New Breakthroughs in Lean Ultra High Strength Sheet Steel through EAF-CSP route Guaranteeing Outstanding Formability and Steel Quality.

Amar K De
Chirag Mahimkar and Shobhit Bhartiya
Big River Steel, a US Steel Company, Osceola, TN 72370, USA
First Steelmaking Facility in NA to achieve site certification from Responsible Steel in 2022, the industry’s first Global Certification initiative for responsible sourcing and production of Steel.
BRS 2 Line Up: 2.8MT

The Breakthrough Technology Conference, Worldsteel Association, Abu Dhabi 5-7 Dec 2023
Big River Steel – EAF Steelmaking and CO₂ Reduction

A Total of 6MT of Steel Production
All through EAF

Emissions from EAF almost 1/6th of Integrated Route of Steelmaking

Reference: Stahlinstitut VDEh

Our Process at Big River Steel ______________________ 410kg/ton of HM
Some Unique Features at BRS

- **DC furnace technology** for reduced flicker and high-power input rates with low secondary electrical losses
  - Foamy Slag Practice ensures **Shielding of Arc, heat conservation**
  - **Higher Heat Efficiency**,
  - Increased **Refractory Life**,
  - Minimize **Nitrogen intake**

- **Eccentric Bottom Tapping (EBT)** to tap heats nearly slag free in 35-45 minutes or less

- **Designed to operate on scrap** or using continuous roof feeding of DRI/HBI

- Sufficient furnace volume to accept Single bucket scrap charge

- Sidewall injection devices for foaming slag and chemical energy
Big River Steel – EAF Steelmaking

Our EAF Charge mix
- Scrap
- Pig Iron
- HBI

Cu is the main driving element to decide the charge mix
- **Low Cu Charge mix**
  - Virgin Metallics, Pig + HBI < 42%
  - Scrap
- **High Cu Charge mix**
  - Virgin Metallics, Pig + HBI < 30%
  - Scrap

Nitrogen Control through Charge Mix and Degassing

Challenges & Opportunities for CSPs
- Too many Recipes
- Switching back and forth between Recipes
- Scheduling
- Order Book and Grades
Big River Steel – Process and Product Innovations

Further Downstream Energy Savings

Because of Continuous nature of Processing
Immense Technological Opportunities exist in Leaning Down Chemistries and Casting difficult-to-cast AHSS Steels and make Breakthroughs

HR Products
- HSLA
- Linepipe,
- construction
- pressure vessel
- NGO
- AHSS

The Breakthrough Technology Conference, Worldsteel Association, Abu Dhabi 5-7 Dec 2023
Current Perspectives in Auto Steel Demand

- Higher Strength,
- Higher Formability specifically high edge stretchability
- Low-C Steelmaking i.e., Greener steel

Steels with > 450MPa > More than 54% of Lightweighting

25% with HSLA/AHSS steels with Tensile Strength up to 800MPa

Catered by
- HSLA, Dual-phase steels, MP (Multi-phase), FB (Ferritic-Bainitic steels)

FSV BEV Steel Types as % of Body Structure Mass

Worldautosteel.org

The Breakthrough Technology Conference, Worldsteel Association, Abu Dhabi 5-7Dec 2023
Product Innovation Breakthroughs: Background

High Cost of Alloying - High Cost of Production - High Maintenance Steels

Dual-Phase (F+M)  Ferritic-Bainite (F+B)  Complex phase (F/B/M/RA)

CSP / ESP

Downstream Processing Needed for Current AHSS Production
A Lean, Low-Carbon, Completely Ferritic Steel Strengthened by Nano-precipitates has been developed to cater to AHSS steels with up to 780MPa tensile Strength and Outstanding HER. Promises to replace costlier, highly alloyed and process-expensive DP, CP, FB Steels.

