# LONG ROLLING MILL PROCESS AND SAFETY ADVANCEMENTS

## IRD @ GERDAU PETERSBURG

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# Contents

# The evolution of rolling

**Roll pass design**

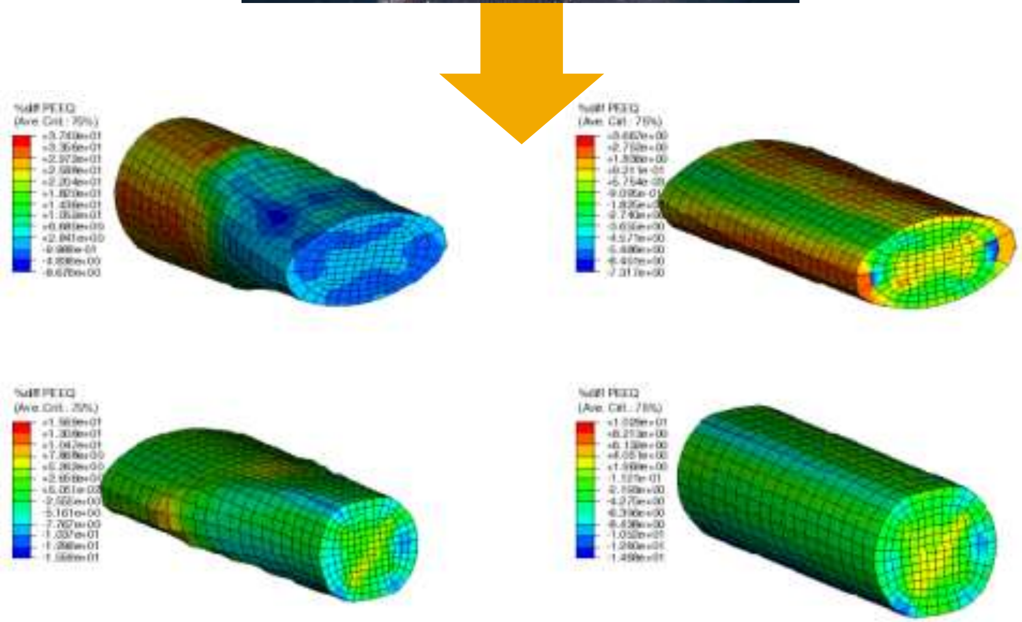
For most long rolling mills, the time of trial and error and secret black books has evolved to a thing of the past

Process modeling and rolling simulations have reduced cobble rates while improving product quality

Long customer rolling campaigns and large on hand inventory have shifted to just in time production requirements to control costs and drive sales

Mills are operating with less manpower but with improvements to safety performance

How does it all connect?



