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

August — 2018

Casteel Commentary

This month's Casteel Commentary is a review of the tariff actions of the US and then possible effects in the steel casting market. The 232 tariffs are not including steel castings. The 301 actions do include steel casting categories and are specific actions to address trade with China. Let me know if you need additional information or have questions.

Fall Leadership Meeting

There is still time to register to attend the SFSA Fall Leadership Meeting, September 8-11 at the 21c Museum Hotel in Nashville, TN. SFSA is pleased to offer another great program for members with a solid lineup of presenters that you will find informative and well worth the investment to attend. Moreover, this meeting looks to be well attended and with the social functions and optional activities, there will be plenty of networking opportunity with your industry peers. Meeting agenda, hotel, and group activities registration are available online here: https://sfsa.site-ym.com/events/EventDetails.aspx?id=1111522. Please note that the room block cutoff is **August 17th at 5 pm**. There is a $500 registration discount after 1st full registration rate for members attending from the same company. If multiple attendees are registering separately, they will need to use the discount code: ***2ndRegFLM*** after the first full registration.

Subject Matter Focus Meeting: Quenching

Our next subject-focused meeting will be on Quenching and held near Vancouver, Canada on September 18. Quenching, or the rapid cooling of a steel casting, can be part of the heat treatment process to prevent undesirable phase transformation, or as a means to harden the steel or drive desired mechanical properties. In support of the Heavy Section Product Group, the meeting will focus on quench tank design and modeling of the quenching process (with presentations from Dante and Airflow Sciences) - presentations and discussions will be relevant to all section sizes.

Meeting and Hotel Registration Information: https://sfsa.site-ym.com/event/quenching

The meeting and a tour of Highland Foundry will both be held on Tuesday the 18th; thus, attendees should plan to arrive on Monday and stay the whole day on Tuesday (Highland is providing transportation to the foundry along with lunch). There is no cost for the meeting - travel, hotel, meals, etc. are the attendees' responsibility. Please bring your own safety shoes for the tour. Attendance is limited to 25 members (if we reach the limit, we will ask each location to prioritize participation to two individuals). Final details for the meeting will be sent to all registered attendees.

National T&O Conference

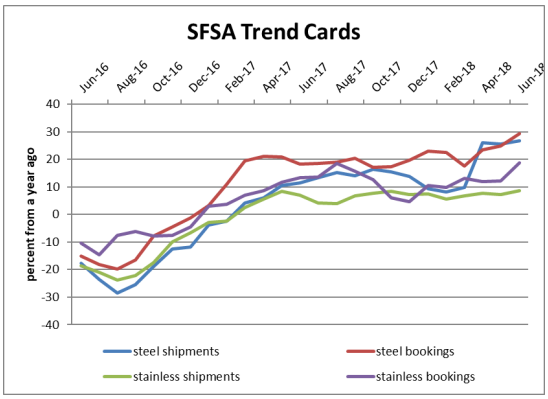
Make your plans now to attend the 2018 T&O in Chicago on December 5-8. The conference is the world's only event on steel casting technical and operating papers, mostly by fellow SFSA members, and this year it will feature several papers on replacing silica sand. Additional details for registration will be sent to members soon.

Heat Resistant and Future Leaders Meetings

Heat resistant alloys are used in applications where service temperatures exceed 1200°F (650°C), and require strength (creep resistance and performance through cyclical stresses) but also the ability to resist attack from the environment. The heat resistant subject-focused meeting will cover the fundamentals of heat resistant alloys – metallurgy, manufacturing and welding; along with SFSA's current research by Lehigh University on heavy section austenitics. The heat resistant meeting will be held in conjunction with a Future Leaders Group meeting. The meetings will be held on October 11-12 with a tour of Duraloy Technologies.

Market News

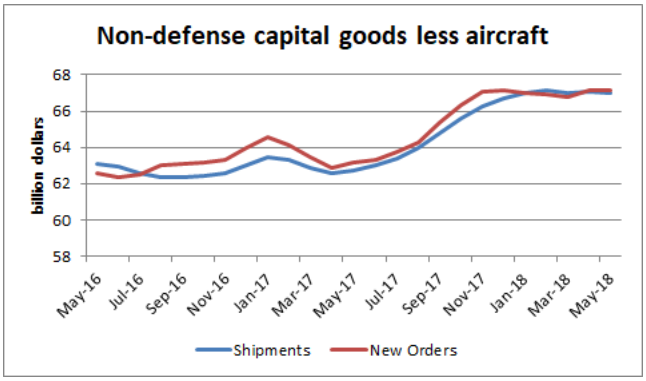
For May and June 2018, steel casting bookings and shipments reported by our members exceeded 25% of the levels last year. Wow!



