Steel Performance Initiative

by Raymond Monroe, SPI Director, March. 1, 2021,*Vol. 2, 2nd Issue*

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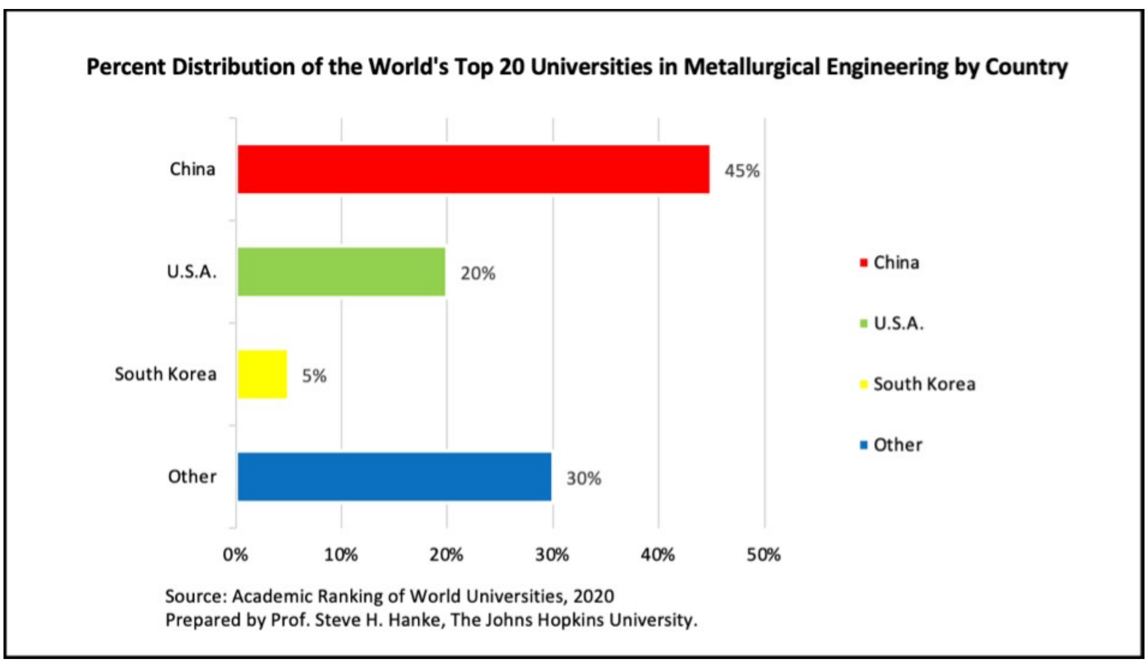
Steel Performance

A fundamental factor in technology development since the modern era becoming strategic for university research is federal funding for defense requirements. Much of the production practices used for specialty steels were supported and developed to respond to challenges in the World Wars for defense equipment.

Going back, steel melting in the crucible process in the early 1700s was to provide accurate chronometers to allow the dominant weapon system, the British Man-o-War to determine its longitude. Steel technology was an enabling factor for the most advanced information technology of the day.

The lack of investment in steel technology for advanced weapon systems is a growing and needed concern for the U.S. The lack of investment in steel has resulted in metallurgy departments being absorbed into material science departments with a limited amount of steel emphasis. This concern was a factor in Kent Peaslee working with NUCOR to endow a faculty chair at MS&T for steel.

Our largest peer competitor is not neglecting investment in technology and has an aggressive program of investment to become dominant. We, the U.S., dominate with 15 of the top 20 largest universities in the world. China has none. But in metallurgical engineering, China has 9 of the top universities and the U.S. has 5. For material science, the U.S. has 10 and China has 5 of the top 20. (https://www.nationalreview.com/2021/02/china-rattles-its-rare-earth-minerals-saber-again/)

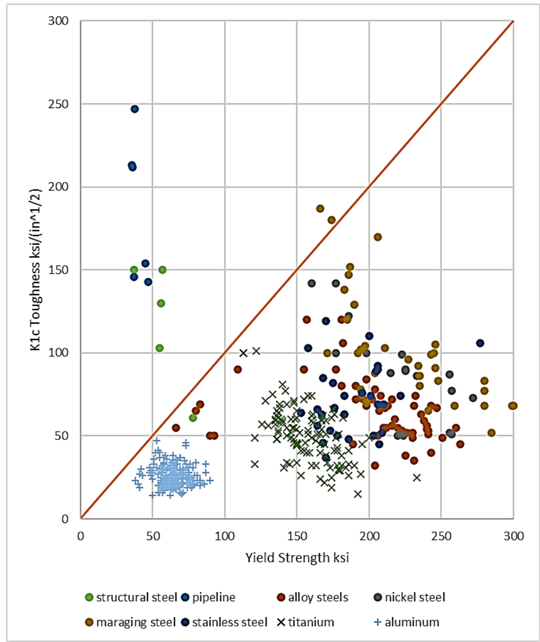


The Steel Performance Initiative (SPI) sees the limit in the U.S. for both technology development and workforce capability to be limited by the remaining university programs that are supportive of industrial research and capable in steel. We want to develop longer term systemic funding that will allow these few university programs to grow and remain. Each one of these programs is regularly reviewed and their support and capital facility requirement questioned as a part of the future of the university. The push is to do more academic science that gets support from NSF and NIST that results in more prestigious publications and larger R&D budgets.