PRIMETALS TECHNOLOGIES

# Roll pass design
# Building blocks for the rolling mill

**Draft, Contact Area, Bite Angle, Spread, Flow Stress, Separating force**

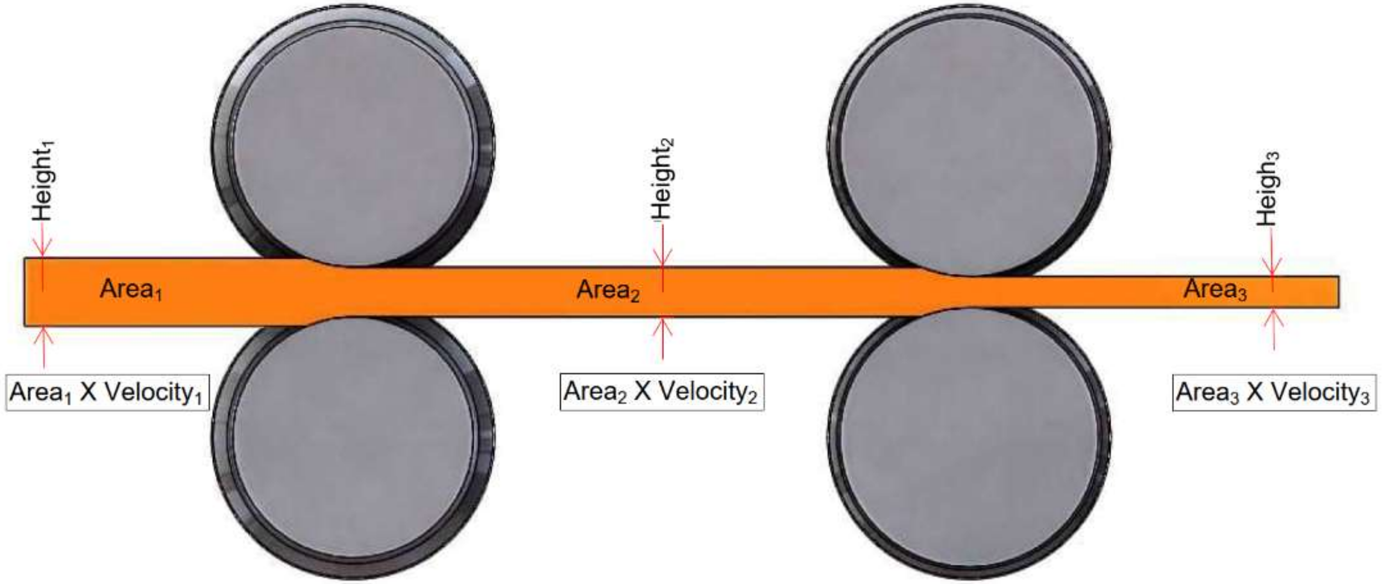
- All elements are critical to complete the overall pass design work for a rolling mill to determine:
  - Stand size selection (capacity)
  - Pass groove shapes
  - Mill roll maximum and minimum diameters
  - Spindle torque and speed capacity
  - Gearbox torque and speed capacity
  - Motor power and speed range
- Each elements are influenced by steel grade and billet temperature during the design and during rolling
- Covering all pass design topics is days of training and years of application but a few basic parameters are key to understand how the mill is designed

# Roll pass design
# Building blocks for the rolling mill

## Mass flow rate and Conservation of mass

- The **Mass flow** rate of a mill is the overall production rate
  - Tons per hour (Q)
- Tons per hour at the mill level in operating units:
  - Q (kg/hr) = Area ($mm^2$)*Velocity(m/s)*density(kg/$m^3$)*360000(s)
- Density is a constant so
  - Q = Area * Velocity
- **Conservation of Mass** - the steel flow is constant through the whole rolling mill

  Therefore:
  - $Area_1 * Velocity_1 = Area_2 * Velocity_2 = Area_n * Velocity_n$
- As the stock area is reduced the bar elongates, making elongation related to velocity



# Roll pass design
# Building blocks for the rolling mill

## Reduction and Elongation

- **Reduction** is the decrease of the stock are from stand to stand and is represented in percentage
  - %Reduction=$\frac{Area_{in}-Areaout}{Area_{in}}x100$
- **Elongation** is the change in length of the rolled bar as the stock area is reduced
  - Elongation=%Elongation= $\frac{1}{1-\%Reduction}-1$
- Elongation and reduction have different rates
- Since elongation it related to velocity it is important to understand these ratios and relationships for a stable rolling process
- As the stock area is Reduced it Elongates and increases in Velocity
- When these parameters are not maintained a cobble is the probable result
  - It is easy to blame the roller guides, as they are the typically what “fails”, but remember these core ratios and the main setup parameters

