be substantiated by the following graph, the highest rate of robotic installations are in these type economies with South Korea, Germany and Japan as three of the top four adopters.



To remain viable in steel casting production in North America, we are going to need to automate. We have to reduce the human labor content of our product to remain viable. Of course, we must continue to develop new workers and improve worker skills, but we also must find equipment and methods that reduce the number and change the kind of workers we need.

Historically we depended on new immigrants to staff our plants but this drop in fertility is global. Even at high rates of immigration, we are unlikely to gain enough workers for business as usual.

Also, we need to be creative at finding the minority of people who would enjoy and excel at the craft of steel casting production. Through unusual alliances with local maker spaces, metal working crafters, scout merit badge programs and community involvement, we can hope to reach those who like us would find satisfaction in the creative work of casting production.

But…

Even with our best efforts, automation is a requirement. For this reason, SFSA has initiated an advanced manufacturing group to develop and guide our efforts in this area.

Raymond

STEEL FOUNDERS' SOCIETY OF AMERICA
BUSINESS REPORT

SFSA Trend Cards (%-12 mos. Ago)	12 Mo Avg	3 Mo Avg	July	June	May
Carbon & Low Alloy					
Shipments	13.4	8.8	10.0	4.0	12.5
Bookings	4.5	-0.5	12.0	0.0	-13.5
Backlog (wks)	9.8	9.2	8.5	9.0	10.0
High Alloy					
Shipments	13.9	12.4	12.1	10.0	15.0
Bookings	8.3	4.2	-0.5	10.0	3.0
Backlog (wks)	10.1	10.4	9.8	9.9	11.4
Department of Commerce Census Data					
Iron & Steel Foundries (million $)					
Shipments	1,460.2	1,490.3	1,484	1,470	1,517
New Orders	1,473.3	1,465.7	1,467	1,469	1,461
Inventories	2,110.8	2,163.0	2,130	2,165	2,194
Nondefense Capital Goods (billion $)					
Shipments	77.7	75.7	74.5	76.7	76.0
New Orders	75.9	72.3	75.8	72.2	68.8
Inventories	183.9	189.2	190.6	189.2	188.0
Nondefense Capital Goods less Aircraft (billion $)					
Shipments	69.3	69.8	69.5	69.9	69.9
New Orders	69.2	69.3	69.6	69.4	68.8
Inventories	127.8	129.6	130.0	129.5	129.2
Inventory/Orders	1.8	1.9	1.87	1.87	1.88
Inventory/Shipments	0.0	1.9	1.87	1.85	1.85
Orders/Shipments	0.0	1.0	1.00	0.99	0.98
American Iron and Steel Institute					
Raw Steel Shipments (million net tons)	8.0	8.0	8.1	7.7	8.1

Research Review Recap

The annual SFSA Research Review meeting was held on July 16-18 in Chicago. SFSA has several R&D projects, most funded sponsored under the Digital Innovative Design program.

Iowa State University (ISU) [D. Eisenmann] is evaluating the effect of surface roughness on the reliability of Magnetic Particle Inspection. Test castings with different levels of surface roughness were inspected per ASTM E1444. The effect of indication size was evaluated by drilling subsurface holes with different diameter and depth. The depth of the indications seems to have a bigger effect on the noise of the data compared to the surface roughness and diameter of indication. ISU will visit selected member foundries to conduct further investigation on actual castings.

ISU [F. Peters] is investigating the effect of surface roughness on fatigue performance. In collaboration with Eagle Alloys, cast plates were designed with minimal centerline shrinkage and allows sectioning of test specimens with as-cast surfaces. The surface roughness of the WCB cast plates were varied. There is another set of specimens to be tested that were designed to have subsurface indications. These tests aim to confirm the hypothesis that fatigue is controlled by the largest feature (surface roughness of the casting does not matter).

ISU is also working on Next Generation Manufacturing technologies such as automated grinding in job shop foundries. Several issues such as fixturing, determining abnormalities and desired surface, and commercially available robot systems need to be further investigated.

University of Arizona (UA) [R. Fleischmann] is conducting structural testing of specimens with surface and subsurface indications. UA collaborated with University of Iowa (UI) in designing test castings with different levels of quality factors such as porosity and inclusions. The 1st casting only had surface indications and no internal indications. Tensile test specimens were extracted to include these surface indications. Specimens with machined indications were also tested along with sound specimens. Another set of castings were made that had different levels of subsurface indications. Results from these tests showed that fracture occurs at the smallest cross section area, which is not always where an indication is. The tensile testing of the specimens with and without indications were modeled. These modeling results are being used to developed a ductile fracture index to relate the presence of indications to the performance of the steel.

