ASSOCIATION FOR IRON & STEEL TECHNOLOGY

# NEW DEVELOPMENTS IN ADVANCED HIGH-STRENGTH SHEET STEELS

30 MAY–2 JUNE 2017
KEYSTONE RESORT & CONFERENCE CENTER

KEYSTONE, COLO., USA

## ABOUT THE PROGRAM

Advanced high-strength sheet steels (AHSS) are of increasing importance, particularly to the automotive industry, where their application enables reduced fuel consumption while guaranteeing passive safety. The scope of the conference is to bring together the international community to highlight state-of-the-art research and development pertaining to AHSS. The conference will focus on the latest developments in dual phase, twinning-induced plasticity, martensitic, quenched and partitioned, medium-manganese steels, other third-generation AHSS concepts and hot-stamped steels along with recent experiences with industrial implementation and end-user application performance. A broad distribution of presentation topics is scheduled from international and domestic speakers from industry as well as academia. The conference is the latest installment in a series of product-specific conferences following the AHSS symposia in Winter Park, Colo., in 2004, Orlando, Fla., in 2008 and Vail, Colo., in 2013.

## WHO SHOULD ATTEND

The conference should be attended by steel researchers interested in new high-strength sheet steel products, along with engineers responsible for the production and implementation of the products in steel mills, automotive facilities, and other industries, along with government and academic professionals and students.

BYOYP
BRING YOUR OWN
YOUNG PROFESSIONAL
Visit AIST.org/byoyp for more information

## ORGANIZED BY

AIST's Metallurgy — Processing, Products & Applications Technology Committee and The Colorado School of Mines' Advanced Steel Processing and Products Research Center.

AIST®
ASSOCIATION FOR IRON & STEEL
TECHNOLOGY

# SCHEDULE OF EVENTS

## TUESDAY, 30 MAY 2017

4–6 p.m.
Registration

6 p.m.
Reception

## WEDNESDAY, 31 MAY 2017

7 a.m.
Registration and Continental Breakfast

8 a.m.
Introductions and Opening Remarks

8:05 a.m.
Persistent Challenges to Advanced High-Strength Steel Implementation

8:30 a.m.
The Spectrum of Enabling Technologies for Implementation of AHSS

8:55 a.m.
Development, Design and Industrial Launch of Next-Generation Steel

9:20 a.m.
New Zn Multi-Step Hot Stamping Innovation at Gestamp

9:45 a.m.
Break

10:10 a.m.
Axial and Bending Crash Performance of Advanced High-Strength Steels

10:35 a.m.
Application and Stability of Retained Austenite in AHSS

11 a.m.
Advanced High-Strength Sheet Steels in Chassis Applications

11:30 a.m.
Lunch

12:30 p.m.
Properties of Ultrafine-Grained V-Microalloyed Dual-Phase Steels

12:55 p.m.
Bending Performance Improvement of Dual-Phase Steel With 1,000 MPa Tensile Strength

1:20 p.m.
Design and Development of Advanced High-Strength Steels Using Non-Peritectic Carbon Composition for Thin-Slab Continuous Casting Compact Strip Production (CSP) Steel Mill

1:45 p.m.
Phase Transformation Behavior of Austenite in Intercritically Annealed Advanced High-Strength Steels

2:10 p.m.
Modeling of Age-Hardening Kinetics During Coiling of High-Performance Nb-Mo Steel

2:35 p.m.
Work Hardening of Ferritic Steel Containing Nanometer-Sized Carbides

3 p.m.
Break

3:25 p.m.
Effects of Grain Refinement on Mechanical Properties of Dual-Phase Low-Carbon Steel

3:50 p.m.
Effect of Al Addition on the End Use Properties of Uncoated Commercial Dual-Phase 1180 Steel

4:15 p.m.
Microstructure Control for Improving Warm Deep-Drawability in Low-Alloy, High-Strength TRIP Steels

4:40 p.m.
Challenges With Design and Processing of Carbide-Free Bainitic AHSS Sheets

5:30 p.m.
Reception

## THURSDAY, 1 JUNE 2017

7 a.m.
Continental Breakfast

8 a.m.
Introduction and Opening Remarks

8:05 a.m.
Implementation Challenges With Generation-Three Advanced High-Strength Steels

8:30 a.m.
Effect of Strain Rate on Tensile Deformation Behavior of a Quenched and Partitioned Steel

8:55 a.m.
Microstructural Evolution During Quenching and Partitioning of 0.2C-1.5Mn-1.3Si Steels With Cr or Ni Additions

9:20 a.m.
Lüders and Portevin-Le Châtelier Bands in a Medium-Mn TRIP steel

9:45 a.m.
Break

10:15 a.m.
Tensile Behavior of Medium-Mn Steels That Exhibit Two-Stage TRIP Behavior

10:40 a.m.
Effect of Starting Microstructure and Intercritical Annealing Parameters on Mechanical Properties of a Medium-Mn Third-Generation Advanced High-Strength Steel

11:05 a.m.
Effect of Reheating Temperature on the Mechanical Behavior of Lamellar Morphology 10Mn Steel Sheets

11:30 a.m.
Double Soaking of a 0.14C-7.14Mn Steel

11:55 p.m.
Lunch

1:15 p.m.
Microchemical Banding of Si and Mn and Their Effect on the AHSS

1:40 p.m.
As-Cast Microstructure Evolution in AHSS Grades and Its Effect on Slab Quality

2:05 p.m.
Comparison of Different Techniques to Improve the Cold Rollability of High-Strength AHSS

2:30 p.m.
Evaluation of Galvanizing Line Furnaces for the Production of Advanced High-Strength Steels

2:55 p.m.
Break

3:20 p.m.
Performance Characteristics of HyCAL Toll Continuous Annealing Facility

3:45 p.m.
Annealing Furnace Concept and Oxide Thickness Control From Laboratory Test to Industrial Control Tolerances

4:10 p.m.
Induction Heating of Advanced High-Strength Steels

4:35 p.m.
Flash Bainite: Room-Temperature Stamping 1,500 to 1,800 MPa Structural and Energy-Absorbing Components to <2T Bend Radii

6–9 p.m.
Reception/Dinner

## FRIDAY, 2 JUNE 2017

7 a.m.
Continental Breakfast

8 a.m.
Introductions and Opening Remarks

8:05 a.m.
Study on Hot Press Forming (HPF) Die Development for Cooling Efficiency Improvement With Direct Spray Process

8:30 a.m.
Fe-Zn Reactions During Annealing of a Galvanized 22MnB5 Steel

8:55 a.m.
Third-Generation AHSS: Nanonphase Refinement and Strengthening During Cold Deformation

9:20 a.m.
Effects of Grain Size on Mechanical Properties of Silicon-Added High-Mn TWIP Steel

9:45 a.m.
Third-Generation AHSS: New Factors Affecting Local Formability

10:10 a.m.
Break

10:35 a.m.
Investigation of Strain Instabilities in Third-Generation Medium-Manganese TRIP Steels

11 a.m.
Deformation-Induced Martensite Transformation and Serrated Plastic Flow in Medium-Mn Steels

11:25 a.m.
Deformation Mechanism of Ultrafine-Grained High-Mn Austenitic TWIP Steel

11:50 a.m.
Lunch

1 p.m.
Segregation in Quenched and Partitioned Steels: The Role of Hot Rolling Parameters

1:25 p.m.
Non-Equilibrium Thermodynamics of Quench and Partition Steels

1:50 p.m.
Recent Advances in TMR-DQP Processing for Tough, Ductile High-Strength Strip Steels

2:15 p.m.
Revealing the Condition of Austenite Decomposition During Partitioning in Q&P Steels

2:40 p.m.
Break

3:05 p.m.
Influence of Oxidizing Gas and Surface Microstructure on High-Temperature Oxidation of Advanced High-Strength Steel