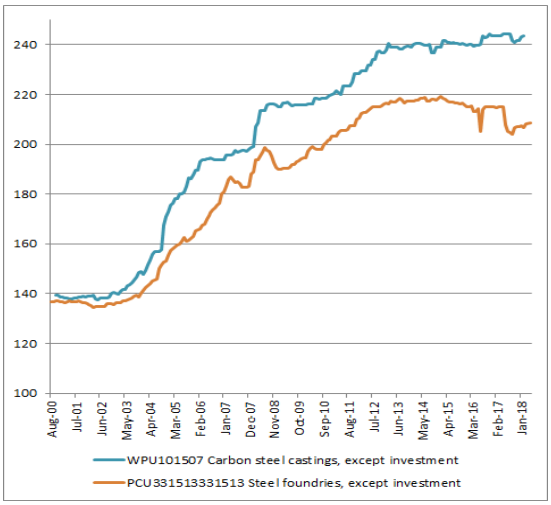
High alloy casting bookings were over 10% and shipments were up 7% from a year ago. The reported backlog now is over 9 weeks indicating fuller order books.

This good report from members was consistent with the improved conditions in the steel mill industry as we report each week in the blog: https://raymondmonroe.wordpress.com. Steel mill shipments are up and prices are higher and stable. It is not clear how much of this improvement in the U.S. is the result of tariffs being imposed by the administration.

Shipments and orders for non-defense capital goods less aircraft, a key measure of capital spending that supports steel casting demand, is high and stable but does not show much growth so far in 2018.



The plot of steel casting prices reported as the PPI or WPU shows the market conditions as well. Since the exposure of lack of global capacity in 2003/2004 pricing has move up significantly, more than 50%. The spikes up in PPI reflect the total costs to customers where the smoother curve of the WPU shows the price of the casting itself. The casting costs as WPU have moved up more and have not seen the reductions that the total cost PPI have seen in 2009 and 2016 forward. PPI has seen a modest recovery through May from lows in early 2017. Pricing action reported to US Census obviously is lagging market conditions as new terms and arrangements are made reflecting current market conditions.



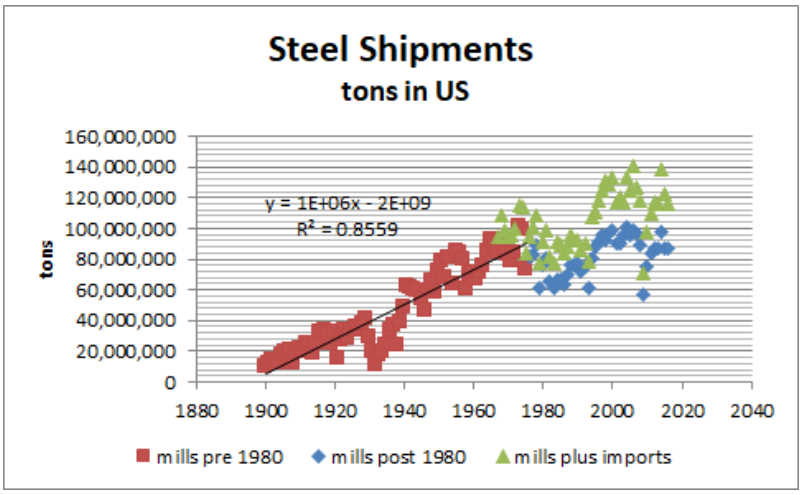
For an overall market perspective, the price of copper and oil remain high enough to support some investment and this should continue to be reflected in demand for steel castings. The continued improvements in markets for steel castings suggests strong conditions for the balance of 2018.