UA will also be conducting structural tests on castings welded to hollow structural steel tubes to show how cast structural components would perform.

University of Iowa (UI) [C. Beckermann] is analyzing data provided by member foundries to develop a lower bound design allowable. The MMPDS approach which sets an A (1st percentile) and B (10th percentile) design allowable is being used in this analysis. In plotting member heat data using a normal distribution and a Weibull distribution, there seems to be a compliance bias in the data. There are a lot of data points right around the minimum property required by the specification, although this could also just be due to human errors when the data were entered to the database. In the plots, outliers were also identified based on the standard deviation (data outside 3 sigma can be considered an outlier). It seems like that analyses like this is the path to pursue in evaluating all data that will be acquired under DID.

UI, along with UAB and MS&T, are also investigating naturally pressurized gating systems for investment castings.

Lehigh University [J. DuPont] is evaluating production welding and fabrication welding of carbon and low alloy steels. Cast plates were welded to mill plates to investigate cast-to-cast, cast-to-mill, and mill-to-mill welds. The cast alloys were WCB and 8630. Various tests and microstructural analysis per ASTM A488, ASME BPVC Section IX, and AWS D1.1 were done. Preliminary results for WCB showed that it has similar properties to a comparable mill grade (A516 grade 70).

Lehigh is also developing welding practice for FeMnAl using commercial filler materials. The alloy does not seem to be sensitive to welding heat input. Direct aging of the weld (i.e. without re-solutionizing) seems to recover the hardness.

Pennsylvania State University (PSU) [B. Voigt] is developing a cast carbon steel grade with a minimum yield strength of 50ksi with carbon equivalent that would match mill steel specifications. The typical level of other alloying elements such as %Cr, %Ni, %Mo was estimated by analyzing the heat data provided by members and a range of %C, %Mn, %V were investigated. Tensile test results confirmed

that 50ksi YS minimum is achievable in cast carbon steels. SFSA will be continuing the work with AWS D1.1 and possibly draft a new ASTM grade that the building construction industry can use.

University of Alabama at Birmingham (UAB) [C. Monroe, R. Foley, J. Griffin] is supporting several of the DID projects by providing microstructural characterization of specimens. AF96 that was melted in an acid based EAF and vacuum degassed exhibited higher yield strength compared to other AF96 data. Max pore cluster size on the fracture surface still seem to have the best correlation with ductility. Ductility of drag samples, with or without chills, had greater than 10%El which was surprisingly high considering the inconsistencies with historical cast AF96 data.

UAB also gave updates of their cast preforms project. Forging ratio of 1.5 closed up the porosity in GET. Forging improved the consistency of tensile and yield strength values. There were some forged specimens that had low ductility. It is speculated that it may be due to sulfides. For AF96, there was no difference in ductility in between reduction ratio of 1.5/1 vs 2/1 although the max pore cluster size decreased. Forged AF96 specimens achieved higher ductility compared to HIP AF96 wedges that were produced under another program. There were no significant differences in tensile properties between cast and forged HY80. Forging did improve the CVN impact toughness particularly for forging ratios 2/1 and 3/1. There seems to be an opportunity for achieving properties similar to forgings even with minimal forging of these alloys. Further investigation on how this project can be implemented to the industry still needs to be done.

UAB is also looking into design allowables by reviewing standards such as the BPVC and understanding how the maximum stress allowables are set by the code. They are conducting a static structural analysis to determine how indication size affect failure and what the critical size of indication is in common steel casting alloys.

Missouri University of Science & Technology (MS&T) [L. Bartlett] is optimizing rolled and cast FeMnAl to improve properties. Results to date show that this alloy can meet the required hardness in high hard armor applications. The use of Nb and V as precipitation strengthening elements will be looked into. Minimizing the ferrite stringers and ferrite on grain boundaries is needed to get good toughness.

MS&T also presented on grain refinement in austenitic stainless steels. It was found that grain refinement in these alloys can be achieved by in-situ formation of TiN-spinel ($MgAl_2O_4$) or by adding a master alloy containing preformed TiN. Grain refinement seemed to minimize segregation of Mo, Cr, Ni. It also reduced the variation in mechanical properties and CVN impact toughness. Grain refined specimens exhibited decreased pitting corrosion resistance but improved intergranular corrosion resistance.

Cal Poly Pomona [D. Hindayani] has just started investigating turning of FeMnAl. The objective of the project is to develop a best practice to reduce machining cost and time of this alloy. A DOE with 5 variables will be done: rake angle, type of coolant, cutting speed, feed rate, and depth of cut.