3:30 p.m.
Enhanced Pickling Speeds and Surface Preparation of AHSS Using Oxigen-X™ Molten Salt

3:55 p.m.
Shearing and Slitting AHSS-ASKO HXTTM Knives

4:20 p.m.
Selective Oxidation of Advanced High-Strength Steels and Ultrahigh-Strength Steels (UHSS) Utilizing Direct-Fired Burners

4:45 p.m.
The Effect of Internal Oxidation on the Bendability of Ultrahigh-Strength Steel

5:10 p.m.
Conference Adjourn

## TUESDAY, 30 MAY 2017

4–6 p.m.
Registration

6 p.m.
Reception

## WEDNESDAY, 31 MAY 2017

7 a.m.
Registration and Continental Breakfast

8 a.m.
### Introductions and Opening Remarks

8:05 a.m.
### Persistent Challenges to Advanced High-Strength Steel Implementation

**Curt Horvath, C. Matthew Enloe, Jason Coryell and Jatinder P. Singh, General Motors Co.**

Significant progress in the industrial-scale production of retained austenite containing advanced high-strength steels that exhibit tensile strengths greater than 1,000 MPa has been achieved in recent years. Application and implementation of this new class of steel to the automobile body structure is intended during the latter years of this decade, but persistent technical challenges remain to ensure the actualization of targeted and concurrent benefits to vehicle mass reduction, vehicle cost, and passenger safety. Most among the remaining obstructions to complete implementation include an acceptable joining strategy with respect to zinc-coated sheet steels; robust numerical methods for forming, crash performance and fracture prediction; and grade homologation within the global steel industry. These challenges are demonstrated, and strategies for retained austenite containing advanced high-strength steel application are outlined for comparison to current technology and alternative methodologies for vehicle mass reduction.

8:30 a.m.
### The Spectrum of Enabling Technologies for Implementation of AHSS

**Narayan Pottore, Sriram Sadagopan and Shrikant Bhat, ArcelorMittal**

New grades of steel with higher strength and ductility are being developed worldwide to simultaneously facilitate weight reduction and enhanced safety in automotive structures. Many of the steel designs that are utilized to produce such grades, however, could result in significant challenges to meet the implementation requirements for part forming, assembly and in-use component performance. This paper provides examples of some of these challenges and potential approaches that may help overcome the likely impediments to the successful application of the new steels.

8:55 a.m.
### Development, Design and Industrial Launch of Next-Generation Steel

**Grant Thomas and Jeremy Hansman, AK Steel Research**

Next-generation advanced high-strength (AHSS) steels are being implemented in automotive structures in order to meet the demands for automotive lightweighting. Many of these new grades of steel (e.g., quenched and partitioned steel) require processing controls that differ slightly from those of conventional steel grades. Special considerations of chemistry, thermal control, and atmospheric conditions are required to meet property and coating requirements while maintaining industrial feasibility for steelmakers and automotive original equipment manufacturers. The present contribution highlights development of such grades at AK Steel, capital improvements enabling production of these grades, industrial launch and characterization of industrially produced steel.

9:20 a.m.
### New Zn Multi-Step Hot Stamping Innovation at Gestamp

**Paul Belanger, Gestamp**

Over the past two decades, the hot press forming, or press hardening, of steel (PHS) has become an important technology enabler for meeting today's safety requirements. Its ability to do this while at the same time lightweighting body structures has been an advantage. The widely used steel grade for hot forming is the boron-added steel 22MnB5 (0.22%C-1.2%Mn), which achieves nominal strengths of approximately 1.5GPa. State-of-the-art PHS processing of that material has included:

- Austenitizing a developed blank in a conventional oven.
- Forming and press hardening of the heated blank in relatively slow, 5 strokes per minute or lower, hydraulic presses.
- Laser cutting to the final dimensions.

Future fuel economy and safety regulation increases are demanding even more aggressive vehicle mass reductions without jeopardizing cost targets. New steels and processes with tailored strengths and faster production speeds are needed. This investigation explores the feasibility and validation of a next-generation zinc-coated material and hot stamping process technology that equates to a revolutionary advancement in the hot stamping process.

9:45 a.m.
Break

10:10 a.m.
### Axial and Bending Crash Performance of Advanced High-Strength Steels

**Todd Link and Brandon Hance, United States Steel Corporation**

Advanced high-strength steels (AHSS) are used in automotive structures to absorb crash energy and minimize intrusion to the passenger compartment. The combination of high strength and good formability contributes to improved performance and potential weight savings. However, the application of higher strength level AHSS can be limited by fracture during impact deformation. In this work, the performance of 980- and 1,180-MPa AHSS was investigated by drop tower crash testing in both axial and bending modes. The results show that energy absorption correlates well with strength and sheet thickness, while some measures of local formability provide promising indications of fracture resistance.

10:35 a.m.

### Application and Stability of Retained Austenite in AHSS

**L. Wang, Y. Zhang, S. Zhou and Y. Zhong, Baosteel R&D Center**

Two important objectives of the automotive industry are the decrease in car weight and improvement in safety. High-strength steels (HSS), especially advanced high-strength steels (AHSS) and third-generation HSS, are the main measures to reduce automotive weight and improve safety in steel industry. In order to achieve good balance properties between tensile strength and elongation, the phase of the retained austenite is necessary for the new-generation AHSS phase design. In this paper, application of retained austenite in AHSS such as TRIP, QP, medium-manganese and TWIP steels were reviewed at Baosteel, and the stability of retained austenite in different steels was evaluated.

11 a.m.

### Advanced High-Strength Sheet Steels in Chassis Applications

**Andreas Frehn, BENTELER Automotive**

Advanced high-strength steels (1st generation) have been successfully developed and applied in many applications. Due to the fact that the steels are mainly cold rolled and partly coated, they have been used mainly in structural components, such as seat rails, bumper beams or A/B pillars. But also in chassis parts, showing mostly higher wall thickness values due to stiffness and corrosion issues, these steels (as hot-rolled grades) are gaining in importance during the last years. The different steels show specific beneficial properties for the different components (like control arms, rear twistbeam axles, subframes), leading to the successive replacement of the well-known high-strength, low-alloy steels and enabling lightweight construction in this sector. Besides showing several examples combined with a look on the relevant important properties, the presentation will also cover the challenges, which can be currently seen for AHSS steels of the 2nd and 3rd generation for this application area.

11:30 a.m.

Lunch

12:30 p.m.

### Properties of Ultrafine-Grained V-Microalloyed Dual-Phase Steels

**Colin Scott, Babak Shalchi, Fateh Fazeli and Irina Pushkareva, CanmetMATERIALS**

Vanadium microalloying additions are very effective in refining DP microstructures. This study demonstrates that it is easily possible to achieve ferrite grain sizes of the order of ~1.5 µm and submicron martensite islands using conventional annealing cycles. The tensile properties of the new alloys are very good; YS ~600 MPa, UTS >1,200 MPa, UE 8–10% in the as-quenched condition. This is mostly due to the ferrite phase, which is strengthened by grain refinement and selectively strengthened by V(C,N) precipitation. Processing is more robust as the mechanical properties are much less sensitive to the martensite fraction, i.e., these alloys can tolerate larger variations in the intercritical annealing temperature. The impact of the reduced strain incompatibility between the ferrite and martensite phase on tensile fracture strains and hole expansion behavior as a function of martensite fraction has been determined.

12:55 p.m.

### Bending Performance Improvement of Dual-Phase Steel With 1,000 MPa Tensile Strength

**Dongwei Fan, Negin Jahangiri, Pallava Kaushik and Howie Pielet, ArcelorMittal, and Hyungjo Jun, ExxonMobil Research and Engineering Co.**

Formability is one of the required characteristics of advanced high-strength steel. In the present study, the formability of dual-phase steel with 1,000-MPa tensile strength was evaluated by using a 90° V-bend test. Samples were investigated by using a scanning electron microscope (with and without automation) and cathodoluminescent microscope. A fractography study indicated that the causes of bend failure were the inclusions near the steel surface and the diffusible hydrogen in the steel. The impacting inclusions were identified as calcium aluminate, alumina and spinel. Bending performance could be improved either by reducing inclusion amount at steelmaking stage, or by removing the diffusible hydrogen through a final heat treatment. However, the latter process would change the tensile properties of the steel.

