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

BP1 (September 2018-December 2019)

AK Steel Corporation
Kelcey Garza

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Overview

Project Title: **Lifetime Energy Savings Via Advanced Manufacturing of Low Density Steels for Transportation Applications**

Timeline:

Project Start:	09/15/2018
Budget Period End:	12/14/2019
Project End :	09/14/2021

Barriers and Challenges:

- Processability
- Strength
- Ductility
- Undesirable phases
- Modeling validation

AMO MYPP Connection:

- Advanced Material Manufacturing
- Tools used to accelerate development:
  - Computational materials engineering
  - Enhanced modeling and simulation
  - High-throughput experimental processes

Project Budget and Costs (Including FFRDC):

Budget	DOE Share	Cost Share	Total	Cost Share %
Overall	$1,231,300	$314,188	$1,545,488	20.3%
Approved (BP-1)	$560,114	$143,303	$703,417	20.3%
Costs as of 4/1/19	$163,317	$39,049	$202,366	19.3%

Project Team and Roles:

AK Steel Corporation

- **Kelcey Garza**, Sr. Research Engineer
- Amrinder Gill, Sr. Research Engineer
- Erik Pavlina, Section Manager
- **Ed Case**, Director

Colorado School of Mines

- **Amy Clarke**, Associate Professor
- Kester Clarke, Assistant Professor
- Tomás Scuseria, Graduate Student

Oak Ridge National Laboratory

- **Dean Pierce**, Staff scientist

Project Objective

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 processing efficiency, optimized aluminum scrap usage, and improved fuel efficiency

Challenges

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

Approach

- High throughput small laboratory heats coupled with computational alloy design
- Utilize novel rolling and annealing strategies

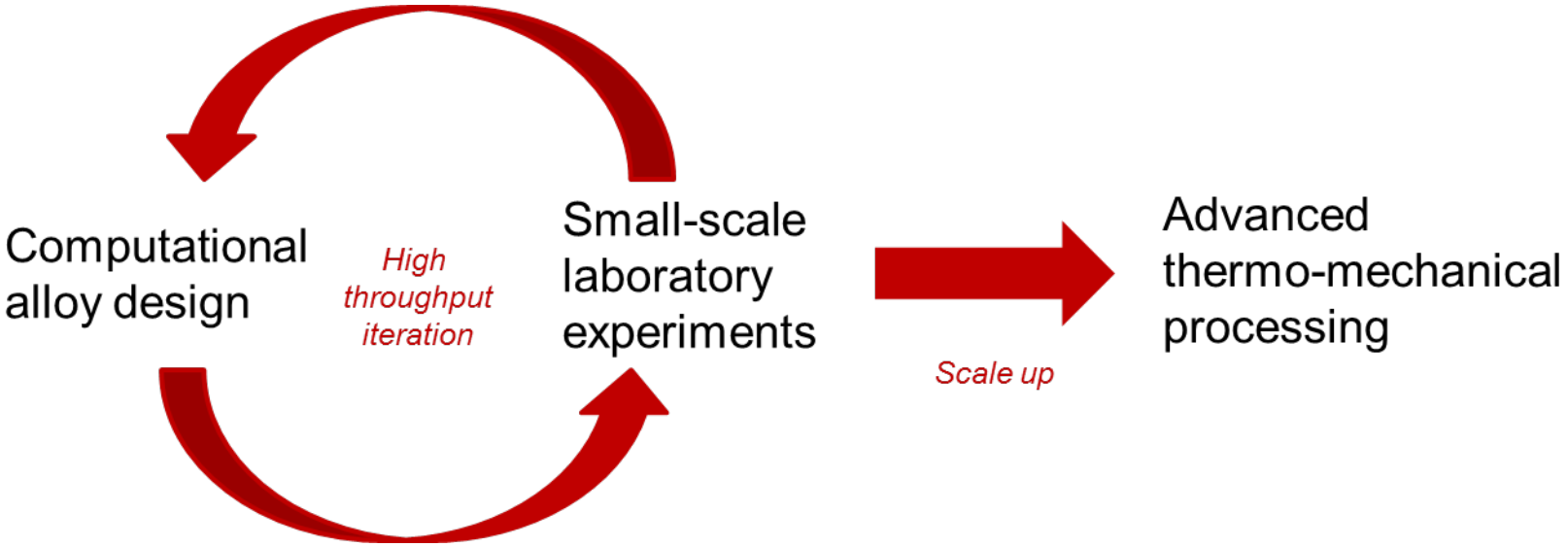
Technical Innovation

- Lightweighting currently performed via down-gauging using zinc-coated AHSS
- Limitations to down-gauging:
  - Application becomes stiffness limited, not strength limited
  - Alloy content (namely, silicon) hinders zinc coating
- Innovative approach:
  - Low density steel would permit lightweighting with heavier gauges or cross-sections
  - Avoid geometric stiffness limitations
  - Potential for uncoated product