Research projects funded under the Innovative Casting Technologies (ICT) program were also presented at the Review.

ISU [F. Peters] is continuing their work on developing a quantitative visual inspection. Comparator plates (GAR C-9 and SCRATA) were scanned and using the variogram method, a surface roughness value was calculated. It was shown that the method can differentiate between the different levels of the comparator plates. Gage R&R was also done and it was 13%. ISU will also visit member foundries and inspect actual castings using this method. The surface roughness outputted by the method will be compared to the surface roughness determined by the operator using the comparator plates.

University of Iowa (UI) [C. Beckermann] gave the recent results of their air entrainment project. Most of the experimental trials to date were on water and on molten aluminum. It was found that the air entrainment ratios for water are the same when pouring in air and in argon atmosphere. For aluminum, air entrainment was higher in an argon atmosphere compared to pouring in air. This difference is assumed to be due to the oxide skin layer that form around the pouring stream. The critical velocity (velocity above which air entrainment occurs) was found to be around 2.17 m/s which is different from what has been reported in the literature (0.5-1.0 m/s). An initial trial with molten steel was done. At the same nozzle height, air entrainment ratio for WCB poured in air is similar to aluminum poured in an argon atmosphere. Additional trials on molten steel will be done.

Lehigh is investigating how the properties of austenitic stainless steels (mainly heat resistant grades) are controlled by the composition and section thickness. They conducted a microstructural modeling to understand how composition affects the type and amount of carbides that form in these alloys. A neural network regression model is being developed that can predict the phases within the ASTM ranges of heat resistant alloy HP. Test wedges were also cast with varying levels of alloying elements (C, Nb, Si, Ti) in HP. Member foundries also provided HP material for Lehigh to cut up and characterize. Lehigh will evaluate the carbides for these castings with different compositions. Lehigh will also conduct weldability studies for these alloys to understand their cracking susceptibility and how foundries can minimize it.

UAB is developing a should-cost modeling tool that categorizes the complexity of a part based on features such as risers, parting line, undercuts. Considering the complexity of the part and additional order info such as quantity, NDT requirements, etc., the tool estimates a should-cost of producing the part. UAB has also developed an orientation-optimization tool that can be useful in identifying how to better orient a part. The tool evaluates different orientation by analyzing design parameters such as core count, riser contact surface area, riser inaccessibility, etc.

MS&T is continuing their work on intensive quenching of steel castings. 4320 and 4350 C-ring castings will be produced and will be intensively quenched at MS&T. These alloys are prone to quench cracking and the geometry of the C-ring allows for the quantification of the distortion.

University of Northern Iowa (UNI) [J. Thiel] showed the results of the additive manufacturing survey that they conducted with foundries. 78% of the respondents indicated their usage of additive manufacturing and they expect to use the technology in the next 5 years. The main limitations of additive manufacturing in some foundries implementing it are: high cost, lack of expertise or engineering resources, and uncertainty of quality (lack of specifications).

Other steel casting related research was also discussed at the meeting.

PSU (P. Lynch) presented his research on carbide formation in AF96. It was found that temperature is the main factor in the transition of epsilon carbides to cementite at tempering range of 350F to 550F. Silicon plays an important role in alloys like this that is processed with Stage I Tempering. Si seems to restrict carbide growth during tempering particularly at 550F.

PSU is also doing a machinability study on AF96. The goals of the project is to develop cutting methods that maximizes material removal rate, minimize work hardening, and maximize cutting tool life. Previous trials on a manual lathe with no/little coolant showed an increase in hardness (up to 11HRC) after 1 pass of the tool. PSU is conducting a more extensive trials with cutting speed, feed rate, and depth of cut as variables. Preliminary results showed tool insert flank wear increases with more aggressive cutting conditions.

UAB [W. Monroe] is continuing their development of a semi-automated image analysis for digital radiographs. Deep learning, which is a subset of machine learning, is being used to train the code in identifying indications in a digitized x-ray film. More x-rays still need to be analyzed to further refine the code.

UNI presented the research they are doing to improve their robotic mold machining capability. The feed rate and cutting speed were varied and it was found that carbide has better wear resistance than high-speed steel (HSS). The main tool wear mechanism is abrasive wear on the flank wedge. Future work includes identifying the tool wear limit of carbide tools and looking into different machining parameters for HSS tools.

UNI [S. Giese] has a project with University of Maryland, George Washington University, and NAVSEA to understand dross (oxide) formation in nickel aluminum bronze. Their goal is to develop a systematic physics-based design tool to predict dross formation.