Fundamental study of the relationship of austenite-ferrite transformation details to austenite retention in carbon steels

Mike Santella (PI)
Eliot Specht
Zhili Feng (Presenter)
Oak Ridge National Laboratory

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Project ID # LM017
Overview

### Timeline
- Start – November, 2008
- End – June, 2012
- 65% complete as of May 2011

### Barriers
- Continuous proposal writing for APS beam time
- Experimentation & data analysis not “canned”
  - Being perfected in parallel with experiments

### Budget
- Total funding spent – $300k
- Funding in FY2010
  - $152k
- Funding in FY2011
  - $125k

### Partners
- None at present time
Relevance: Project Objectives:

• The objective is real-time characterization of austenite-ferrite transformation behavior
  – During T/t conditions representative of processing AHSS
  – Determine conditions that promote retained austenite
    • This will contribute to building the scientific foundation needed for development of Gen III AHSS

• Deliverables:
  – Quantitative description of austenite-ferrite transformation behavior during simulated finishing operations
    • including the effects of carbon, manganese, and silicon
  – Quantitative description of alloying element partitioning between austenite and ferrite
  – Assessment of how retained austenite can be maximized within constraints of normal sheet processing infrastructure
Relevance: Develop high strength-high ductility steel at current pricing

Controlling costs will require:

- Gen III AHSS be no more than modestly alloyed compared to Gen I steels
- Capability of being produced within existing steel-mill infrastructures
- Forming and welding characteristics consistent with existing steels

Source: www.autosteel.org
Relevance: Possible path to Gen III includes:

1. Alloying, but with content near those of Gen I steels
   - Only modest additional alloying tolerated

2. Modified/novel processing & heat treatments
   - Must produce desired bcc + fcc microstructures

Predictions suggest high strength + high ductility may be possible with microstructures of:

- Austenite + martensite, bainite, ferrite
- Ferrite + larger amounts of metastable austenite
  - Larger TRIP effect

Relevance: Milestones

1. Experimental and data analysis procedures will be reexamined to determine possible sources of errors, and an approach for minimizing the effects of surface reactions will be established. October 2010

2. Experimental alloys will be formulated and analyzed for the possibility of increasing retained austenite over commercial steel grades which generally contain around 10%. October 2011
**Approach:**

- High-speed diffraction experiments was conducted at the Advanced Photon Source
  - The austenite-ferrite phase transformation behavior was characterized *in-situ* under the rapid heating/cooling conditions
Approach: Specimens are heated by resistance in vacuum

- Thermocouple feedback is used for temperature control
- Specimen grip is spring-loaded to maintain positioning
Approach: APS synchrotron permits diffraction patterns at ~ 1 s intervals

- Calibrated Debye arcs are converted into plots of Intensity-vs-(d-spacing)
Approach: Direct comparison method is used to determine phase fractions

- Peak areas are corrected for polarization, temperature
- Integrated intensities are corrected for texture
FY2010 Accomplishments: Example of overall transformation behavior

- Time-temperature approximates normal steel processing during cooling
FY2010 Accomplishments: Effects of process conditions on transformation during intercritical hold

- Ferrite should but did not stabilize at a fixed amount near equilibrium value
FY2010 Accomplishments:
Effects of coatings on characterization

- Coatings caused unacceptable preferential attenuation of ferrite
- Coatings did not prevent increase with time of ferrite amount
FY2010 Accomplishments:
Effect of temperature on transformation during intercritical hold

- Drift of ferrite/austenite fractions was found over a range of intercritical temperatures
FY2010 Accomplishments: Effect of time on transformation during intercritical hold

- A possible explanation of increasing ferrite at diffracting surface is carbon loss
Collaborations/Coordination

• Activities were summarized at AS/P-organized workshops for projects funded through NSF to develop 3<sup>rd</sup> generation steels
• Experimental techniques need improved before productive collaborations could be established
Proposed Future Work

• Conventional diffraction facilities at the APS/synchrotron do not appear suitable for characterizing ferrite-austenite transformation behavior
  – Other facilities such as for transmission diffraction may be more appropriate
  – Use of neutron diffraction is also being considered

• Both processing and alloying approaches will be evaluated during remainder of project
Summary

• Data collection at APS/synchrotron is fast enough to characterize transformations during carbon steel processing
  – Critical transformation temperatures can be determined
  – Measurements of lattice parameters are possible

• To date, ferrite-austenite phase fractions cannot be accurately determined by conventional diffraction
  – Experimentation and data analysis needs further developments to accurately represent transformation behavior