Overview

- TimkenSteel
- Design for Center Soundness
- Virtual Process Path
- Large Bar Capability
- Conclusions
TimkenSteel Corporation

- We help customers push the bounds of what’s possible by creating steel products and services to overcome their toughest challenges

- Innovative team of experts driving custom and tailored solutions
  - Institutional expertise developed over 100 years
  - Deep technical knowledge of processes and applications
  - ~30% of our product offerings are less than 5 years old

- A 100-year old start-up
A market leader in a broad range of products and services
Advanced Steel Technology

- Applications Metallurgical Laboratory
- Advanced Modeling
- Advanced Product & Process Engineering
- Development Labs

- Corrosion
- ASPEX
- Dual Beam SEM/FIB
- Modeling Software
- UT
- Gleeble
- Microscopy
Design for Center Soundness

- Paradigm shift from reduction ratio to measured soundness
  - Why? – Because TimkenSteel has the knowledge & tools to implement
  - Reduction ratio accounts for geometric shape change only
    - How does that tell me what is going on at the center?
  - Use virtual process path to assess and predict center soundness

Reduction Ratio = \( \frac{A_I}{A_F} \)
Steel Ingot Manufacturing & Conversion
Characteristic of Interest: Soundness

Goal: Produce large bar (> 9”) sound center product that meets customer specifications

Soundness ≈ Microporosity

- Cause → volume shrinkage during solidification
- Mitigate via
  - Casting process parameters
  - Hot work while converting to bar
- Important to know where microporosity forms
Virtual Process Path: Casting

- Niyama criterion value accounts for temperature gradient & cooling rate during solidification
- Indicates a risk that porosity or shrinkage may occur
Virtual Process Path: Hot Work

“Hot work eliminates porosity, but the amount required to produce full density in bars is a function of the method by which the hot work is applied.” —ASPPRC Publication

- Two process paths: Rolled & Forged-Rolled
- With respect to center soundness:
  - Forging Reduction ≠ Rolling Reduction
  - Overall Deformation = Forging Deformation + Rolling Deformation
- Hot work has to be simulated, evaluated and combined

Virtual Process Path: Open-Die Forging

Forging Simulation Includes:
- Incoming Workpiece & Die Geometry
- Process Parameters

Tracks key process results that indicate evolution of center soundness
Virtual Process Path: Rolling

- Rolling Simulation Includes:
  - 46” Blooming Mill & 36” Billet Mill
  - Multiple passes through each mill
- Results used to assess soundness and final shape
Virtual Process Path: Validation

- The TimkenSteel Large Bar UT is a mechanical inspection machine
- Utilizes reflection transducers and multi-element phased array probes
- Inspects for both internal and surface indications

Example Forged-Rolled large bar inspection scan
Virtual Process Path: Results

“Hot work eliminates porosity, but the amount required to produce full density in bars is a function of the method by which the hot work is applied.”
– ASPPRC Publication

Now, with respect to deformation:

\[ \text{Overall Deformation Distribution} = \text{Deformation Distribution} + \text{Strain} \]

Case Study: Results Validation

Rolled-only process ultrasonic indication frequency increases in larger bar sizes (remnant porosity)

Forged-Rolled process ultrasonic indication frequency shows sound center across size range
Physical Process Path: Trial

- Trial Details:
  - Work Piece: Cast blooms
  - Process: Forged-Rolled
  - Sequence: Non-optimized & Optimized
  - Material, initial size and final size all held constant

- Simulations run and post-processed for parameter which tracks center soundness

- Simulated tracking results compared directly to measured UT indications
Physical Process Path: Trial Results

Non-Optimized Process UT Scan [Indications in Red]:

Optimized Process UT Scan [No Indications]:

Soundness Parameter (From Simulation)

Length Along Bloom
Ultrasonic Soundness Specification

Minimum Reduction Ratio Required

Further Optimization

Forged-Rolled Expanded Capability

Rolled
Forged-Rolled
Conclusions

- Using advanced modeling tools, TimkenSteel can bypass the use of reduction ratio and focus on **optimizing center soundness**

- The Forged-Rolled process path contains the **best of both worlds** – center consolidation of forging plus the size control of rolling

The Forged-Rolled process allows TimkenSteel to produce sound, large bar product at geometric reduction ratios lower than historically possible in rolled-only product
We help customers push the bounds of what’s possible by creating steel products and services to overcome their toughest challenges.

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