Lifetime Energy Savings Via Advanced Manufacturing of Low Density Steels for Transportation Applications

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AK Steel Corp. / Oak Ridge National Laboratories Colorado School of Mines

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Overview

Timeline

- Start: August 2018
- End: August 2021
- 36 months

Barriers

- Processability – Embrittling phases
- Cost – Raw materials

Budget

	Budget Period 1 (15 months)	Budget Period 2 (12 months)	Budget Period 3 (9 months)	Total Planned Funding
DOE Funds	$560,127	$377, 167	$294,006	$1,231,300
Cost Share	$143,303	$95,847	$75,038	$314,188

Partners

- AK Steel Corporation
- Oak Ridge National Laboratory
- Colorado School of Mines

Project Objectives

Problem

- Aluminum significantly reduces stiffness and sheet steel formability

Objective

- Design a formable, high strength, low density steel with a >10% reduction in density compared to typical advanced high strength sheet steels (AHSS)

Benefits

- Lifetime energy savings via a reduction in processing steps, optimized aluminum scrap usage, and improved fuel efficiency

Challenges

- Embrittlement as a result of alloying
- Ductility at room temperature
- Crystallographic Texture

Approach

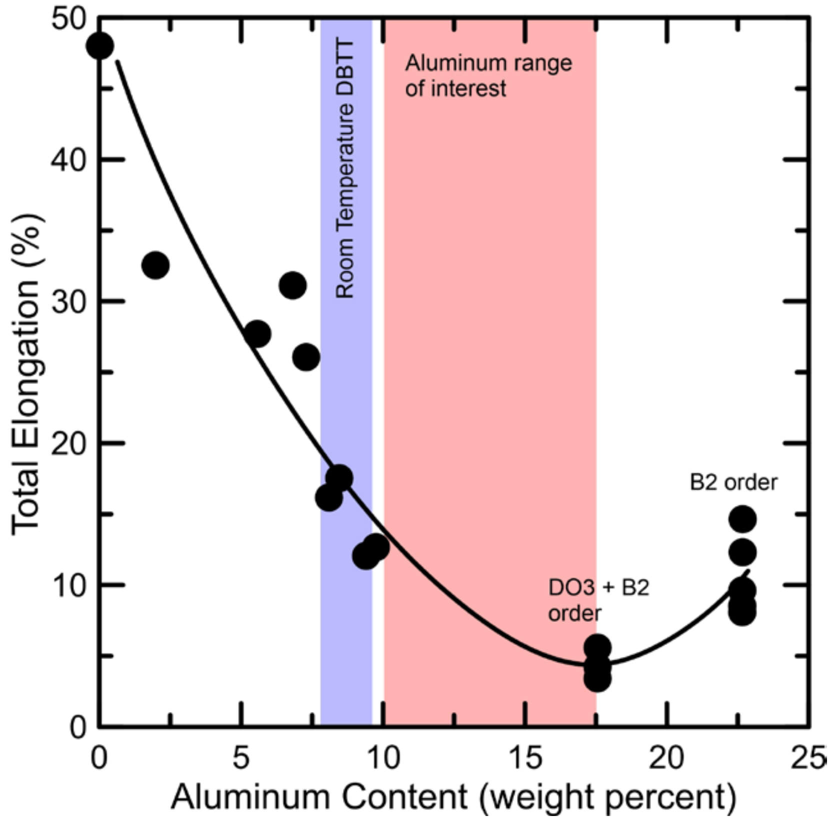
- Iterate small laboratory heats with computational alloy design
- Utilize novel rolling and annealing strategies

Technical Innovation

Technology Barriers of Existing Low Density Steels

- Aluminum reduces the ductility of steel and increases the ductile-to-brittle transition temperature → cracking during reduction or forming at room temperature forming
- Austenitic alloys are costly because of necessary large nickel and manganese additions

Ductile behavior can be achieved with proper alloying and processing



Rana *et al.*, *Scr Mater*, 2013.
Herrmann *et al.*, *Acta Mater*, 2003.
Maziasz *et al.*, *Intermetallics*, 1997.
McKamey *et al.*, *J Mater Res*, 1991.

Technical Innovation

Technical Innovation Required to Overcome Existing Barriers

- Advanced steel processing
  - Optimized hot rolling
  - Warm/shear rolling (novel textures)
  - Continuous annealing (enables rapid thermal treatments/improved process control)
- Advanced alloy design
  - New computational alloy design approaches to optimize microstructure/control of aluminide precipitation
  - Leverage past success form iron aluminide research successes (grain size control, suppression of κ-carbide, etc.)
- Novel Microstructures
  - Fine grain size
  - Precipitation for optimal strength-ductility
  - Density to <7 g/cm^3 with sufficient ductility

Technical Approach

AK Steel Corporation

- 119 years of steel making expertise and a history of innovation in carbon, stainless, and electrical steels
- Excellent operational flexibility
- Substantial capabilities and equipment for lab trials

Oak Ridge National Laboratory

Alloy Behavior and Design Group

- ORNL is a world leader in research and development of structural alloys
- Extensive computational modeling, design capabilities
- State-of-the-art mechanical and microstructural characterization expertise and capabilities.

Colorado School of Mines

Advanced Steel Processing and Products Research Center

- 30+ years of experience developing and implementing steel alloys and processing strategies
- Developed 3rd generation AHSS alloying and processing concepts, such as quenching and partitioning (Q&P)
- Broad spectrum of heat treatment, deformation, and thermomechanical processing capabilities

Technical Approach

Budget Period 1 (15 months)

- Melt a broad set of compositions based on historical and thermodynamic data
- Use small heats (<200 g)
- Primarily Ferritic microstructure
- Process and evaluate hot and provide input for computational alloy design
- Iterate and refine.
- UTS> 600 MPa, Min elongation: 8%, Density : 7.0 g/cm^3

Budget Period 2 (12 months)

- Melt larger laboratory heats (23 Kg.)
- Process and characterize
- Design thermo-mechanical treatments
- Some analysis of manufacturability will be performed
- UTS > 700 MPa, Min elongation: 8%, Density : 7.0 g/cm^3
- Evaluate downstream process ability: Toughness (DBTT <135 °C)

Budget Period 3 (9 months)

- Develop cold rolling and annealing strategies
- Cold rolling: warm rolling and asymmetric shear rolling
- Annealing: strip and/or batch annealing
- Assessment of manufacturability
- Yield strength: 600-1000 MPa, UTS: 1100- 1500 MPa, El: 15%, Density : 7.0 g/cm^3

Transition (beyond DOE assistance)

Next Steps

- Perform manufacture and usage analysis for the transportation sector
    - Market Assessment
    - Manufacturing Cost
    - Energy Savings
    - Capital Investment
    - Life-cycle Cost Analysis
    - Environmental Benefits
- Initiate mill trials within AK Steel product development structure
- Utilize existing channels with OEMs to evaluate the alloy

Questions?