SPI can only play a small role in supporting and sustaining this capability. More investment is needed.

Steel Technology

One ordinary investment supported by SPI is the development of improved alloys for an increased performance capability and better value. To understand the space of alloy development and the framework for investment, it is useful to look at the traditional trade-off between strength and toughness. The graph shows in English units the relationship between toughness and strength for common DoD materials. The line has a slope of one inch. The toughness divided by the strength squared gives a critical length, $(K_{1c}/YS)^2$. The thickness of a test specimen to get plane strain and evaluate toughness by inducing cracking is that length times 2.5. The critical flaw size for a common textbook example is 0.625 times the length.



For DoD applications, high-performance high-strength alloys are in the lower right. The SPI program on low alloy high performance steel is to develop an alloy with more of this capability. For structures that must avoid cracking like pipelines, the alloys need high toughness and are on the upper left. The SPI program to improve the high yield low alloy steel-type materials is targeted at these crack resistant grades. Common commercial alloy steels are closer to the line.

On properties alone based on geometry, steel alloys outperform aluminum and titanium materials. Titanium has added benefits of corrosion resistance. Both aluminum and titanium have higher strength properties when compared based on weight rather than geometry (volume). Higher strength steels with smaller sections are able to meet comparable weight targets. The developing technology for aluminum manganese steel reduces the density of that steel by 10 to 15% allowing the steel to be more comparable for reducing weight.

This graph is useful for us in SPI to understand where we are in steel properties and what our program needs to develop to meet the challenging needs of the future.

Projects & Partners: Colorado School of Mines

As performance requirements increase for DoD applications, thicker section steel components are needed to meet these requirements. High properties are difficult to meet in thick sections due to the complexities associated with effectively heat-treating large cross-sections. Colorado School of Mines, an expert in the development of steel alloys for mill products and heat treatment practices, is using state-of-the-art ICME tools to design an inter-critical heat treatment for thick section high yield, low alloy steels in order to decrease the rejection rate of these materials due to low impact properties. This directly supports the RAHSS objective in that industrial implementation of these heat treatments will improve the ability of the material to meet impact and tensile properties more consistently with reduced scrap and lead time.

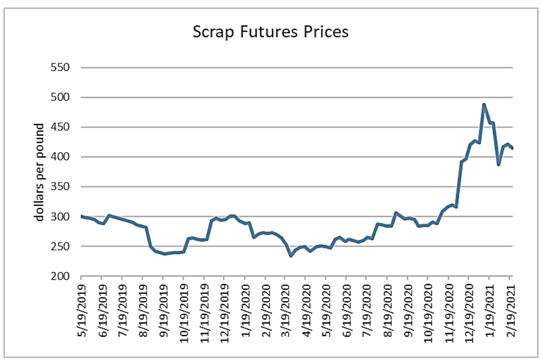
While improving the producibility and manufacturing efficiency of existing RAHSS is critical to supporting the domestic specialty steel supply chain, other alloy approaches and processes for superior performance are needed. A newer class of alloy types with more complex mixtures of elements, called Multiple Principal Element Alloys (MPEAs), offers opportunities for even more capable performance. However, a roadblock for the successful use of these alloys is the high cost associated with expensive alloying elements (e.g., CrCoNi). To overcome this roadblock, CSM is developing an Fe-containing MPEA that will meet or exceed the strength and ductility of existing MPEAs, but without the expensive alloying elements. They are using thermodynamic simulations to design MPEAs with advantageous starting microstructures for thermomechanical processing (TMP), which will then be poured and characterized in terms of performance and cost. Using ICME to successfully design an affordable, high-performing MPEA will open the door for these new materials to develop into a transitionable RAHSS for DoD applications.

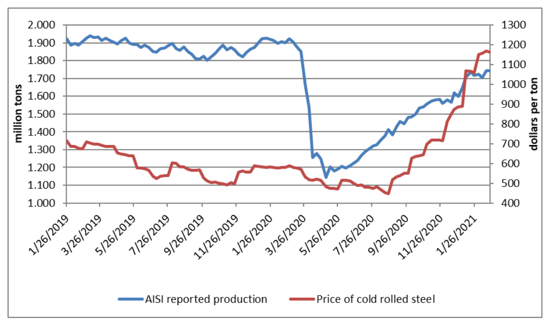
Call for White Paper Proposals

SPI is requesting white papers for potential funding. The request for white papers and the white paper template may be downloaded from http://www.steelperformance.org/proposals.html. White papers are due on or before March 31, 2021. Please contact Ryan Moore, Hayley Brown, or Raymond Monroe with any questions.

Steel Markets

Steel production and pricing remain high after recovering from low levels in the midyear of 2020. The production levels are still 10% below typical levels of 2019. On the other hand, prices are much higher than the prior couple of years. There is current speculation on a continued increase in pricing for commodities. Copper prices are at high levels. This can also be seen in the price for scrap shown in the graph.





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http://www.steelperformance.org/