1:20 p.m.

### Design and Development of Advanced High-Strength Steels Using Non-Peritectic Carbon Composition for Thin-Slab Continuous Casting Compact Strip Production (CSP) Steel Mill

**Ranga Nikhil V Yellakara, Nikhil Kulkarni and Jagnyaseni Tripathy, Steel Dynamics Inc., and Haley Doude, Center for Advanced Vehicular Systems, Mississippi State University**

Global steelmaking technology moves closer to the CSP process, which requires the steel to be continuously cast into thin, 65-mm slabs before rolling. Continuous casting of peritectic steels to produce thin slabs is often difficult and critical as it may lead to bad surface quality, cracks, breakouts, etc. The current study focuses on developing AHSS using grades with non-peritectic carbon content (C<0.08%) and microalloy addition. The mechanical behavior of such steels is to a large extent a function of the microstructure. The microstructure is, in its turn, a result of the chemical composition and the process parameters during its production. The connection between microstructure and mechanical properties is studied, with a focus on the microstructure development after hot rolling and during annealing in a continuous galvanizing line. In-line plant trials have been carried out in order to investigate the impact

of alloying elements and process parameters on the microstructure.

1:45 p.m.

### Phase Transformation Behavior of Austenite in Intercritically Annealed Advanced High-Strength Steels

**Luis Garza-Martinez and Erik Pavlina, AK Steel Research and Innovation**

The phase transformation behavior during cooling of intercritical austenite depends on the relationship between the volume fraction of the intercritical austenite and the composition of the austenite — both which are a result of the intercritical annealing temperature. The cooling profile of a continuous annealing operation, such as a hot-dip galvanizing line, presents additional complexity as a result of the need to utilize isothermal holds at different temperatures to accommodate the coating operation. The phase transformation behavior dictates the final mechanical properties, since these depend on the resulting products of the transformed intercritical austenite. This investigation assessed the phase transformation behavior of austenite in an intercritically annealed Fe-0.09C-2.1Mn-0.2Si-0.55Cr-0.12Mo steel using dilatometry and other standard techniques. Results indicate that the martensite start temperature increases as the fraction of intercritical austenite increases. Regardless of the intercritical austenite fraction, the bainite transformation starts almost immediately after quenching to temperatures corresponding to the zinc bath temperature in hot-dip galvanizing lines. Rapidly cooling the steel below the martensite start temperature prior to entering the zinc bath may minimize the formation of bainite during hot-dip coating.

2:10 p.m.

### Modeling of Age-Hardening Kinetics During Coiling of High-Performance Nb-Mo Steel

**Matthias Militzer and Jean-Yves Maetz, The University of British Columbia; Jer Ren Yang, National Taiwan University; Nam Hoon Goo, Hyundai Steel Co.; and Bian Jian, Niobium Tech Asia**

Precipitation strengthening and tempering of the bainitic ferrite microstructure has been investigated in four Nb-Mo-bearing high-strength, low-alloyed (HSLA) steels. Hot torsion tests were conducted to simulate a typical hot strip rolling schedule in conjunction with a range of coil cooling and aging conditions. The obtained microstructures were characterized using electron backscatter diffraction, highlighting the effects of Nb and Mo additions on formation and tempering of the bainitic ferrite microstructures. Further, the evolution of nanometer-sized precipitates was quantified with high-resolution transmission electron microscopy studies. The resulting age-hardening kinetics has been modeled by combining a phenomenological precipitation strengthening model with a tempering model for bainitic ferrite. Analysis of the model suggest a coiling temperature window to maximize the precipitation strengthening potential in bainite/ferrite HSLA steels to be narrower than that for conventional HSLA steels with polygonal ferrite/pearlite microstructures.

2:35 p.m.

### Work Hardening of Ferritic Steel Containing Nanometer-Sized Carbides

**Noriaki Kosaka and Yoshimasa Funakawa, JFE Corp.**

The work hardening in the early stage of plastic deformation of ferritic steels containing the several sizes and amounts of TiC was investigated. According to Ashby's theory, a well-known theory of metals with hard particles, the work hardening is related to the size and amount of particles. Hence the carbide size varied from 3 nm to 15 nm by controlling the isothermal treatment temperature after hot rolling, and the amount of carbides was changed by addition of C and Ti. In the steels containing nanometer-sized carbides, a specific plastic deformation appeared; namely, the incremental stress suddenly changed at certain plastic strain. The phenomenon is explained only by Ashby's theory. The generation of geometrically necessary dislocation around carbide during plastic deformation should be taken into account. A new model that can explain the work hardening of ferritic steel with nanometer-sized carbide was proposed.

3 p.m.

Break

3:25 p.m.

### Effects of Grain Refinement on Mechanical Properties of Dual-Phase Low-Carbon Steel

**Nobuhiro Tsuji, Myeong-Heom Park and Akinobu Shibata, Kyoto University**

Dual-phase (DP) steels composed of soft phase (ferrite) and hard phase (martensite or bainite) are known to show good strength-ductility balance, but the reason for their superior mechanical properties is still unclear. In the present study, the microstructural refinement of the DP structures in a 2Mn-0.1C steel was achieved by various thermomechanical processes. The grain size of ferrite in the DP structures, where ferrite is surrounded by martensite (prior austenite), ranged from 58 μm to 4 μm. It was found that the grain refinement significantly changed the tensile properties of the DP steel at room temperature and, interestingly, both strength and ductility were enhanced together. The mechanism of the improvement of mechanical properties will be discussed in the presentation.

3:50 p.m.
### Effect of Al Addition on the End Use Properties of Uncoated Commercial Dual-Phase 1180 Steel
**Sriram Sadagopan, Narayan Pottore, Gang Huang and Hassan Ghassemi, ArcelorMittal Global R&D**
This paper presents the results of intentional aluminum addition on the formability and weldability of commercially produced DP1180 steel grades produced at ArcelorMittal. Formability was evaluated using a suite of "standard" tests such as hole expansion, bendability and the plane strain forming limit, FLD0, and some simulative formability bending under tension tests such as stretch bend and the draw stretch tests. Results of the formability test demonstrate that the local formability of the product with the higher Al addition was improved in comparison with the nominal Al product. Weldability was evaluated using the current range and maximum load determined using the cross-tension test where the improved performance of the product with the higher Al addition was demonstrated. In addition, more detailed microstructural characterization and mechanical behavior of the products was conducted to further the understanding of the effect of Al on the performance of the DP1180 steel.

4:15 p.m.
### Microstructure Control for Improving Warm Deep-Drawability in Low-Alloy, High-Strength TRIP Steels
**Elijah Kakiuchi, Toshio Murakami, Naoki Mitzuta and Tatsuya Asai, Kobe Steel Ltd.**
Tensile strength reduction in warm forming temperature was investigated for low-alloy, high-strength transformation-induced plasticity (TRIP) steels in order to improve deep drawability in warm forming. Volume fraction of ferrite and carbon content of retained austenite were controlled to investigate their effect on tensile strength reduction. Tensile strength was minimized at 473K and it was found that tensile strength reduction was increased as carbon content of retained austenite decreased. Deformation-induced martensite transformation behavior was investigated and it was found that retained austenite volume fraction was hardly changed during 473K tensile testing in all steels, but decreased in inverse proportion to carbon content of retained austenite during room-temperature tensile testing. The results indicated that tensile strength reduction was determined by the difference of the amount of retained austenite transformed to martensite during deformation at room temperature and warm forming temperature.

