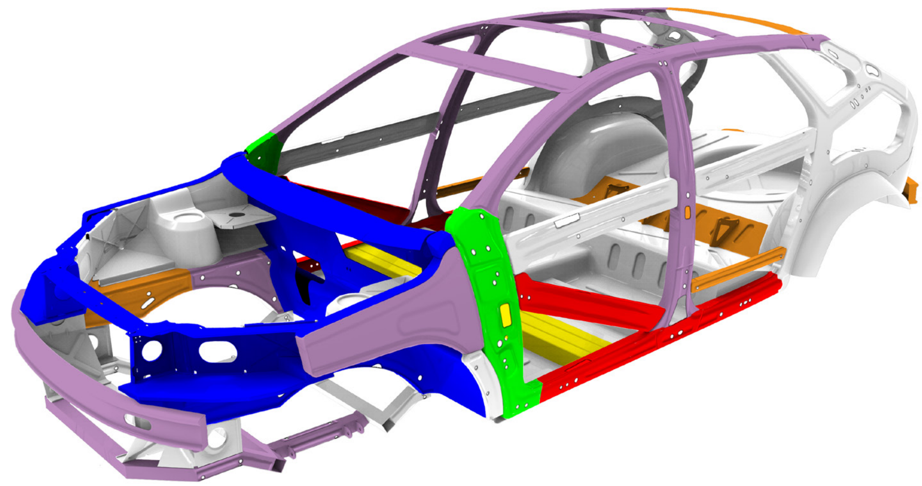
U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

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



Low density steels are being investigated for use in automotive structures.
Graphic image courtesy of AK Steel Corporation

Steel products continue to be used significantly in automotive structural applications. Advanced steel products can help achieve next generation automotive targets that yield vehicle lightweighting, improved fuel economy, and increased passenger safety. Advancing steel alloy design and processing will help to both decrease steel density and maintain mechanical properties, which will lead to an increase in the specific properties—for example, the strength-to-weight ratio—of the steels. These improved steels will also help decrease energy consumption in manufacturing compared to existing high strength steel processing.

This project is aimed at developing novel alloying and processing strategies to manufacture new steels with significantly lower density—down to 6.6 g/cm3—using conventional manufacturing facilities. The project will begin with a computational alloy design that incorporates first-principles and thermodynamic calculations. The proposed steel alloys will then be experimentally verified via laboratory trials. These laboratory trials will then determine the physical properties, structure, and mechanical properties of the alloys. Subsequently, the processing and manufacturability of these steels will be assessed.

Benefits for Our Industry and Our Nation

Implementing low-density steels in lightweight vehicle structures can provide substantial end use energy savings because fuel efficiency in passenger vehicles typically improves 6–8% for every 10% reduction in vehicle weight. Conventional steel products have relatively high densities (approximately 7.8 g/cm3), and steel alloying additions are becoming increasingly expensive to achieve weight reduction strategies via down gauging. Using state-of-the-art steel alloys is expected to have a variety of benefits for automotive applications, including:

- Energy savings that result from the use of low-density steels would be even greater than those savings achieved from state-of-the-art 3rd generation advanced high strength steels (33% greater reduction in mass for equal strength).
- Along with the increased energy efficiency achievable by using low-density steels in lightweight vehicle designs, these novel steels create the opportunity to reduce energy consumption during steel making, roughing, and finishing operations.

Applications in Our Nation's Industry

These low-density steels will provide extensive benefits to automotive manufacturers. Because lightweighting has been proven to be an efficient strategy in automotive structural applications, these steel alloys will have a direct impact. This application may provide competitive advantages to U.S. steel makers as well because these steels have high oxidation resistance, which reduces yield losses during energy-intensive hot mill processing.

Project Description

The project objective is to develop novel alloying and processing strategies toward the development of steels with significantly reduced density using conventional manufacturing practices. The project outcomes address manufacturing and end use steps: (a) incorporating large alloying additions of aluminum and carbon for exceptional corrosion and high temperature oxidation resistance compared to conventional steels; and (b) improving yields during manufacturing by eliminating the need to apply a protective coating to the steel, and potentially eliminating, or minimizing, pickling operations that are typically used to remove scale during manufacturing. Full development of low-density steels should result in energy savings during product manufacturing and end use.

Barriers

- Avoiding significant reduction in stiffness and sheet formability associated with increasing aluminum additions to iron in solid solution up to 10 weight percent. The ductile to brittle transition occurs at room temperature in binary iron-aluminum alloys containing 8–9 weight percent aluminum, making conventional cold rolling challenging.
- Avoiding negative influences to crystallographic texture associated with increasing aluminum additions; related to sheet formability after cold rolling and annealing.
- Controlling intermetallic phase formation associated with increasing aluminum levels above the solubility limit. These phases are strong and stiff, but are brittle and require careful control over their size and dispersion.

Pathways

The project is structured to address the key barriers and to minimize risk. The ultimate goal is to develop novel alloying and processing strategies toward the production of steels with significantly lower density using existing manufacturing facilities.

The first project pathway will design and test the performance of a low-density steel alloy. Computation tools will generate broad chemistry ranges for the proposed steels. This model will then be validated by processing and evaluating small laboratory steel heats with respect to mechanical and physical properties.

The second pathway will refine the laboratory-scale alloys. These refinement techniques will be applied to alloy processing with cold rolling and annealing strategies. Coating requirements and manufacturability assessments will also be addressed.

Milestones

This three-year project began in September 2018.

- Develop at least one low density hot-rolled steel alloy that is not brittle and meets the following properties: ultimate tensile strength (UTS) > 600 MPa, minimum elongation of 8%, and density/sheet weight reduction of 10% compared to conventional AHSS (2019)
- Successfully refine the laboratory-scale hot-rolled sheets to meet the following properties: UTS > 700 MPa, minimum elongation of 8%, and density/sheet weight reduction of 10% compared to 3rd generation AHSS (2020)
- Develop and document optimized alloy manufacturability with respect to cold rolling, annealing, welding, pickling, and coating requirements (2021)

Technology Transition

AK Steel Corporation is partnering with the Oak Ridge National Laboratory and the Advanced Steel Processing and Products Research Center at the Colorado School of Mines for the design, refinement and testing of these low-density steel alloys. Following successful development and further validation, AK Steel would leverage its existing distribution channels to market and supply a low density steel to end users. AK Steel supplies widely to the automotive sector and is well positioned as a lead for technology-to-market for this material.

Project Partners

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