Casteel Commentary

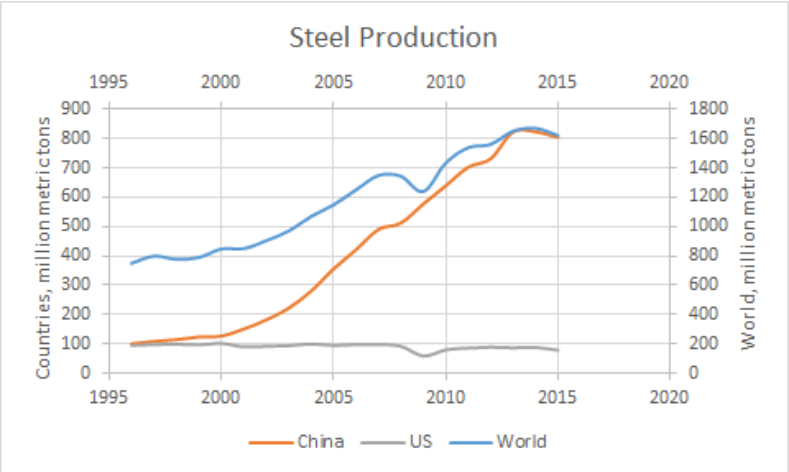
Possible impact of the US 232 and 301 actions on steel castings

Economic conditions, competitive pressures and globalization has resulted in the US having less capacity that required to fully supply the higher levels of demand for steel products. As seen in the graph below, U.S. steel shipments grew with the economy and with the rise in population from the

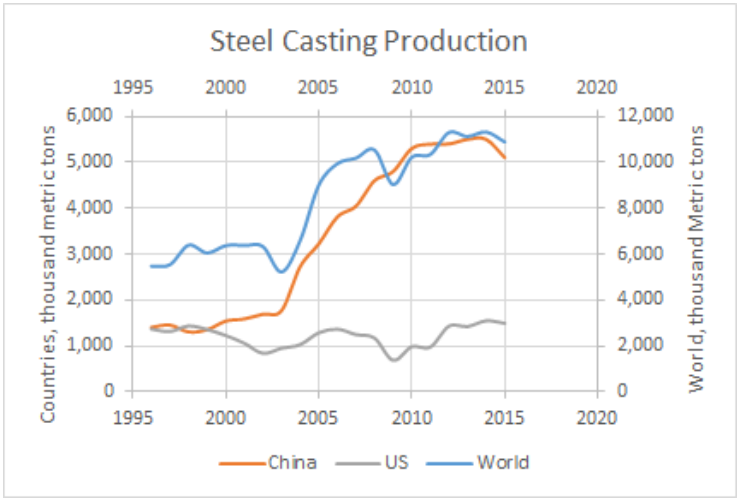
beginning of industrialization until 1980. Imported steel was a small factor in the total demand required. After 1980 with a severe downturn in capital investment and steel demand, the US industry maintained their production with a peak capability of around 100 million tons. After the suppressed demand with resuming more typical trends after 2000, the US industry supplied their 100 million tons and imports supplied an additional 20 to 40 million tons. In 2016, which was not a period of strong demand, U.S. producers supplied about 80 million tons while imports provided the rest to meet the demand for 120 million tons.



Coincidental with the restraint of capacity increases in the U.S., China embarked since 2000 on a massive unprecedented investment and expansion of their steelmaking capacity. In 2000, China's steel production was marginally higher than the U.S., 127 million tons to 102 million tons. In 2015, China's steel production was 800 million tons to the U.S. production of 80 million tons in a world production of 1600 million tons. So the rapid expansion of China in steel production and their ownership, economic and business practices threaten the viability and capability of the US steel industry.



Steel castings producers in the U.S. have also suffered from the same conditions with China rapidly adding capacity from 2000 until today. In 2000, China's steel foundry production was estimated at 1.5 million tons and the U.S. production was 1.0 million tons. In 2015, China's production was reported to be 5.1 million tons and the U.S. made 1.5 million tons. China's steel casting industry, however; is facing significant challenges not unlike the U.S. They are having a challenging time attracting workers willing to learn and stay in the foundry. The sharp drop in young population compared to the aging existing workforce adds to this problem. The difficulty of attracting workers has been made more difficult by rising wages in industrial areas making casting prices less competitive or forcing plants to operate unprofitably. Increasing concerns about air pollution and the systemic shortage of water has brought additional pressures on steel foundries.



In addition to China alone, globalization has resulted in consolidation and reduction of the remainder of the world's supply for steel and steel castings. While globalization allows multinational firms to source worldwide and take advantage of economic diversity and dislocations, it also has the effect of driving second and third tier suppliers out of business in regional economies reducing the total supply.