4:40 p.m.
### Challenges With Design and Processing of Carbide-Free Bainitic AHSS Sheets
**Fateh Fazeli, Colin Scot, Babak Shalchi Amirkhiz and Irina Pushkareva, CanmetMATERIALS**
Superior AHSS sheets are required for the manufacture of lightweight body-in-white components to address stringent safety and fuel economy regulations. Carbide-free bainitic (CFB) sheets are potential candidate steels with mechanical properties exceeding current commercial TRIP and DP steels. The main challenge is to develop suitable alloy compositions that can be processed by existing continuous annealing or galvanizing lines. This study describes proper processing routes for the manufacture of CFB sheets and presents alloying strategies to tailor the phase transformation response of potential candidate steels. Some examples of alloying systems that have been optimized for different processing lines and their ensuing mechanical properties with tensile strength between 1,200 to 1,500 MPa will be demonstrated and discussed.

5:30 p.m.
Reception

## THURSDAY, 1 JUNE 2017
7 a.m.
Continental Breakfast

8 a.m.
### Introduction and Opening Remarks

8:05 a.m.
### Implementation Challenges With Generation-Three Advanced High-Strength Steels
**Louis Hector, Tyson Brown, John Carsley, Li Sun and Anil Sachdev, General Motors Research and Development**
Generation-three advanced high-strength steels (GEN3 AHSS) are typically multi-phase TRIP steels that exhibit unprecedented strength and ductility. Consequently, they hold significant promise as room-temperature stampable alternatives to hot-stamped steels. GEN3 AHSS properties are achieved by regulating the stability of austenite retained at room temperature through sophisticated heat treatments and alloying. Balancing the amount of retained austenite and the kinetics of the stress-assisted or strain-induced transformation to martensite provides control over the yield behavior, work-hardening rate and necking onset. Once GEN3 AHSS becomes commercially available, they must meet specific requirements for integration into vehicle body structures. These requirements can broadly be categorized as material-related, e.g., micro- and macroscale deformation behaviors for forming and vehicle performance, and manufacturing-related, e.g., weldability, springback, formability, coatings. The purpose of this paper is to discuss these challenges in the perspective of implementing GEN3 AHSS in automotive applications.

8:30 a.m.
### Effect of Strain Rate on Tensile Deformation Behavior of a Quenched and Partitioned Steel
**Whitney Poling, Kip Findley, Emmanuel De Moor and John Speer, Colorado School of Mines**
The effects of strain rate on tensile properties and strain-induced austenite to martensite transformation were investigated for a quenched and partitioned steel. A 0.3C-3Mn-1.5Si (wt.%) steel was subjected to quenching-and-partitioning heat treatments to produce a microstructure composed of martensite and 14 vol.% austenite. Tensile testing was performed at 10 different rates in the strain rate range 0.0001 to 200 $s^{-1}$. At four of the strain rates, the tests were interrupted at various strain levels up to failure. The extent of retained austenite transformation as

a function of strain, measured with x-ray diffraction performed on interrupted tensile test specimens, was similar across the strain rate range. Yield strength increased with increasing strain rate, but tensile strength was independent of strain rate. Ductility had a minimum value at a strain rate of 1 $s^{-1}$. The results are compared to strain rate effects in other steels with high martensite content.

8:55 a.m.

### Microstructural Evolution During Quenching and Partitioning of 0.2C-1.5Mn-1.3Si Steels With Cr or Ni Additions

**Dean Pierce, Oak Ridge National Laboratory; Dan Coughlin, Los Alamos National Laboratory; Kester Clarke and Emmanuel De Moor, Colorado School of Mines**

The influence of Cr and Ni additions and quench and partition (Q&P) processing parameters on microstructural development during Q&P, including carbide formation and austenite retention, was studied in two steels with a base composition of 0.2C-1.5Mn-1.3Si wt.% and additions of 1.5 wt.% Cr (1.5Cr alloy) or Ni (1.5Ni alloy). Additions of 1.5 wt.% Cr significantly reduced the kinetics of austenite decomposition relative to additions of 1.5 wt.% Ni at all partitioning temperatures, promoting greater austenite retention in the 1.5Cr alloy after Q&P. Mössbauer effect spectroscopy, transmission electron microscopy, and atom probe tomography were used to quantify and characterize the amount, structure and composition of carbides in the microstructures. In general, carbide amounts below ~0.3 vol.% were measured in both alloys after partitioning for short times (10 seconds), irrespective of quench or partitioning temperature, which corresponds to a relatively small portion of the bulk C in the alloy.

9:20 a.m.

### Lüders and Portevin-Le Châtelier Bands in a Medium-Mn TRIP steel

**Mingxin Huang, The University of Hong Kong**

Lüders band and Portevin-Le Châtelier (PLC) bands in a medium-Mn transformation-induced plasticity (TRIP) steel were investigated by in-situ digital image correlation (DIC) technique coupled with in-situ full-field temperature measurement. The full-field strain and heat source measurements are used concurrently to investigate in-situ the propagative bands. The local Lüders strain is demonstrated both space- and time-independent, and its magnitude is equivalent to the macroscopic Lüders strain. The spatio-temporal independent characteristic is also verified on the local strain in the PLC bands. Then the estimated heat sources are applied to establish an experimental energy balance during the plastic deformation. The quantitative energy analysis reveals that the strain-induced martensitic transformation takes place in the Lüders band but barely in the PLC bands. The ex-situ x-ray diffraction measurement on the phase content and surface hardness testing of the material confirm well this determination.

9:45 a.m.

Break

10:15 a.m.

### Tensile Behavior of Medium-Mn Steels That Exhibit Two-Stage TRIP Behavior

**Daniel Field and David Van Aken, Missouri University of Science and Technology**

Medium-manganese steels often demonstrate dynamic strain aging and rapid work hardening. Tensile behavior of three medium-manganese steels are studied in both the hot band condition and a cold worked and batch annealed condition. Starting microstructures were a combination of γ-austenite, ε-martensite, α-martensite and α-ferrite. Intrinsic stacking fault energies calculated at room temperature, varied between –2.1 and 0.2 $mJ/m^2$. Tensile strengths ranged from 1,215 MPa to 1,404 MPa with total elongations of 23.6% to 34.1%. Interrupted tensile tests were performed and x-ray diffraction was used to characterize the strained microstructures. All three alloys showed evidence of two-stage transformation-induced plasticity (TRIP) where the starting microstructure TRIP'd in sequence of $\gamma \rightarrow \varepsilon \rightarrow \alpha$ or $\varepsilon \rightarrow \alpha$. One of the alloys was modified with 4.4 wt.% Cr and the dynamic strain aging observed in the hot band condition was significantly reduced as a result of M23(C,N)6 precipitation during batch annealing for 20 hours at 600°C. Strain hardening exponent for the Cr-bearing steel decreased from n = 0.78 in the hot band condition to n = 0.29 in the batch annealed condition.

10:40 a.m.

### Effect of Starting Microstructure and Intercritical Annealing Parameters on Mechanical Properties of a Medium-Mn Third-Generation Advanced High-Strength Steel

**Joseph McDermid, Daniella Pallisco and Elizabeth McNally, McMaster University; and Frank Goodwin, International Zinc Co.**

Third-generation advanced high-strength steels (3G AHSS) are relatively cost-effective alloys with superior combinations of high strength and ductility that make them promising candidates for vehicle lightweighting. The present work investigates the microstructural evolution and mechanical properties of a prototype 0.2C-6Mn-1.5Al-0.5Si 3G AHSS resulting from heat treatments that are compatible with the continuous galvanizing process. This paper will discuss the effects of starting microstructure and intercritical annealing parameters on the microstructural evolution of the alloy, focusing on retained austenite volume fraction and morphology, and resultant uniaxial tensile properties within the context of established U.S. Department of Energy targets.

