Agenda

- ThyssenKrupp Steel USA
- Automotive Industry Challenges
- Steel Industry Solutions
ThyssenKrupp Steel USA LLC

- The company was created in 2007 to construct and operate a carbon steel processing facility to serve customers in the NAFTA market.
- 4.3 million metric tons of flat rolled carbon steel products annually.
- ~1750 employees.
- Full range of steel grades, hot rolled bands, hot rolled pickled and oiled, cold rolled, and coated (galvanized, galvannealed and Galvalume®).
- Focus on automotive steel grades from Mild, HSS, AHSS and UHSS.
Automotive Manufacturers and Suppliers Face Critical Challenges

Choice of materials is essential in meeting the requirements.

- Maintain government and industry safety standards (NHTSA/IIHS)
- Meet CAFE and other global FE/CO₂ regulations
- Lightweight Design

Automotive OEM
Built vehicles that customers will buy
Lightweight Design with Advanced Material Applications

Body-in-white structures with diverse material mix

1974 VW Beetle
- 100% Mild Steel

2012 Ford Fiesta
- 8% DP780
- 18% DP600
- 20% HSLA (300 – 400 Mpa)
- 5% Boron
- 5% BH – HSLA (<300 MPa YS)
- 41% Mild Steel

2013 Cadillac ATS
- 4.80%
- 22.60%
- 29.60%
- 17.50%
- 5.70%
- 2.90%
- 17%

2013 Infiniti JX35 (QX50)
- 680 MPa
- 750 MPa
- 840 MPa
- 930 MPa
- 1030 MPa
- 1120 MPa
- 1210 MPa
- 1300 MPa
- 1390 MPa
- 120 MPa
- 100 MPa
- 80 MPa
- 60 MPa
- 40 MPa
- 20 MPa
- 0 MPa
NHTSA and IIHS Crash Load Cases

Light-weighting cannot compromise the compliance of vehicles

Source: SMDI
The Corporate Average Fuel Economy (CAFE)

- CAFE standards serve as a means to conserve petroleum and to reduce US reliance on imported oil. The fuel economy had not changed from 1985 till the Energy Independence and Security Act (EISA) in 2007.

- The footprint formula assigns each car and light truck a fuel economy target based on its footprint, which is track-width x wheelbase.

- The idea is not to advantage OEMs with smaller cars and disadvantage those with bigger cars, but to encourage development of new technologies and offer customer the whole fleet of models.

- The sales-weighted average of the targets for an automaker’s fleet is the CAFE average that the company must achieve in a given model year. No vehicle is required to meet a specific fuel economy number.

- When the average fuel economy of a manufacturer’s fleet is below the standard, the manufacturer must pay a penalty (over $700 million penalties paid so far).
CAFE Requires A Fuel Economy of 54.5mpg (163g/mi equivalent)
Applies to combined passenger cars and light trucks
Other Countries Have More Stringent Fuel Economy Regulations
Where will the enabling technologies be developed?

Source: ICCT, August 2011
Life Cycle Assessment (LCA) is critical
GHG Emissions in The Production and Use of Materials for Automotive

LCA needs to be part of the thinking behind CAFE and other CO$_2$ regulations
Life Cycle Assessment

Higher production emissions may not offset lower use-phase emissions

Source: WorldAutoSteel, UC Davis

Cumulative GHG emissions

Use phase emissions

End of vehicle life

Vehicle production & recycling emissions

Lower density material

Steel

Total driven distance

Source: WorldAutoSteel
Agenda

- ThyssenKrupp Steel USA
- Automotive Industry Challenges
- Steel Industry Solutions
Steel Facts

**Market:** 2012 Shipments of 96 Mio. tons (Automotive 25%)

**Employment:** 161,900 direct and more than one million indirect jobs

**Recycling:** 97% of steel by-products can be re-used, recycling rate of steel itself is 92%

**Efficiency:** Industry has reduced energy intensity by 27% and CO$_2$ emissions by 33% since the 1990s.

**Productivity:** 1980’s: 10.1 man-hours per ton

2011: 2.1 man-hours per ton

**Innovation Power:** Excellent collaboration activities throughout the industry
Steel Industry Regularly Conducts Intensive R&D Projects
Drivers are lightweight design, safety, fuel economy and cost efficiency

- **1998 - 2004**
  - ULSAB – ULSAB-AVC

- **2003**
  - NSB® NewSteelBody

- **2009**
  - InCar®

- **2011**
  - Future Steel Vehicle

- **2014**
  - InCar® Plus
Steel Has The Inherent Potential for Large Scale Computational Studies
Opens Enormous Opportunities for Material Science and Engineering

- Discipline
- Engineering Design
- Continuum
- Microstructural
- Atomistic/Nanometric
- Electronic

Log (length scale):

Timo Faath, Bruce Wilkinson
May 15th, 2013
15

ThyssenKrupp Steel USA
Steel’s unique properties are determined by laws of chemistry and physics

- Need for stronger and more ductile materials to meet current and future safety requirements
- Better computational models to develop and characterize new materials
Key Gaps in Implementing Advanced High-Strength Steels (AHSS)
Defined by NIST, AISI and A/SP

