8. HIGH-STRENGTH STEELS

A. Evaluations of the Effects of Manufacturing Processes and In-Service Temperature Variations on the Properties of Transformation-Induced Plasticity (TRIP) Steels

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Objective

- Develop an understanding of the effects of typical automotive manufacturing processes, such as welding and forming, on the retained properties of advanced transformation-induced plasticity (TRIP) steels.
- Evaluate the effects that in-service temperature variations have on the retained properties and energy absorption characteristics of TRIP steels.
- Compare the range of TRIP steel grades to determine their mechanical property sensitivity to thermal histories and manufacturing conditions.

Approach

- Develop a mechanical property vs in-service temperature relationship for the available grades of TRIP steels to determine their suitable vehicle applications and allowable thermal processing histories for manufacturing and vehicle performance. A temperatures range of –40°F to 200°F will be considered. Room temperature mechanical properties will be obtained from steel suppliers.
- Determine the effects of welding and forming on the retained mechanical properties of different grades of TRIP steels; tensile samples will be cut out from formed parts and welded parts. Tensile tests will then be done at three different rates to determine the effects of forming and welding on the static and dynamic strength of TRIP steel.
- Develop a database for the static, dynamic, fatigue, and corrosion behavior of dissimilar material joints, consisting of different material selections and different joining techniques.

Accomplishments

- Held project kick-off meetings with original equipment manufacturer (OEM) participants.
- Identified TRIP 800 as the initial material grades to be studied.
- Identified three TRIP steel suppliers from the United States, Europe, and Japan.
- Started materials acquisition processes from three material suppliers.
- Started experimental evaluation of 304 stainless steel as high-alloy TRIP steel.
- Began base material chemistry composition analysis on 304 stainless steel.
- Began Marciniak cup-stretch forming test on 304 stainless steel.

Future Direction

- Complete current tests on 304 stainless steel.
- Complete temperature- and prestrain-dependent material evaluations for all three populations of low-alloy TRIP steels.
- Transfer material performance database to U.S. Automotive Materials Partnership (USAMP) and OEM participants.

Introduction

This project is a collaborative effort between the Department of Energy (DOE), Pacific Northwest National Laboratory, and the U.S. Automotive Materials Partnership (USAMP) of the U.S. Council for Automotive Research (USCAR). The work started in July 2004.

Because of the excellent strength and formability of transformation-induced plasticity (TRIP) steels, they offer the potential to reduce vehicle weight and improve vehicle crash performance. The presence of retained austenite in TRIP steels enhances ductility at a particular strength level by means of TRIP. Because the enhanced ductility is the result of a phase transformation, thermal cycling, forming, and welding could be expected to impact the final microstructure and, thus, final material properties. Although the combination of strength and energy-absorbing capabilities of TRIP steels make them attractive, their sensitivity to thermal processing and in-service temperature variations has not been sufficiently established. To introduce TRIP steels into critical areas of the body structure (such as crash energy management areas), the automotive original equipment manufacturers (OEMs) must know what the retained properties of the material are after exposure to a range of manufacturing and in-service conditions.

This project will examine key aspects of the manufacturing process that TRIP steels would be exposed to, and it will systematically evaluate how the forming and thermal histories affect final strength and ductility of the material. The project will also evaluate in-service temperature variations, such as under-hood and hot/cold cyclic conditions, to determine whether these conditions influence final strength, ductility, and energy absorption characteristics of several available TRIP steel grades. As part of the manufacturing thermal environment evaluations, stamping process thermal histories will be included in the studies. As part of the in-service conditions, different loading rates will also be included. At the completion of the study, a thermal history/materials property relationship will be established over a full range of expected thermal histories and selected loading rates. Establishing these relationships will then allow OEM designers to select TRIP steels for proper vehicle applications and to specify manufacturing process conditions that yield reliable final material property levels.

Project Deliverables

The project deliverables include the following:

- Mechanical properties, that is, strength and ductility, vs in-service temperature relationship for the selected grades of TRIP steel to determine their suitable vehicle applications and allowable thermal processing histories for manufacturing and vehicle performance. A temperatures range of –40°F to 200°F will be considered.

- Effects of prestraining on the retained mechanical properties of different grades of TRIP steels. Tensile samples will be cut out from prestrained sheets. Tensile tests will then be done at three different temperatures to determine the effects of forming on the static strength of TRIP steel under different temperatures.
- Formability of TRIP steel using LDH and Marciniak type forming tests under different stamping temperatures.
- Axial crush and energy absorption characteristics of TRIP steel hexagonal columns under different loading rates.

Technical Approach

We will follow the standard American Society for Testing and Materials (ASTM) tensile-test procedures to conduct our materials characterization at different temperatures. Tensile samples will be cut from the steel sheet stock along the rolling directions. The following procedures will be followed to ensure the testing temperature:

Heating. Heating the tensile specimens will be done in a furnace that encompasses the entire specimen and grips. This furnace has a maximum temperature output of 450°F, so the required test temperature of 200°F can be set and reached easily by the controller for the furnace. This furnace is an air-circulating furnace. Thermocouples will be placed on the bottom and top grip (and on the specimen if necessary) to monitor the temperature. Once 200°F is reached, a soak time of 5 min will be needed before testing can begin. Temperature will be maintained throughout the test. Temperature will be recorded using an analog output temperature indicator, and it will be taken by the computer that is monitoring other test data such as load, displacement, and time.

Cooling. Cooling for the tensile specimens will be done in an enclosure that encompasses the entire specimen and grips. This enclosure will be cooled with liquid nitrogen that will be circulated by a fan to promote the even distribution of temperature. Thermocouples will be placed on the bottom and top grip (and on the specimen if necessary) to monitor the temperature. Once –40°F is reached, a soak time of 5 min will be needed before testing can begin. Temperature will be maintained throughout the test. Temperature will be recorded using an analog output temperature indicator, and it will be taken by the computer that is monitoring other test data such as load, displacement, and time.

Recent Accomplishments

- Held project kick-off meetings with OEM participants.
- Identified TRIP 800 as the initial material grades to be studied.
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Conclusions

- Material acquisitions of TRIP steel continue to be very difficult.
- TRIP steels are performance-based steels; therefore, different suppliers have different chemistries and surface coatings on the same steel grade. OEMs need to pay particular attention to the tolerance of yield strength and ultimate strength from the steel supplier. In general, the common perception that “the higher the strength, the better” is not necessarily true.