11:05 a.m.

### Effect of Reheating Temperature on the Mechanical Behavior of Lamellar Morphology 10Mn Steel Sheets

**Dong Hwi Kim, Yoon-Uk Heo and Sung-Joon Kim, Graduate Institute of Ferrous Technology, POSTECH**

Medium-Mn steels show a variety of microstructures and mechanical properties depending on the heat treatment conditions. In this research, the difference of tensile properties between ultrafine-grained (UFG) and lamellar structure with different annealing histories and the effect of tempering were investigated for an Fe-0.2C-10Mn-Al steel. The UFG structure was formed by annealing and water quenching after cold rolling. To obtain diverse volume fraction and mechanical stability of $\gamma$, three different annealing temperatures — 650, 700 and 750°C — were used. The heat treatment at 900°C was added before annealing to make lamellar structure. The UFG structure showed yield point elongation at 650 and 700°C. However, lamellar structure exhibited smooth and serration behavior, respectively. At 750°C, both structures showed low yield strength and severe work hardening due to the abrupt martensite transformation in unstable austenite. In order to overcome these weaknesses, tempering was applied. Through tempering at 200°C, very high yield strengths up to 900 MPa were achieved.

11:30 a.m.

### Double Soaking of a 0.14C-7.14Mn Steel

**Alexandra Glover, Emmanuel De Moor and John Speer, Advanced Steel Processing and Products Research Center, Colorado School of Mines**

Double soaking has been proposed as a novel heat treatment to create a microstructure of martensite and retained austenite in medium-manganese steels. The primary soak, an intercritical annealing treatment, results in austenite nucleation and growth with manganese partitioning from ferrite/martensite to austenite. The secondary soak, conducted at temperatures above the primary soak, transforms some of the remaining ferrite to additional austenite. The secondary austenite transforms to martensite upon quenching, leading to a microstructure of martensite, austenite and potentially ferrite, depending on the secondary soak temperature. Substantial alloy partitioning during the secondary soak treatment is not desired, as this would reduce austenite retention after quenching. As an example of this concept, this paper presents the response of a 0.14C-7.14Mn (wt.%) medium-manganese steel to a double-soaking heat treatment using dilatometry, x-ray diffraction and tensile testing. Retained austenite fractions up to 30 vol.% have been measured after double soaking in this alloy.

11:55 p.m.

Lunch

1:15 p.m.

### Microchemical Banding of Si and Mn and Their Effect on the AHSS

**Monika Krugla, Tata Steel Research & Development and Delft University of Technology; S. Erik Offerman and Jilt Sietsma, Delft University of Technology; and Dave Hanlon, Tata Steel Research & Development**

The casting processes currently employed for producing sheet steels, although effective, result in macro- and microchemical segregations of the elements. The next production steps are not effective or even designed to remove those. The possibility of producing materials with banded microstructure is dealt with as a result. Much effort is put into preventing this since it can adversely affect the mechanical properties of the final product. Since most sheet steels are produced containing some levels of Si and Mn, an investigation was conducted on how the whole process is influenced by changing Si levels in model alloys Fe-Si-C and Fe-Si-Mn-C. The effect of bending on final properties is also considered.

1:40 p.m.

### As-Cast Microstructure Evolution in AHSS Grades and Its Effect on Slab Quality

**Rafael Coura Giacomin and Bryan Webler, Carnegie Mellon University**

New advanced high-strength steel (AHSS) grades with elevated C, Mn and Si for the automotive industry must be compatible with existing steel production infrastructure. One of the challenges to this has been cracking of continuously cast slabs either before or during hot rolling. This study examines the three lab-scale ingots in the as-cast state with compositions 0.2 wt.% C; 3 wt.% Mn; and 0.5, 1.5 and 3.0 wt.% Si. The objective of this study was to identify features of solidification structure and microstructure that may influence the cracking. Macrostructure consisted of mainly columnar grains. The room-temperature microstructure presented granular bainite with proeutectoid ferrite as the main components. The steel Si level was identified as an important variable in microstructure development as the amounts of proeutectoid ferrite and retained austenite increased with Si.

2:05 p.m.

### Comparison of Different Techniques to Improve the Cold Rollability of High-Strength AHSS

**Annette Baumer, Ekaterina Bocharova, Richard Thiessen and Roland Sebald, thyssenkrupp Steel Europe**

Driven by the demands of the automotive industry, advanced high-strength steels with increasing strength levels have been developed. In many cases, an increase in the final strength of the product is synonymous with an increase of the strength of the material during the manufacturing process. This means for example that cold rolling becomes more challenging. On the other hand, there are of course ways to meet these challenges like changing the process parameters of hot rolling, batch annealing of the hot strip or intermediate batch annealing between two cold rolling steps. Nevertheless, all these methods can influence the material properties of the final product. In this paper, the advantages and disadvantages of the methods are discussed.

2:30 p.m.

### Evaluation of Galvanizing Line Furnaces for the Production of Advanced High-Strength Steels

**John Stedge, Primetals Technologies USA LLC**

The development of third-generation advanced high-strength steels requires more challenging thermal processing: higher peak metal temperatures, faster cooling to lower temperatures, reheating and holding. Consideration of the practical limitations of modern strip heat treatment lines is a necessity when developing new steel grades. In many cases, due to the lack of market demand, modification of an existing line is more cost effective than investment in a new processing line. However, a modification not only adds physical constraints to the design of the thermal cycle, but it also presents the challenge of minimizing lost production by reducing outage time. An optimum solution considers the trade-offs with variations of the desired thermal cycles, as well as the existing and future needs of new material development. This paper reviews key aspects of furnace design for third-generation AHSS and a methodology for evaluating existing furnaces as candidates for modification to produce these products.

2:55 p.m.

Break

3:20 p.m.

### Performance Characteristics of HyCAL Toll Continuous Annealing Facility

**Mark Blankenau, HyCAL Corp.; Matthias Brenninger, Ebner; and Mark Slack, Ferrous Metals Processing Co.**

HyCAL has constructed a continuous annealing line for the toll processing of AHSS products in Gibraltar, Mich., USA. Ebner supplied the bulk of the equipment using their HiCON/H2® technology. The process will be described, and the facility's capabilities demonstrated since the start-up in the fourth quarter of 2016 will be presented.

3:45 p.m.

### Annealing Furnace Concept and Oxide Thickness Control From Laboratory Test to Industrial Control Tolerances

**Kahoul Karim, Danieli Centro Combustion**

Nowadays, many papers describe the effect of the pre-oxidation of AHSS then the reduction and the effect the wettability of the strip through the zinc bath. This paper intends to highlight the different pre-oxidation and reduction methods that can be used in the annealing furnace, in the direct flame, in the radiant section and through a muffle furnace. The paper intends also to explain the different kinetics at a process control level and highlight the limits of the available instrumentations compared to any test that can be done at the laboratory scale. The intention is to also describe possible new annealing furnace combinations that can further the quest for the processing of third-generation AHSS.

4:10 p.m.

### Induction Heating of Advanced High-Strength Steels

**Gerald Vellente, Ajax TOCCO Magnethermic**

The production of advanced high-strength steels (AHSS) is gaining more importance in order to provide lighter-weight steels and, at the same time, maintain safety. Part of the process of producing these steels is reheating the steel prior to entering the coating pot. Most producers, whether in a new line or retrofitting an existing line, are considering induction heating to accomplish this reheat. One of the difficulties in determining what induction equipment is required is the magnetic properties of the steel at the point where the reheating is required. This paper will review the background information in determining these properties, setting up and performing lab tests, and comparing the theoretical information with the test data. The presenter will then discuss a typical application using the information developed and package an induction heating system.

4:35 p.m.