This supplier consolidation is partially offset by the normal increase in capacity from process improvements that most firms make to remain competitive.

The challenges facing U.S. domestic suppliers has been an issue for the current administration, both from an economic impact and from a defense supply chain capability standpoint. To address perceived and real trade structures and practices that have disadvantaged domestic producers in the global marketplace, the administration has opened trade discussions with all major trading partners including NAFTA, the EU, and China. In an effort to strengthen the U.S. position and to provide some immediate relief to domestic sources, the administration has imposed tariffs under the section 232 provisions and is initiating efforts under the section 301 provisions.

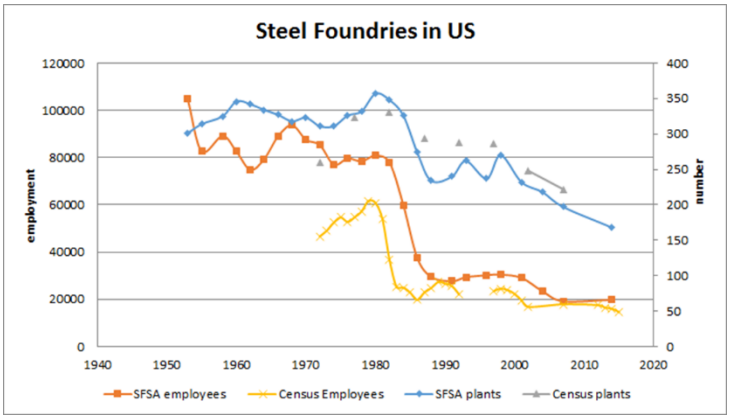
The Section 301 actions target the trade practices of China that but the U.S. producers at risk. https://ustr.gov/sites/default/files/USTR%20301%20Fact%20Sheet.pdf

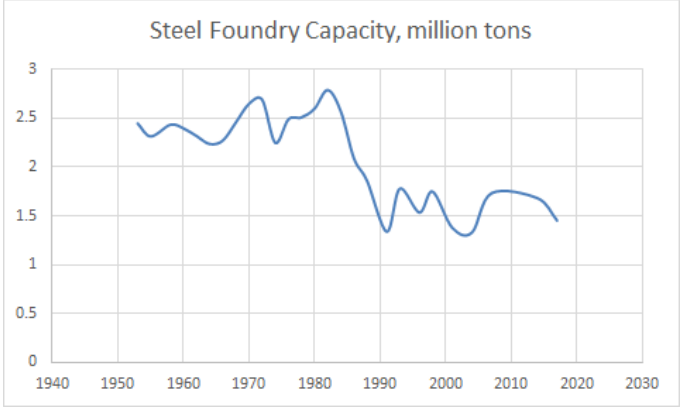
Steel products and steel castings are included in the proposed 301 tariffs to be imposed on China. Not all categories of steel castings are included but some of the major products are. While other regional economies may suffer as China diverts this capacity to other markets, domestic suppliers and non-China suppliers should gain benefits if these tariffs are imposed.

The section 232 actions targeted steel and aluminum products. The administration issued the presidential decision on March 22, 2018: https://www.cbp.gov/trade/programs-administration/entry-summary/232-tariffs-aluminum-and-steel. This decision did not cover all steel products and steel castings were not included in the list of items subject to tariffs. This decision left out a number of steel products and there is an effort to add additional steel items to the list. The presidential decision is a final document and it is not clear how it can be amended or modified. It looks unlikely at this point that additional items like castings will be added to the list. In any case, resolution of trade issues in the different regions should result in resolutions of the tariff issues as well. The ongoing discussions with NAFTA and EU parties should come to some agreement on these issues and the tariffs are a factor in aiding the US to get more favorable treatment.

In any case, the US steel industry in general and the steel casting industry in particular is not able to meet the anticipated requirements to support either the US domestic economy or its security needs. Exceptions and other accommodations will be available to allow non-U.S. suppliers to provide products that are not able to be supplied by domestic sources: https://www.bis.doc.gov/index.php/232-steel.

As a result of these challenges, many steel foundries have closed. The number of steel foundry plants in the U.S. has fallen from over 250 to around 150 from 2000 to 2015. The capacity peaked in 1982 around 2.7 million tons and has since fallen dramatically to around 1.5 million tons in 2015. Not only has the number of steel foundries and their capacity been reduced, particular expertise for special steel cast products has been lost as particular plants have been closed. For example, the closure of Falk meant the loss of expertise in the casting of large gear blanks. They were the only plant with that capability and were the only supplier of those castings.





