Introduction to 3rd Generation Advanced High Strength Steels

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Overview

• Description of Gen 3 AHSS
• Manufacturing Gen 3 AHSS
• Applications for Gen 3 AHSS
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Brief Lesson on Steel Metallurgy

• The Iron-Carbon phase diagram
Description of Gen 3 AHSS

Brief Lesson on Steel Metallurgy

- Stable structures in the iron-carbon system

**δ - Ferrite**
- Highest temperature form of solid pure iron
- Body-Centered Cubic (BCC) crystal structure
- Forms from liquid upon initial solidification

**γ - Austenite**
- Intermediate temperature form of solid iron
- Face-Centered Cubic (FCC) crystal structure
- Much more formable than ferrite phases
- Requires high alloy (Ni, Mn, C) to stabilize at room temp

**α - Ferrite**
- Room temperature form of solid iron
- BCC crystal structure
- Less formable than austenite phase
Description of Gen 3 AHSS

Brief Lesson on Steel Metallurgy

• Metastable structures in the iron-carbon system

Martensite
• Forms at low temperature from Austenite upon rapid quenching
• Unique, Body-Centered Tetragonal (BCT) structure
• Achieves highest strength of any Iron phase; higher C = higher strength
• Relatively low ductility, but good toughness when tempered

Bainite
• Forms at elevated temperature from Austenite upon isothermal holding
• Composed of feathery BCC ferrite phase with iron carbides precipitated throughout
• Although not as strong as Martensite, has appreciably better ductility
Description of Gen 3 AHSS

Evolution of Gen 3 AHSS – Conventional Steels

- Based primarily on BCC Ferrite structure
- Solid solution, precipitation strengthening
Description of Gen 3 AHSS

Evolution of Gen 3 AHSS – First Generation AHSS

- Combinations of BCC Ferrite, Martensite, Bainite
- Small amount of metastable FCC austenite in the TRIP grades
- Like conventional steels, trade strength for ductility
- Great for safety cage, but energy absorption requires greater strength AND ductility
Evolution of Gen 3 AHSS – Second Generation AHSS

Description of Gen 3 AHSS

- Based on FCC Austenite made metastable at room temperature by large additions of Mn and C
- TWIP = TWinning-Induced Plasticity
- Excellent formability, but...
- High alloy = high cost, poor weldability
- Formability much more than needed

Legend:
- IF
- PHS
- Mild
- BH
- TRIP
- Ductibor®
- CMn
- CP SF
- HSLA
- DP
- Usibor®
- MartINsite®
Description of Gen 3 AHSS

Evolution of Gen 3 AHSS – Second Generation AHSS

- Actually need something in between the First and Second Generation AHSS
Evolution of Gen 3 AHSS – Third Generation AHSS

- Fortiform® = ArcelorMittal brand of Gen 3 AHSS
- Based on Ferrite, Martensite, and Bainite with just enough Austenite to gain needed ductility
- Provide enough ductility for forming and crash energy management with minimal alloy to keep cost down and provide good weldability

Description of Gen 3 AHSS

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Manufacturing Gen 3 AHSS

**Alloy Strategy**

- **Carbon**
  - Strong austenite stabilizer, hardenability agent
  - Increases strength of Martensite phase
- **Manganese**
  - Strong austenite stabilizer, hardenability agent
  - Increases strength of Ferrite and Austenite phases
- **Silicon**
  - Inhibits carbide precipitation to keep carbon in solution in austenite
  - Detrimental to weldability, so its use is minimized

- **Aluminum**
  - Increases carbon solubility in austenite to keep it in solution
  - Increases strength of Ferrite and austenite phases
  - Lowers density slightly
- **Niobium**
  - Helps refine grain size for better ductility and toughness
- **B, Cr, Mo, Ti**
  - Hardenability agents added as necessary to accommodate mill process conditions
Manufacturing Gen 3 AHSS

Gen 3 AHSS Manufacturing Process Flow

- Mining
- Pelletizing
- Ironmaking
- Steelmaking
- Cold Rolling
- Pickling
- Hot Rolling
- Casting
- Continuous Annealing

- Entry accumulator
- Soaking furnace
- Heating furnace
- Overaging chamber
- Cooling tower
- Furnace

- Entry Looper
- Clean
- Payoff And weld
- Anneal
- Zinc Pot
- Tempering
- Post-Treat
- Exit Looper
- Cut and Recoil

- Bare
- Jetgal® (Jet Vapor Deposition Galvanized)
- Electrogalvanized

- Hot Dip Galvanized
- Hot Dip Galvannealed
Manufacturing Gen 3 AHSS

Quenching and Partitioning Thermal Cycle

- Temperature vs. Time diagram
- Heating, annealing
- Hold to stabilize Austenite structure
- Quench to partially form Martensite
- Reheat to partition carbon back to Austenite
- Final cool to ambient

Ms - Martensite start
Mf - Martensite finish
Applications for Gen 3 AHSS
Fortiform® High Formability (HF) and High Strength, High Formability (HSHF) for cold stamping

Goal: 10 to 20% weight reduction from current AHSS applications

Dedicated to cold formed parts

Fortiform® HS, Fortiform® S HSHF

- **Austenite content:**
  - High strength vs ductility compromise

- **Quenching and Partitioning (Q&P) process:**
  - High yield strength, good hole expansion rate (HER)

- **Ductility:**
  - Sufficient for good crash energy absorption AFTER cold forming
Goal: 10 to 20% weight reduction from current AHSS applications

Fortiform® High Formability (HF) and High Strength, High Formability (HSHF) for cold stamping

Families of Fortiform®:
- Fortiform® HS, Fortiform® S HSHF

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- Quenching and Partitioning (Q&P) process: High yield strength, good hole expansion rate (HER)
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UTS (MPa)

Fortiform® S / HSHF ready for 2021+ SOPs

Fortiform® / HF ready for 2018+ SOPs

20% weight reduction

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Applications for Gen 3 AHSS

**Candidate Parts**
- Front upper and lower motor compartment rails
- Cowl side outers
- Rocker outers
- B-pillar outers
- Rear roof rails
- Rear rails

Source: ArcelorMittal S-in motion® solutions catalogue
Gen 3 WILL NOT replace PHS!

Perhaps in SOME applications

- PHS today is used in some parts needing higher strength and better formability than DP, but not full PHS strength
- Strength of strain-plus-paint bake 1180 HF approaches that of as-quenched Usibor® 1500
- Gen 3 may replace PHS in some, but not all, of these parts
Gen 3 AHSS Limitations

Gen 3 AHSS also some limitations

• Higher alloy than other AHSS, including PHS:
  – Greater susceptibility to LME
  – Hydrogen sensitivity
  – Higher cost
  – Poorer weldability

• Higher strength means greater problems with springback
• Gen 3 formability still poorer than that of PHS
Applications for Gen 3 AHSS

PHS are still lighter in key anti-intrusion parts

Lighter car parts thanks to higher strength

≈10% weight-saving
Introduction to 3rd Generation Advanced High Strength Steels

Summary and Conclusions

• Third Generation (3G, 3rd Gen, Gen 3) AHSS provide a superior combination of strength and ductility for crash energy management parts in the BIW

• Gen 3 AHSS can reduce by up to 20% the weight of the current steel parts they replace

• While Gen 3 AHSS may replace some PHS grades in lower strength applications, they **WILL NOT replace PHS** in the most strength challenged parts in the BIW
Thank You.

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