### Flash Bainite: Room-Temperature Stamping 1,500 to 1,800 MPa Structural and Energy-Absorbing Components to <2T Bend Radii

**Gary Cola, Flash Bainite**

Flash® Bainite processing employs rapid thermal cycling (<10 s) to strengthen COTS steel sheet, plate and tubing into AHSS. In a continuous process, induction technology heats a narrow segment of the cross section in just seconds to atypically high temperatures (1,000–1,300°C). Quenching substantially immediately follows. Flash processing optimizes the inherent heterogeneity of steelmaking to create an intragranular multi-chemistry, complex mixture of bainite, martensite and other morphologies. Carbon migration and carbide dissolution are controlled by limiting time in the austenitic range. Unlike conventional heat treating, homogeneity is intentionally avoided. Flashing steel such as AISI1010 (1,100 MPa UTS) and AISI1020 (1,500 MPa UTS) has shown excellent room-temperature stampability.

6–9 p.m.

Reception/Dinner

## FRIDAY, 2 JUNE 2017

7 a.m.

Continental Breakfast

8 a.m.

### Introductions and Opening Remarks

8:05 a.m.

### Study on Hot Press Forming (HPF) Die Development for Cooling Efficiency Improvement With Direct Spray Process

**John Hyung and Jin Moon, CoreLink Tech; Chung-Gil Kang, Pusan National University; Baeg-Soon Cha, KITECH; OkDong Lim, AutoGen**

Demand for higher safety and fuel efficiency of the automobiles has increased because of environmental regulations. Weight reduction and high-performance materials are needed to fulfill this demand. Ultrahigh-strength steel parts are the answer, which are made through hot press forming operation. Compared to cold press forming, hot press forming has lower productivity. Hot press forming requires longer time for press-hardening. To shorten this, a direct spray process is preferable over indirect cooling process by a gun drill. In this study, sprayers and cooling runners will be manufactured on die surface to cool heated blank with the direct spray process. As a result, a deviation of blank temperature within ±10˚C was achieved and more than 50% efficiency was secured on the pressing duration of 14 seconds. When the mechanical properties of blank were evaluated, the tensile strength was 1.5 GPa. However, recently, the issue of hydrogen embrittlement on ultrahigh-strength steel has come up. Considering this, hydrogen diffusivity and penetration were studied, which occur by external factors of ultrahigh-strength steel parts using the direct spray process. Based on this study, the direct spray process was applied to a center pillar die and studied.

8:30 a.m.

### Fe-Zn Reactions During Annealing of a Galvanized 22MnB5 Steel

**Sung-Joo Kim, Jee-Hyung Kang, Doyub Kim and Dong-Hwi Kim, Graduate Institute of Ferrous Technology, POSTECH; and Young-Duk Seo, Kyungpook National University**

Hot sheet metal forming involves annealing of steel sheets normally up to ~900°C. When galvanized steel sheets are introduced to hot stamping, the process is complicated by Fe-Zn reactions at the interface during the annealing. In order to investigate the Fe-Zn reactions, galvanized 22MnB5 steel sheets were annealed at 500–900°C for 5 minutes. Fe-Zn intermetallics and Zn-rich α were observed to generate following their equilibrium compositions. The intermetallics are formed at the interface and grow toward the coating, while Zn rich α forms at both the substrate/coating interface and grain boundaries of substrate and Γ1. The morphology of Zn-rich α depends on temperature. At the temperatures < 800°C where Γ1 is stable, Zn-rich α assumes submicron grains along the grain boundaries of the substrate. However, at both 800 and 900°C, both Γ1 and a part of substrate are rapidly consumed by large Zn-rich α grains.

8:55 a.m.

### Third-Generation AHSS: Nanonphase Refinement and Strengthening During Cold Deformation

**Daniel Branagan, Alla Sergueeva, Andrew Frerichs, Brian Meacham and Sheng Cheng, The NanoSteel Co.**

The historical development of autobody steels has demonstrated a paradoxical relationship between strength and ductility. Automotive lightweighting requires increased strength, but current steels have ductility that is too low for cold formability, resulting in geometric constraints in part design and manufacturing. This effect ultimately limits usage of the higher-strength steel grades in automobiles. NanoSteel's new class of third-generation AHSS has a unique and compelling combination of tensile strength (~1,200 MPa) and elongation (~50%) with high cold formability. In this presentation, the role of the enabling cold-deformation mechanism called nanophase refinement and strengthening will be demonstrated in association with property changes and structural evolution involving complex interaction of dislocation dominated deformation mechanisms with sequential phase transformation, nanoscale phase formation, nanoprecipitation and dynamic strain aging effects. The role of each structural microconstituent in the deformation process leading to advanced property combination of the third-generation AHSS will be discussed.

9:20 a.m.

### Effects of Grain Size on Mechanical Properties of Silicon-Added High-Mn TWIP Steel

**Sukyoung Hwang, Yu Bai, Si Gao, Akinobu Shibata and Nobuhiro Tsuji, Department of Materials Science and Engineering, Kyoto University**

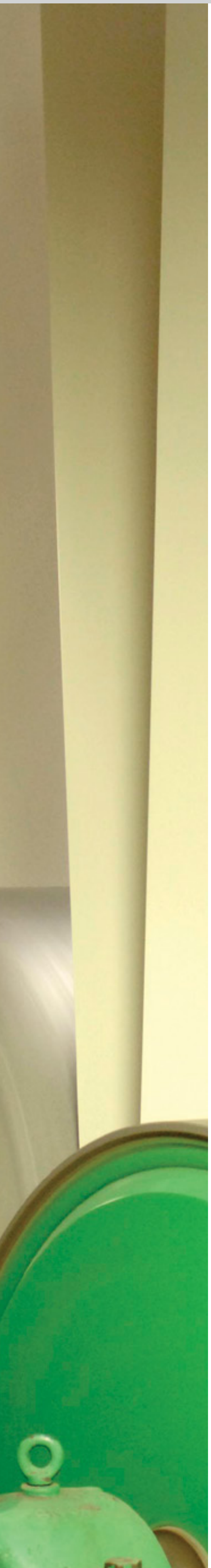
Twinning-induced plasticity (TWIP) steel is well known for the outstanding mechanical properties combining high strength and ductility, which result from formation of mechanical twin during plastic deformation. However, the yield strength of the TWIP steel is not as high as other advanced high-strength steels (AHSS). Grain refinement is one of the methods to increase the strength, especially the yield strength, of polycrystalline materials according to the well-known Hall-Petch relationship. In the present study, the 22Mn-0.6C-3Si TWIP steel having fully recrystallized ultrafine grain (UFG) sizes were produced through repetitive cold rolling and subsequent annealing processes. Mechanical properties at room temperature are discussed in relation to the microstructures, focusing on the effect of silicon on the strain hardening and the microstructure evolution during deformation.

9:45 a.m.

### Third-Generation AHSS: New Factors Affecting Local Formability

**Alla Sergueeva, Daniel Branagan, Andrew Frerichs, Brian Meacham and Sheng Cheng, The NanoSteel Co.**

For advanced high-strength steels (AHSS), local formability has proven to be a challenging limitation for designers seeking to use these materials for automotive lightweighting applications as evidenced by unpredicted failure in stretch bending and edge stretching. There are various factors known to influence local formability in autobody steels, including hole/edge preparation method, total elongation, hardness differences of structural phases, yield to tensile strength ratio, true strain at fracture, and post-uniform elongation. In many cases, these existing correlations, especially when derived from global tests such as uniaxial tensile testing, do not represent observed local formability results for AHSS grades. In this presentation, both existing and new factors enabling substantial improvement of local formability due to unique mechanistic responses in NanoSteel third-generation AHSS will be discussed. Local formability response will be demonstrated using hole expansion ratio testing in



correlation with deformation mechanisms and resulting structural evolution.