**Advantages**
- No-centerline segregation,
- No banded microstructure,
- No second phase hard constituents,
- Least Carbon Equivalence for enhanced, easy weldability

**Fine Ferritic Matrix, \( d_{av} \approx 4\mu m \)**

<table>
<thead>
<tr>
<th>Steel</th>
<th>C</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Ti</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP590-SP780</td>
<td>0.060</td>
<td>1.10-1.50</td>
<td>0.015</td>
<td>0.003</td>
<td>0.10 -0.15</td>
<td>0.009</td>
</tr>
</tbody>
</table>
Product Innovation Breakthroughs: SP Steel

SP Nano-Precipitate Strengthened Steel

CSP / ESP

- Energy Saving,
- Process elimination,
- Lead time reduced

No Downstream Processing Needed for SP Steel
Product Innovation Breakthroughs: SP Steel

SP Nano-Precipitate Strengthened Coated Steel

1. EAF Steelmaking
2. Scrap refining and Steel melting and pouring
3. Continuous travel through furnace without losing heat
4. Hot rolling
5. Accelerated cooling
6. Coiling and shipping
7. Low Temp. Annealing and Galvanizing
8. Coil with 780MPa tensile strength (Galvanized)
9. Coil with 780MPa tensile strength (uncoated)
10. 3. No Pickling, Cold Rolling and high temperature annealing required

The Breakthrough Technology Conference, Worldsteel Association, Abu Dhabi 5-7Dec 2023
Product Innovation Breakthroughs: SP Steel

SP Nano-Precipitate Strengthened Steel

Outstanding Stretchability

<table>
<thead>
<tr>
<th>Steel</th>
<th>C</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Ti</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP590-SP780</td>
<td>0.060</td>
<td>1.10-1.50</td>
<td>0.015</td>
<td>0.003</td>
<td>0.10 -0.15</td>
<td>0.009</td>
</tr>
</tbody>
</table>
SP Steel – Applications Demonstrated

Structurals and Machinery:
UHSS 100, Gauge 4.5mm-10mm
Product Successfully commercialized and used in structural, machinery applications

Automotive

SP780 : Component of a Car Seat Retractor

SP 600 : Component of a Car Seat
CR500LA

SP 650 : Front Link
CR550LA
Summary

- A Technological Breakthrough in Product Processing could be achieved in designing a chemistry and processing for a Lean, Very Low-Carbon Nano precipitation-strengthened, Single Phase Ferritic Steel to produce steels up to 780MPa tensile Strength in Hot Rolled and Coated Condition and also achievable in fully processed and coated condition.

- The Steel can be offered in most applicable gauges in HR and HR+Coated condition as well as fully processed condition and **eliminates need for downstream processing**.

- The steel exhibited outstanding mechanical, formability, bendability and weldability properties in both **HR and CR fully processed and Coated Condition** and promises to be a **game changer**.

- The New Steel has the Potential to replace medium-strength **DP steels, CP and MP steels** up to 780MPa tensile strength in both coated and uncoated condition.

- Most Importantly, the development of this Steel is achieved through **EAF-CSP route** and hence the greenest of all that is produced with similar strength.
Publications

1. Iron and Steel Technology, Oct 2022, pp. 60-72
   Development of Nano-precipitation Strengthened Cold-Rolled Batch-annealed HSLA Sheet Steels (>490MPa Yield Strength) with Superior Formability.

2. SAE Int., 2023-0100612, 2023
   Forming Characteristics of Nano-precipitation Strengthened Cold-Rolled Batch Annealed HSLA Sheet Steels (>490MPa yield strength)

3. Iron and Steel Technology, September 2023
   Fundamentals for Developing Nanoprecipitation-Strengthened Thick Gauge HSLA 550 Steel Through a Flex CSP Mill

Awards

- Steelie Award for Innovation of the Year 2023
- Fastmarket Global Innovation of the Year (Products) Award in 2021,
- Won AIST Gilbert R Speich Award in 2022 for best Physical Metallurgy Paper

Patents

- HSLA Single Phase Ferritic Nano-strengthened steel with 100ksi min yield strength – patent approved
- High Strength Low Alloy Sheet Steels with minimum yield strength of 500MPa produced using batch annealing – applied
- High Strength Low Alloy Sheet Steels with minimum yield strength of 550MPa produced using batch annealing – applied
- High Strength Low Alloy Sheet Steels with minimum tensile strength of 780MPa – applied
Thank You