Steel Development
- Identify steel microstructures to meet 3rd Generation AHSS
- Set up independent labs capable of rapid prototyping of AHSS and 3rd Generation AHSS
- Develop welding/joining processes insensitive to steel composition

Joining
- Develop reliable weld and joint modeling software to predict weld performance
- Update and develop guidelines for AHSS weld performance requirements
- Develop a cost effective and practical approach to improve weld fatigue

Fracture
- Develop theoretical understanding of fracture mechanics of multiphase material under different loading conditions
- Identify drivers of shear fracture behaviors in order to begin improving both performance and uniformity of materials
- Understand what modes of deformation (manufacturing processes) and their associated variables control shear fracture with the goal of developing manufacturing processes that are more robust in resisting shear fracture
Key Gaps in Implementing Advanced High-Strength Steels (AHSS)
Defined by NIST, AISI and A/SP

Modulus Characterization and Application:
- Characterize elastic behavior and develop standard tests including unloading/reloading
- Develop and validate predictive multi-scale model to explain changes in elastic behavior, including: microstructural effects, texture, anisotropy, and processing effects
- Evaluate the QPE model to determine if it can correlate with mechanical elastic behavior for springback prediction and extend to more materials and load cases (e.g. biaxial)

Delayed Fracture/Hydrogen Embrittlement (HE):
- Identify or develop appropriate test method(s) for assessing delayed fracture and HE
- Conduct basic microstructural research on HE sensitivity in high strength steels
- Develop an on-vehicle sensor to monitor in-service changes in hydrogen during operation of automobiles

Plasticity
- Develop a fracture limit diagram for AHSS
- Develop a cost efficient standard method to measure forming limits of AHSS under linear and nonlinear strain paths
- Develop improved constitutive models for AHSS currently used in BIW applications, and extend this work to 3rd Generation AHSS as they become available
DOE Funded Project to Develop 3rd Generation Steel Grades

New ICME Project on Third Generation Advanced High Strength Steels (3GAHSS)

Award to USAMP through Sec. Chu’s Office (DOE): February 1, 2013

DOE Funding: $6,000,000 with 30% in-kind match

Duration: Four Years, starting 1Q 2013 (kick-off March 12, 2013)

Recipients, Sub-recipients, and Key Contractors
- USAMP – Chrysler, Ford, General Motors
- A/SP - SMDI (AAC Steel Companies): AK Steel, ArcelorMittal, Nucor Steel, Severstal North America, ThyssenKrupp USA, U. S. Steel
- Universities: Brown University, Clemson University, Colorado School of Mines, Michigan State University, University of Illinois
- National Lab: PNNL
- Engineering Companies: EDAG, LSTC
Integrated Computational Material Engineering
DOE Project

Motivation
- Up to March 12, 2013, no steel ICME program in the U.S.
- Steels are looked upon as “mature,” “not-in-vogue,” “not nano” – just plain “not cool” compared to other materials
- Only 8 accredited university metallurgy programs in the U.S.

Project Goal
- $6M DOE Award to develop integrated computer model that allows atomistic and microstructure properties of steel to be carried over to forming, crash, and structural analysis. The model will be applied to generate a 3rd Generation AHSS.

Main Challenge
- Integrate state-of-the-art, multi-scale computational and experimental tools to produce a single ICME model to facilitate design of lightweight components.
# Studies on Advanced High-Strength Steel

## Increased activities

<table>
<thead>
<tr>
<th>University</th>
<th>Professor</th>
<th>Topic</th>
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<tr>
<td>Carnegie Mellon University</td>
<td>Warren Garrison</td>
<td>AHSS through microstructure and mechanical properties</td>
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<td>Case Western Reserve Univ.</td>
<td>Gary Michal</td>
<td>AHSS through C partitioning</td>
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<tr>
<td>Texas A &amp; M</td>
<td>Abu Al-Rub Rashid</td>
<td>AHSS through particle size and interface effects</td>
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<td>Colorado School of Mines, Ohio State University</td>
<td>David Matiack (CSM) and Robert Wagoner (OSU)</td>
<td>Collaborative GOALI Project Formability and Springback of AHSS</td>
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<td>Drexel University</td>
<td>Surya Kalidindi</td>
<td>FEM using crystal plasticity simulation modeling tools</td>
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<td>University of Pennsylvania</td>
<td>Ju Li</td>
<td>Multiscale modeling of deformation for design of AHSS</td>
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<tr>
<td>Missouri Inst. Of Science &amp; Tech.</td>
<td>David C. Van Aken</td>
<td>AHSS through nano-acicular duplex microstructures</td>
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<tr>
<td>Wayne State University</td>
<td>Susil K. Putatunda</td>
<td>High-strength high-toughness bainitic steel</td>
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Summary

- ThyssenKrupp Steel USA
  - Brand new steel mill to serve the Automotive Industry
- Automotive Industry Challenges
  - Built cars that people will buy
  - CAFE and LCA are challenging
  - Focus also on safety and weight reduction
- Steel Industry Solutions
  - Continued R&D efforts
  - Endless possibilities with steel
  - Gaps in implementing AHSS
  - ICME to develop 3rd generation steels
Is there a Future for Steel in Automotive?

CARS Magazine
October, 1953

“The day of the passenger car made primarily of iron and steel is on the wane” giving ground to aluminum, magnesium and plastics.