10:10 a.m.
Break

10:35 a.m.
### Investigation of Strain Instabilities in Third-Generation Medium-Manganese TRIP Steels
**Michael Callahan and Jean-Hubert Schmitt, CentraleSupelec**
Efforts of the automotive industry in vehicle lightweighting has led to the development of third-generation advanced high-strength steels, notably medium-manganese steels. Engineering of the strain hardening rate of these steels is difficult due to undesirable Lüders and Portevin-Le Châtelier-type strain instabilities that are sometimes present. The tensile properties of a Fe-0.2C-5Mn-2.5Al medium-Mn TRIP steel were investigated to study the strain hardening behavior of the alloy. Intercritical annealing temperatures of 740°C, 760°C and 780°C produced varying rates of strain-induced martensitic transformation (TRIP). Previous work showed that the strain instabilities coincide with the TRIP effect. Here, the strain rate was varied and to investigate its effects on both the strain instabilities and TRIP effect. Bake-hardened specimens were tested as well to observe the effects of low-temperature anneals on instabilities. The results of these experiments are presented along with an explanation of the source of the strain instabilities.

11 a.m.
### Deformation-Induced Martensite Transformation and Serrated Plastic Flow in Medium-Mn Steels
**Binhan Sun, Nicolas Vanderesse, Jianqiang Chen, Philippe Bocher and Stephen Yue, McGill University; and Fateh Fazeli and Colin Scott, CanmetMATERIALS**
The stability and dynamic transformation of retained austenite upon straining remain critical in controlling the mechanical performance of medium-Mn steels. In the present study, the phenomenon of serrated plastic flow due to the Portevin-Le Châtelier (PLC) effect was observed in duplex ferrite and austenite 7 and 10 wt.% Mn steels with certain austenite stability. The kinetics of deformation-induced martensite transformation (DIMT) is essentially affected by this localization of plastic flow. In order to investigate the interplay between these two, the magnetic induction method with a Feritscope was used to characterize the DIMT of the steel samples during tensile tests at different strain rates. Further, the PLC banding behavior of the tensile specimens was investigated by digital image correlation. A discontinuous martensite transformation behavior was observed, and its contribution to the overall work-hardening behavior of the medium-Mn steels was further analyzed.

11:25 a.m.
### Deformation Mechanism of Ultrafine-Grained High-Mn Austenitic TWIP Steel
**Yu Bai, Hiroki Kitamura, Akinobu Shibata and Nobuhiro Tsuji, Kyoto University; and Yanzhong Tian, Shengyang National Laboratory for Materials Science, Institute of Metal Research, Chinese Academy of Sciences**
In a previous study, it was found that high-Mn austenitic TWIP steels with fully recrystallized ultrafine-grained (UFG) structure having mean grain sizes smaller than 1 μm could be fabricated by simple cold rolling and annealing process without severe plastic deformation. The UFG TWIP steels showed both high strength and large ductility, but the reason for such good mechanical properties was not understood yet. In the present study, the deformation mechanism of UFG 31Mn-3Al-3Si steel was investigated. It has been believed that deformation twinning is suppressed with decreasing the grain size of austenite. However, the fraction of deformation twins increased in the UFG specimen. It was also confirmed by in-situ synchrotron diffraction that the dislocation density increased rapidly at the yield point in the UFG specimen. Based on these results, the deformation mechanism of the UFG TWIP steel is discussed.

11:50 a.m.
Lunch

1 p.m.
### Segregation in Quenched and Partitioned Steels: The Role of Hot Rolling Parameters
**Ali Smith and Luciano Bozzetto, Centro Sviluppo Materiali**
Quenched and partitioned (Q&P) sheets steels are fabricated by hot and cold rolling, annealing, and a quench and partitioning heat treatment. The aim is to produce a steel microstructure of tempered martensite and metastable austenite, which exhibits superior mechanical properties combinations (e.g., 15% total elongation with tensile strength of 1,500 MPa). An essential component of these steels is the addition of several percent of manganese for improved hardenability. However, manganese promotes segregation, leading to banding and non-uniform mechanical properties. For industrial production of sheets with uniform properties, the hot rolling parameters should, therefore, be optimized to reduce the banding phenomenon as far as possible. Based on these considerations, the current work presents results of laboratory rolling trials on a Q&P steel, illustrating the effects of hot rolling parameters on microstructural banding.

1:25 p.m.

### Non-Equilibrium Thermodynamics of Quench and Partition Steels

**Amit Behera and Greg Olson, Northwestern University**

Quench and partitioning (Q&P) is a novel concept that promises to take the third generation of advanced high-strength steels (AHSS) to better combinations of strength and ductility while reducing the overall manufacturing costs. Thermodynamics-based genomic design approach supported by advanced microstructural characterization techniques would help design optimized processing routes and new steel compositions without the need for prolonged experimental studies. The current work endeavors to understand and model non-equilibrium thermodynamics behind the different phase transformations occurring during the Q&P cycle. Experimental measurements are used to quantify stored energy for displacive transformations. Models based on the thermodynamic and kinetic aspects of these transformations are developed and simultaneously used to design optimized processing cycles and new alloy compositions. The thermodynamic and kinetic simulations with use of commercially available software such as ThermoCalc and DICTRA are calibrated and compared to highly accurate experimental measurements using electron microscopy and three-dimensional atom probe.

1:50 p.m.

### Recent Advances in TMR-DQP Processing for Tough, Ductile High-Strength Strip Steels

**Mahesh Chandra Somani, David Porter, Jukka Komi and L. Pentti Karjalainen, University of Oulu; and Raja Devessh Misra, University of Texas at El Paso**

The TMR-DQP processing route developed at the University of Oulu, comprising thermomechanical rolling followed by direct quenching and partitioning, has shown good potential for the development of not only tough ductile ultrahigh-strength structural steels but also hard abrasion-resistant steels. Right from designing appropriate compositions to establishing the DQP parameters with the aid of physical simulation, the emphasis was essentially made to ensure that the process was cost-effective and amenable for industrial hot strip production. Evaluation of DQP-processed laboratory-rolled samples confirmed achieving the desired martensite-austenite microstructures and targeted mechanical properties. Ausforming in Tnr regime resulted in extensive refining and randomization of the martensite packets/laths besides fine division of interlath austenite, thus resulting in an all-around improvement of mechanical properties, including low-temperature toughness and uniform elongation. The paper will highlight recent advances made in the direction of TMR-DQP processing and the associated challenges.

2:15 p.m.

### Revealing the Condition of Austenite Decomposition During Partitioning in Q&P Steels

**Wei Xu, Northeastern University**

Quenching and Partitioning (Q&P) steels presents a very promising solution of the third-generation AHSS steels, of which only partitioning of carbon is assumed during the partitioning stage and no decomposition of austenite is taken into account. However, various studies have suggested that the austenite decomposition may actually take place and hence place a very important role in determining the mechanical properties, depending on the chemical composition and Q&P processing parameters. In this study, the isothermal decomposition of austenite during partitioning stage is systematically investigated using dilatometer, on a series of alloys with different Mn concentrations, following both one-step and two-step Q&P process routes. The microstructures are characterized in detail. The results reveal the composition and processing domains wherein the austenite decomposition cannot be ignored. The results can be used as guideline for the design and optimization of Q&P process window.

2:40 p.m.

Break

3:05 p.m.

