NanoSteel 3rd Generation AHSS:
Auto Evaluation and Technology Expansion

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Outline

- **NanoSteel 3rd Generation AHSS**
  - Structural formation pathway
  - Enabling mechanisms

- **OEM Delivery**
  - Targeted chemistry and properties
  - Sheet production
  - Structure and property correlation

- **Technology Expansion**
  - Development of new high ductility alloys
  - Mechanism for high ductility
  - Property recovery

- **Future OEM Delivery**
  - Developmental pathway toward cooling rate independence
  - Slab casting technology
NanoSteel 3rd Generation AHSS
Targeted requirements for 3rd Generation AHSS identified by auto/steel community
NanoSteel 3rd Generation AHSS

NanoSteel AHSS enabled by unique chemistries and mechanisms leading to unique nanostructures
NanoSteel 3rd Generation AHSS Development

NanoSteel alloys positioned to fill the property requirements for 3rd Generation AHSS
Structural Development In NanoSteel Class 2 Alloys

Structural Development Overview

Casting

- Modal Structure
  - Matrix Grain (Austenite)
  - Pinning Phase (Bondes)
  - Structure #1

Heat Treatment

- NanoModal Structure
  - Refined Matrix (Austenite)
  - Pinning Phase (Bondes)
  - Mechanism #1
  - Dynamic NanoPhase Strengthening
  - Structure #2
  - Plastic Deformation
  - Mechanism #2

Deformation

- High Strength NanoModal Structure
  - Transformed Matrix (Ferrite)
  - Pinning Phase (Bondes)
  - Nanoprecipitates (Hexagonal Phases)
  - Structure #3

Novel enabling mechanisms key to development of new class of 3rd Generation AHSS
Mechanism #1: NanoPhase Refinement

- **Stable** grain refinement occurring with elevated temperature exposure
- Refinement occurs between 0.75 to 0.95 $T_m$

NanoPhase Refinement creates NanoModal microstructure
Mechanism #1: NanoPhase Refinement Process

**NanoModal Structure**

**Modal Structure**

NanoPhase Refinement occurs at elevated temperature

**Schematic M-M_2B phase diagram**

- Liquid
- \( \gamma \rightarrow \alpha \)
- \( \alpha \rightarrow \gamma \)
- \( \gamma + M_2B \)
- \( \alpha + \gamma + M_2B \)
- \( \alpha + M_2B \)
- M
- Atomic Percent Alloying
- M_2B

Solid Schematic:

Nanoparticle

Modal Structure:

NanoPhase Refinement occurs at elevated temperature
Mechanism #2: Dynamic NanoPhase Strengthening

- Dynamic process occurring after yielding with applied stress
- Stress induced nanoscale phase formation
  - Austenite > Ferrite + Hex Phase$_1$ + Hex Phase$_2$

Dynamic NanoPhase Strengthening delivers strain hardening to enhance cold formability
Mechanism #2: Dynamic NanoPhase Strengthening

**X-Ray Diffraction Scans**

- NanoModal Structure
- High Strength NanoModal Structure

**Structural changes:** NanoModal Structure to High Strength NanoModal Structure transformation
Dynamic NanoPhase Strengthening: Nanoprecipitation (TEM)

High Strength NanoModal Structure

Ferrite + Nanoprecipitates

Ferrite (α-Fe)

Boride Phase
Initial OEM Delivery
NanoSteel is able to correlate laboratory scale trials to commercial scale production.
Initial OEM Delivery: Structure / Enabling Mechanisms Comparison

Structure #1
- Modal Structure

Mechanism #1
- Nanophase Refinement

Structure #2
- NanoModal Structure

Mechanism #2
- Dynamic Nanophase Strengthening

Structure #3
- High Strength NanoModal Structure

Laboratory Scale Sheet

Commercial Scale Sheet
Initial OEM Delivery Status

Strip Casting Production Process
Enabling mechanisms and targeted structures deliver properties at the OEM target (1200 MPa, 20%)

NanoSteel AHSS Coils
Spec: ✓
Melt: ✓
Cast: ✓
Roll: ✓
Finishing:

Re-Coiling | Batch Annealing | Trimming | Cold Rolling | Pickling
Technology Expansion
NanoSteel alloys for thin strip production fulfill the property requirements for 3rd Generation AHSS
New NanoSteel development has allowed property expansion to much higher ductility levels.
Development of new high ductility alloys extends the technological runway for cold formable steels.
High Ductility Alloys: Dislocation Mechanisms Deliver Superior Results vs. Twinning

Dislocation dominated deformation enables higher strength with similar ductility
NanoSteel 3rd Generation AHSS: New High Ductility Alloys

Wide range of properties possible depending on customer needs and requirements
NanoSteel 3rd Generation AHSS: New High Ductility Alloys

An example high ductility alloy is shown for subsequent slides.
New High Ductility Alloy Properties: Independent Validation

NanoSteel Alloy: Testing Results
(ASTM E8 Specimens)

View of the Specimens
Before Deformation

After Deformation: 1204 MPa, 50%

New high ductility alloy properties were confirmed by independent testing
Different property combinations can be achieved in the same alloy by post-processing.
Future OEM Delivery
Continuous cooling transformation diagram shows challenges with increasing thickness.
Enabling Mechanisms to Produce Nanoscale Structures

Glass formation followed by devitrification / spinodal decomposition enabling for thin products

Glass Devitrification (1996)
Enabling Mechanisms to Produce Nanoscale Structures

NanoPhase Refinement enabling for thin strip casting
Enabling Mechanisms to Produce Nanoscale Structures

New mechanism enabling for thin and thick slab casting
New mechanism enables targeted structure formation from thicker casting.
Future OEM Delivery

- **Future:** Will utilize thin slab/slab casting for steel production
- **Current:** Utilizing strip casting for initial OEM steel delivery
NanoSteel In 2014 & Beyond

- Supply pilot material for OEM and Tiered supplier evaluation
  - Initiate validation testing

- Work with partners on expanding production capabilities
  - Into thin and thick slab production

- Further develop new high ductility steels in production environment
  - Expand alloy portfolio to include new capabilities

- Work with steel producers to further establish the advantages of 3rd Generation AHSS
  - Optimal combination of weight reduction, cost efficiency and minimal disruption to the existing manufacturing infrastructure.
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