Meeting the future requirements for domestic needs and especially defense needs is problematic. This will be exacerbated by increasing regulatory costs associated with compliance required by the new OSHA requirement on respirable silica. This regulation requires exposure levels not possible in many operations and non-compliant areas will need to

be marked and medical monitoring and other practices used to meet the standard. The U.S. foundry industry is not yet certain of how this onerous regulation will affect the business.

STEEL FOUNDERS' SOCIETY OF AMERICA
BUSINESS REPORT

SFSA Trend Cards (%-12 mos. Ago)	12 Mo Avg	3 Mo Avg	June	May	April
Carbon & Low Alloy					
Shipments	16.0	26.7	11.9	10.9	57.2
Bookings	21.6	28.8	27.9	20.0	38.5
Backlog (wks)	9.0	9.0	9.0	8.0	10.0
High Alloy					
Shipments	7.3	8.7	14.2	4.0	8.0
Bookings	13.1	18.7	32.5	8.7	15.0
Backlog (wks)	9.0	9.6	9.0	8.8	11.0
Department of Commerce Census Data					
Iron & Steel Foundries (million $)					
Shipments	1,336.8	1,375.0	1,354	1,374	1,397
New Orders	1,358.3	1,399.7	1,403	1,394	1,402
Inventories	1,996.5	1,974.7	1,988	1,976	1,960
Nondefense Capital Goods (billion $)					
Shipments	74.7	76.2	78.1	76.5	74.0
New Orders	75.6	77.9	78.3	76.8	78.6
Inventories	178.2	175.9	174.9	176.6	176.3
Nondefense Capital Goods less Aircraft (billion $)					
Shipments	66.5	67.5	67.8	67.3	67.2
New Orders	66.9	68.2	68.5	68.3	67.8
Inventories	123.8	123.2	123.6	123.2	122.7
Inventory/Orders	1.9	1.8	1.80	1.80	1.81
Inventory/Shipments	0.0	1.8	1.82	1.83	1.83
Orders/Shipments	0.0	1.0	1.01	1.01	1.01
American Iron and Steel Institute					
Raw Steel Shipments (million net tons)	7.7	8	8.1*	8.1	7.8

* SFSA's best estimate – the final number was not available at time of publication.

SFSA Research Review Recap

The SFSA Research Review meeting was held on July 10-12 at Rosemont, IL. SFSA has a full portfolio of steel casting R&D underway, with a majority of the research sponsored under the Digital Innovative Design program.

UA (R. Fleischmann) is collaborating with UI (C. Beckermann) in designing test castings with different levels of quality factors such as porosity and inclusions. The aim is to quantify the effect of indications on the structural performance of steel castings. UI designed test castings with different rigging to obtain varying levels of quality factors. A member foundry will cast and inspect the castings to categorize the quality level of each. UA will conduct structural tests on these castings and will correlate the structural performance to design rules. UA and UI are also designing other specimen designs that will be tested at UA later on.

UA is also supporting SFSA's goal to promote the use of steel castings to the building construction industry. UA will conduct structural tests on castings welded to hollow structural steel tubes, evaluating different weld interface to show how cast structural components would perform.

On behalf of John DuPont, David Poweleit presented Lehigh University's research. Lehigh is conducting metallurgical characterization of welds in cast carbon steels to support SFSA's proposal to include cast grades in AWS D1.1. Various tests and microstructural analysis will be done to evaluate cast-to-cast, cast-to-mill, and mill-to-mill welds. Lehigh will also investigate repair welding by characterizing the microstructure and properties of the welds in common cast steel grades.

PSU (B. Voigt) is developing a cast carbon steel grade with a minimum yield strength of 50ksi. Current casting specifications only require 36ksi YS for carbon steels even though most foundries can achieve higher yield strength. This research aims to address the concern of the building construction industry that current casting specifications have lower strength requirement compared to mill product specifications. Initial trials demonstrated that 50ksi can be achieved in C-Mn-V in the normalized and tempered condition. Several compositional variations will be produced at foundries to evaluate if properties can be consistently achieved.