### Influence of Oxidizing Gas and Surface Microstructure on High-Temperature Oxidation of Advanced High-Strength Steel

**Mary Story and Bryan Webler, Carnegie Mellon University**

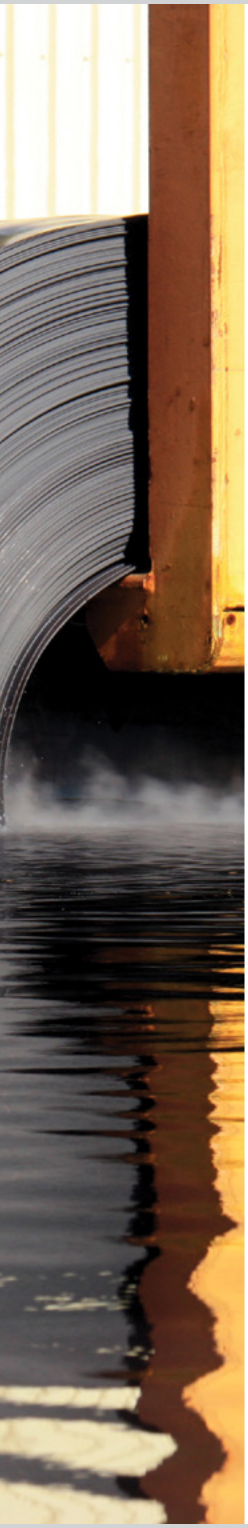
This work examined how steel surface microstructure affected oxidation behavior under conditions typically encountered during continuous annealing. Alloy chemistry and annealing furnace conditions can lead to surface oxides that inhibit galvanized coating adherence. Surface oxide growth and morphology of a dual-phase CMnSi steel (0.0902 wt.% C, 0.906 wt.% Si and 2.019 wt.% Mn) were viewed in-situ during heating with a confocal scanning laser microscope (CSLM). These results were correlated with information obtained via thermogravimetry (TG). Experiments investigated oxidizing gas, surface microstructure, gas flow and heating rate. The effects of these variables on promoting internal oxidation over external oxidation were examined.

3:30 p.m.

### Enhanced Pickling Speeds and Surface Preparation of AHSS Using Oxigen-X™ Molten Salt

**David Sequeira and Dan Balcer, Fives ST; Louis Pignotti and Jim Malloy, Kolene Corp.; and Oscar Lanzi, ArcelorMittal Research & Development**

Silicon, manganese, aluminum and other alloying elements used to improve the mechanical properties of high-strength steels will diffuse to the surface of the steel during hot milling operations. The resulting surface is an alloy-rich scale that requires slower pickling speeds to remove. Even with decreased line speed, complete surface preparation is difficult to obtain with acid immersion alone. Traditional line speed can be obtained by using Oxigen-X molten salt in combination with traditional hydrochloric acid pickling. Work presented here includes surface analysis of AHSS samples treated with and without Oxigen-X molten salt. The results of the analysis show the samples treated with Oxigen-X molten salt have an improved surface over the samples that were pickled only.



3:55 p.m.
### Shearing and Slitting AHSS-ASKO HXTTM Knives
**Brian Shaw and Joel Kneisley, ASKO Inc.**
The mechanical properties of AHSS are rapidly increasing beyond the capabilities of in-place processing equipment. Pickle lines, galvanizing lines and service centers face the challenges of processing steels with tensile strengths from 600 to 1,700 MPa. Most existing equipment and knives were not designed to sidetrim, scrap chop, shear or slit AHSS grades. To address this challenge, ASKO has developed its HXTTM knife technology (patent pending) to process third-generation advanced high-strength steels on existing equipment, producing optimum sheared edge quality. For many pickle lines and processors, ASKO HXTTM knives have demonstrated 3X to 6X the life of conventional knives. The HXTTM combines knife material grade, heat treatment and edge conditioning.

4:20 p.m.
### Selective Oxidation of Advanced High-Strength Steels and Ultrahigh-Strength Steels (UHSS) Utilizing Direct-Fired Burners
**Scott Brown, Frank Beichner, David Schalles and Matthew Valancius, Bloom Engineering Co. Inc.**
This paper will address the utilization of direct-fired burners for the production of advanced high-strength steel (AHSS) and ultrahigh-strength steel (UHSS) utilizing the selective oxidation process. The paper will concentrate on hot-dip galvanizing lines (HDGLs) to show how to implement the selective oxidation process, utilizing direct-fired burners, to increase the wettability of the steel in the zinc coating pot, as well as improving physical properties of the steel. The process discussed will include placement of the selective oxidation zone in the furnace, combustion setup needed to perform the process, as well as common process parameters. This paper will also discuss the way that new and current HDGLs can be built or retrofitted to allow for the selective oxidation process, by utilizing direct-fired burners.

4:45 p.m.
### The Effect of Internal Oxidation on the Bendability of Ultrahigh-Strength Steel
**Yuyi Zhu and Barbara Shollock, Warwick Manufacturing Group; and Wanda Melfo Prada, Tata Steel**
Ductile ultrahigh-strength steels (UHSS) are finding increased use in automotive applications. The so-called third generation of AHSS utilizes alloy additions that may have negative consequences for surface quality. During steel processing, external and internal oxides form and can affect the forming of final products. The current research is focused on the simulation of the surface/subsurface reactions that lead to the formation of the internal oxides during processing and establishing the link between the near surface condition and the formability of the final product. The internal oxidation depth largely depends on the temperature, atmosphere, top surface composition and alloying additions. Rolling, hot coil cooling, pickling and annealing were simulated under lab conditions to create a better understanding of how internal oxides develop during the whole flat steel production process. Microstructural characterization, including EBSD and STEM, were used to determine the nature and distribution of the internal oxides formed on the hot coil. Bendability tests were conducted on as-annealed material.

5:10 p.m.
Conference Adjourn

## ORGANIZING COMMITTEE

**Emmanuel De Moor**
Colorado School of Mines

**Narayan Pottore**
ArcelorMittal Global R&D

**Grant Thomas**
AK Steel Research

**Matt Merwin**
United States Steel Corporation

**John G. Speer**
Colorado School of Mines

# REGISTRATION

US$1,075
AIST Member

US$1,290
Non-Member

## REGISTRATION FEES

Advance registration by 17 April 2017: Member US$1,075, Non-member US$1,290.
Registration after 17 April 2017: Member US$1,175, Non-member US$1,390.

## REGISTRATION INCLUDES

Registration fee includes receptions Tuesday and Wednesday, continental breakfasts and lunch Wednesday through Friday, dinner Thursday and conference proceedings.

## HOTEL ACCOMMODATIONS

A block of rooms has been reserved at The Keystone Lodge and Spa and the Keystone Conference Villages. Please call the hotel at +1.800.258.0437 by 8 May 2017 to secure the AIST discount rate of US$125–149 per night for single/double occupancy. Please note that each room night has an additional US$15 resort fee per night. This includes: complimentary self-parking, wireless internet access in guestrooms and public areas, business center access and fitness center, pool and hot tub access at Keystone Lodge Spa, and other amenities. Also, when staying one or more nights, the resort offers the Play for Free deal, which includes activities such as free 9 holes of golf after 4 p.m. on day of arrival, free yoga or fitness classes, free guided hike, free scenic lift ticket for kids under 12, and free cookies upon arrival.

Association for Iron & Steel Technology
186 Thorn Hill Road
Warrendale, PA 15086-7528 USA
+1.724.814.3000 • Fax +1.724.814.3001 • AIST.org



# UPCOMING EVENTS

- **24th Annual Crane Symposium**
  11–13 June 2017 | Pittsburgh, Pa., USA
- **Managing Technology — Big River Steel**
  12–14 September 2017 | Memphis, Tenn., USA
- **Sheet Processing and Finishing Lines — A Practical Training Seminar**
  17–21 September 2017 | Ypsilanti, Mich., USA
- **Material Handling and Transportation Logistics**
  10–12 October 2017 | Louisville, Ky., USA
- **Continuous Casting — A Practical Training Seminar**
  16–19 October 2017 | Fort Wayne, Ind., USA
- **Secondary Steelmaking Refractories — A Practical Training Seminar**
  23–26 October 2017 | Milwaukee, Wis., USA
- **Maintenance Solutions — A Practical Training Seminar**
  5–8 November 2017 | Charleston, S.C., USA
- **Modern Electric Furnace Steelmaking — A Practical Training Seminar**
  5–9 February 2018 | Memphis, Tenn., USA