Development of Lightweight steel for high energy absorbing applications

Lightweight steels in the *Fe-Mn-Al-C* system are currently being developed as high energy absorbing materials and as a substitution quenched and tempered steel. At a composition of Fe-30Mn-9Al-1Si-0.9C-0.5Mo, all compositions in weight percent, these alloys are almost 15% less dense than traditional steels and are completely austenitic when solution treated above 950° C. Steels with aluminum contents greater than 5% and carbon contents greater than 0.3% are age hardenable and this makes these steels vary tailorable with regard to mechanical properties. In the solution treated condition, lightweight steels have high work hardening rates and excellent ductility with elongations up to 64%. Tensile strength depends on the degree of age-hardening with cast tensile strengths greater than 1,000 MPa and wrought strengths as high as 2,000 MPa. Dynamic fracture toughness in cast steels is mainly a function of the amount of phosphorus, inclusion content, and age-hardening. First principles calculations show that phosphorus substitutes for aluminum in the κ-carbide structure and lowers the cleavage energy by 45%. However, with proper steelmaking practice and elimination of phosphorus to levels below 0.006%, this alloy attains Charpy 'V' notch (CVN) breaking energies of 39 J at -40° C and room temperature dynamic fracture toughness values of up to 420 kJ/m^2 in the aged condition. This talk serves as an introduction into the development of these lightweight steels and their applications in the military and automotive sector.

Biographical sketch

Laura Bartlett
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Professional Preparation

Missouri University of Science and Technology, Rolla MO
Metallurgical Engineering Ph.D. 2013
Missouri University of Science and Technology, Rolla MO
Metallurgical Engineering B.S. 2008

Appointments

Assistant Professor, January, 2013 – Present
Texas State University, Department of Engineering Technology, San Marcos, Texas

Instructor, August, 2011 – December, 2011
Missouri University of Science and Technology, Materials Science and Engineering, Rolla, MO

Graduate Research/Teaching Assistant, January, 2009 – December, 2012
Missouri University of Science and Technology, Materials Science and Engineering, Rolla, MO

Metallurgical Engineering Intern, May, 2008 – August, 2008
TyssenKrupp Waupaca, Metallurgy Department, Tell City, Indiana

Research Interests

Casting, solidification, and heat treatment of ferrous and non-ferrous alloys
Thermodynamics and kinetics of phase transformations
The physical metallurgy of advanced high strength steels

Products

Significant Publications

L.N. Bartlett, A. Dash, D.C. Van Aken, V.L. Richards, and K.D. Peaslee, "Dynamic Fracture Toughness of High Strength Steels," *International Journal of Metal Casting* (2013).

L.N. Bartlett and D.C. Van Aken, "On the Effect of Aluminum and Carbon on the Dynamic Fracture Toughness of Fe-Mn-Al-C Steels," *AFS Transactions (2013), accepted for publication.*

S.A. Buckholz, D.C. Van Aken, and L.N. Bartlett, "On the Influence of Aluminum and Carbon on Abrasion Resistance of High Manganese Steels," *AFS Transactions, accepted for publication* (2013).

D.C. Van Aken, S.A. Buckholz, and L.N. Bartlett, "Abrasion Resistance of High Manganese and Aluminum Steels," Paper 3.2, *Steel Founders of America 66th Technical and Operating Conference,* Chicago, IL, December 13, (2012).

L.N. Bartlett, A. Dash, D.C. Van Aken, V.L. Richards, and K.D. Peaslee, "Dynamic Fracture Toughness of High Strength Steels," *AFS Transactions,* (2012).

L.N. Bartlett, D.C. Van Aken, S. Lekakh, and K.D. Peaslee, "Mechanical Properties of Cerium Treated *Fe-Mn-Al-C* Steel Castings," *AFS Transactions*, Vol. 119, pp. 545-560 (2011) *Best Paper Award 2012.

L. Bartlett, A. Schulte, D. Van Aken, K. Peaslee, and R. Howell, "A Review of the Physical and Mechanical Properties of a Cast and Lightweight *Fe-Mn-Al-C* Steel," *MS&T Conference Proceedings,* Houston, Texas Oct. 17-21(2010).

L.N. Bartlett, D.C. Van Aken, K.D. Peaslee, and R.A. Howell, "Effect of Phosphorus and Silicon on the Precipitation of κ-carbides in the Fe-30%Mn-9%Al-X%Si-0.9%C-0.5%Mo Alloy System," *AFS Transactions,* Vol. 118, pp. 413- 423 (2010) *Best Paper Award 2011.

D.C. Van Aken, R.A. Howell, L.N. Bartlett, A.M. Schulte, S.N. Lekakh, J. Medvedeva, V.L. Richards, and K.D. Peaslee, "Casting P900 Armor with Lightweight Steel," *63rd Technical & Operating Conference of the Steel Founders' Society of America* (2009).

Publications Not In Print

L.N. Bartlett and D.C. Van Aken, "On the Influence of Silicon on the Dynamic Fracture Toughness of Austenitic Manganese and Aluminum Steels," submitted to *AFS Trans*. 2013

L.N. Bartlett, D.C. Van Aken, J. Medvedeva, D. Ishiem, and K. Song, "Atom Probe Tomography Study of Kappa Carbide in Lightweight Steel Part I: Effect of Silicon Addition," submitted to *Metallurgical and Materials Transactions*, 2013.

L.N. Bartlett, D.C. Van Aken, J. Medvedeva, D. Ishiem, and K. Song, "Atom Probe Tomography Study of Kappa Carbide in Lightweight Steel Part II: Effect of Phosphorus," submitted to *Metallurgical and Materials Transactions*, 2013.

(d) Synergistic Activities

Reviewer for *Metallurgical and Materials Transactions A*

Reviewer for the *International Journal of Metal Casting*

Two Best Paper Awards in Steel Division, American Foundry Society (2011, 2012)

G.A.A.N.N. Fellow (2010-2012)

Alpha Sigma Mu (Vice President), Missouri S&T Chapter (2011)

Tau Beta Pi, Missouri S&T Chapter (2010)

Member of Association of Iron and Steel Technology – AIST

Member of The Minerals, Metals, and Materials Society –TMS

Member and Faculty Advisor for the American Foundry Society – AFS