Technical Innovation

- Develop novel alloying and processing strategies toward the commercialization of steels with significantly lower density than existing steel grades
- Potential for lifetime energy savings
  - Steel melting using aluminum scrap
  - Processing efficiency
    - Improve yield
    - Eliminate coating requirement
  - Increasing fuel efficiency of automobiles

Technical Approach



- Study, understand, and mitigate fundamental mechanisms of the embrittling behavior of high-aluminum steels
- Leverage knowledge of large-scale industrial manufacture of highly-alloyed steels with advanced modelling and characterization capabilities of academic and national laboratories

Industrial/Academic Collaboration:

AK Steel: Melting, processing, and characterization of unique alloy compositions

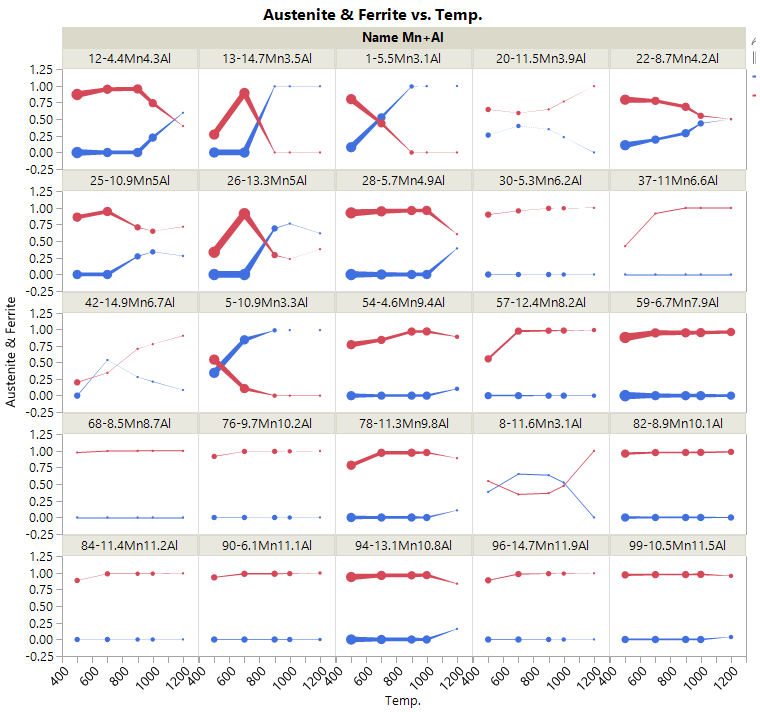
CSM: Microstructural characterization and heat treating optimization

ORNL: High-throughput CALPHAD, advanced processing

Technical Approach

Thermodynamic Modeling
CALPHAD (CALculation of PHAse Diagrams)

- Al + Mn alloy strategy with Cr, Ni, Si, Nb, Ti, V
- High throughput simulation (1,000+ compositions)
- Create a database for rapid interrogation for combinations of composition, density, phase fractions, critical temperatures
- Identify potential phases which could be present over previously defined composition ranges
  - Define processing windows
  - Control precipitation reactions
  - Eliminate or avoid embrittling mechanisms
- Iterate with small-scale laboratory (<200 g) steel heats to rapidly screen and test compositions



Results and Accomplishments

- Completed high-throughput CALPHAD phase modeling for 1000 unique alloy compositions
- Melted, processed, and evaluated initial laboratory heats
- Initiated iterative alloy refinement process using the thermodynamic modelling and rapid small scale laboratory melting and processing

Transition

- Working with award partners to evaluate and characterize material properties
- Perform manufacture and usage analysis for the transportation sector
  - Market Assessment
  - Manufacturing Cost
  - Capital Investment
- Laboratory scale up to plant trials