ISU (F. Peters and D. Eisenmann) is in charge of evaluating NDT methods and assessing gage R&R. One of the main objectives of the DID program is to provide quantitative assessment of performance. ISU will investigate the effect of indications on properties of steel castings. As a start, ISU inspected weld plates that will be used in the Lehigh University welding studies. ISU will be working with a member foundry to make test castings with various levels of NDT indications.

UAB (C. Monroe, R. Foley, J. Griffin) is spearheading the material characterization of test castings under the DID program. They evaluated the effect of hot isostatic pressing (HIP) on the microstructure of AF96 (high strength low alloy). Wedge casting that was HIP-ed (2125F) were compared to castings that were normalized either at 1850F or 2100F. HIP lowers porosity but there was no difference in segregation of the HIP-ed samples and the samples normalized at 2100F. High temperature seems to dominate reduction in segregation in AF96 and not the pressure. UAB was also tasked to investigate low impact toughness in investment castings compared to sand cast specimens. There were some porosity and nitrides found on the fracture surfaces but further analysis needs to be done. The investment casting process will be evaluated in the DID program to determine if it is a quality factor.

In addition to designing the test castings for UA's structural tests, UI designed 1", 2", and 4" thick wedges that would allow the team to extract tensile and Charpy V-notch specimens with similar properties. These wedges were cast in WCB and 8630 by 2 member foundries. There are some unexpected variations in the tensile and CVN test results particularly for the low alloy steel. Further analysis is needed to better understand the variation.

UI and UAB also investigated heavy section test coupons provided by a member foundry. UI modeled the solidification of the 4" Y block based on process information from the foundry. UAB sectioned the test coupons into tensile specimens. The tensile properties of the WCB samples were similar throughout the 4" thickness. There seems to be a slight difference in mechanical properties of the 8630 samples. The model needs to be refined to match the measured properties. The model did not predict the porosity in the sample taken near the riser. It was suggested that evaluation should be shifted to castings thicker than 4".

MS&T (L. Bartlett) is developing cast and wrought FeMnAl for military applications. FeMnAl is a high manganese, high aluminum austenitic steel. The goal is to improve the properties and the manufacturability of the alloy. They are currently investigating chemistry and heat treatment variations to improve strength and toughness.

Other on-going projects that are not funded under the DID program were also presented at the review. UAB is examining various alloys under the cast preforms project. They are characterizing the effect of reduced forging reductions on FeMnAl, AF96, and HY100. They are also investigating the feasibility of improving toughness in Ground Engaging Tools.

UAB has been developing a semi-automated image analysis for digital radiographs. Software still needs to be optimized as more x-rays are analyzed. They are also leveraging this image analysis method in measuring microstructural features such as dendrite arm spacing.

PSU (P. Lynch) is investigating carbide formation in AF96 and how it can be controlled in processing to achieve properties needed for certain DoD applications. Like most high strength low alloys, AF96 is susceptible to temper embrittlement (TE) and tempered martensite embrittlement (TME). PSU is also conducting a machinability study on this alloy which is difficult to process due to its high strength.

On behalf of S. Chumbley, G. Harrington provided updates on ISU's research on ferrite prediction in duplex stainless steels and on cold spray. ISU established a ferrite prediction diagram for duplex stainless steels based on the relationship between measured ferrite content and homogenization temperature. Homogenization temperature seems to set the amount of ferrite. The cooling rate showed a small effect. This diagram needs to be validated using industry data from member foundries. ISU also is evaluating cold spray as a potential alternative to fill-up small porosity found on surfaces of machined castings. The cold spray trials have only been done on stainless steel and the process still needs to be developed to improve bonding of the cold spray powder to the casting. Currently, chrome carbide needs to be mixed with the steel powder for the cold spray material to stick to the part. Penetrant testing and corrosion testing of a cold sprayed part also need to be considered in the future.

UNI (J. Thiel) provided updates from their Additive Manufacturing Center. UNI is investigating 2 ceramic aggregates as potential alternatives to silica sand. They also presented work they are doing on robotic sand milling.

UI has developed a test set-up that allows them to measure air entrained by a plunging jet. This would generate data to further refine their air entrainment model which was presented at the T&O in 2016 and 2017. Initial development of this system was using water and they are working on transitioning to molten aluminum. Future work will be on molten steel.

New research projects funded under AMC's Innovative Casting Technologies which kicked off early this year were also briefed at this year's review. A list of SFSA's research portfolio can be found on the SFSA website [https://sfsa.org/research.php].