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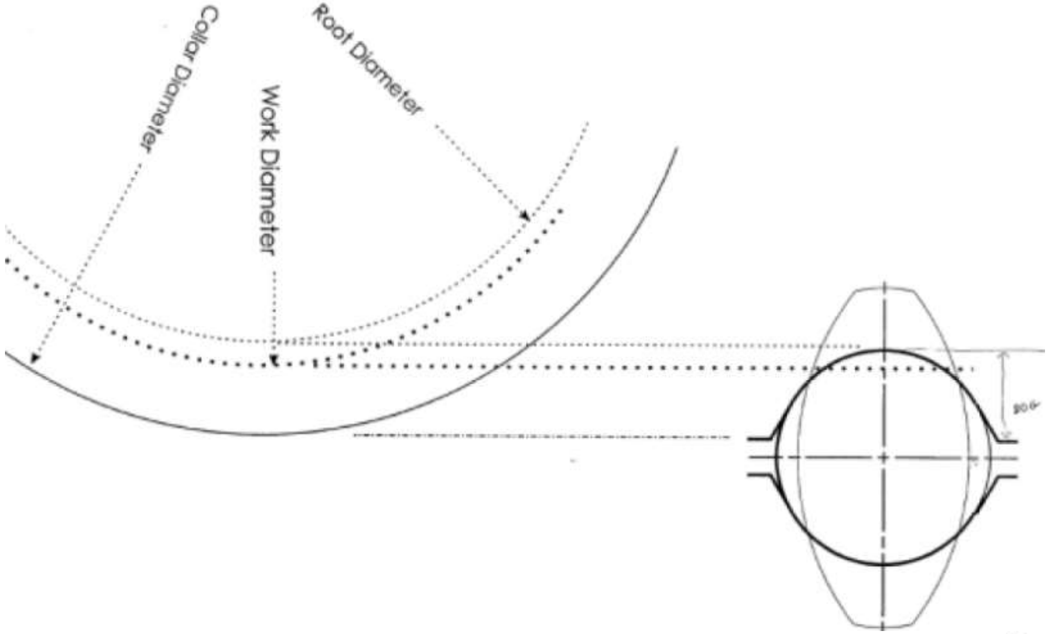
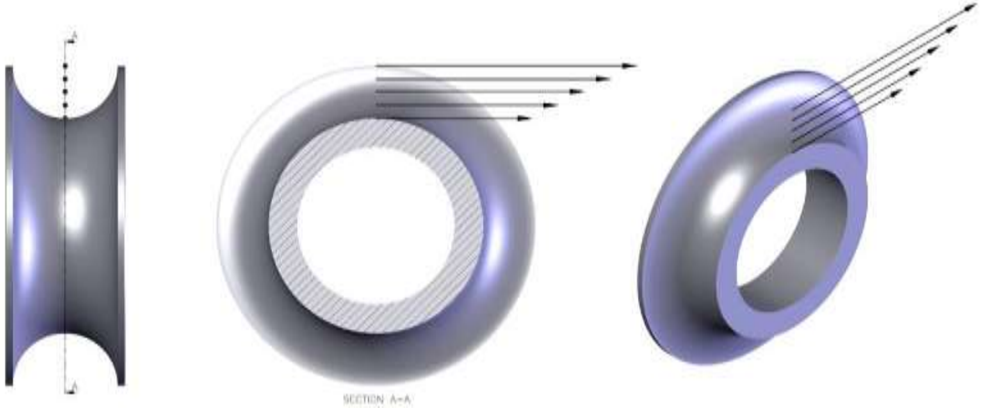
# Roll pass design
# Rolling mill setup parameters

## Reduction Factor (R-Factor) and Working Diameter

- **R-factor** is used by the control system to monitor and adjust the speed from stand to stand. Taking mass flow and conservation of mass from previous slides we can define:
  - R-Factor=$\frac{Area_{in}}{Area_{out}} = \frac{Velocity_{out}}{Velocity_{in}}$
- Proper R-Factor is critical to ensure minimum tension control to minimize cobbles and maximize pass groove and guide life
- The mill operates with an overall speed cascade based on the elongations through the mill stands
  - Cascade can be forward or backward depending on the overall design of the plant
- **Working diameter** is input for the proper mill motor to mill roll ratio to have the proper bar speed
  - This is the point within the pass groove where the speed of the roll matches the speed of the stock



# Roll pass design
# Building blocks for the rolling mill layout

## Production Calculations

- Once the stand selections are made from the pass design shapes based on the billet and final products, the process modeling can start to determine the mill layout and full production calculations
  - Locate and determine capacity of mill shears based on section area, with the drive train and type based on speed of stock
    - Typically, 6 to 8 stands of rolling before head cuts are needed
  - Uploopers considered in intermediate or finishing stands for minimum tension control
  - Water cooling boxes for temperature control
  - Cooling bed and/or Stelmor® lengths based on processing speeds and steel grades
  - Bar handling or Coil handling layouts based on overall mill productivity rates to maximum capacity and control temperature
  - Final bottleneck analysis ensures product mix and production rates can be acheived
  - Ensure operating time and utilization figures are reasonable

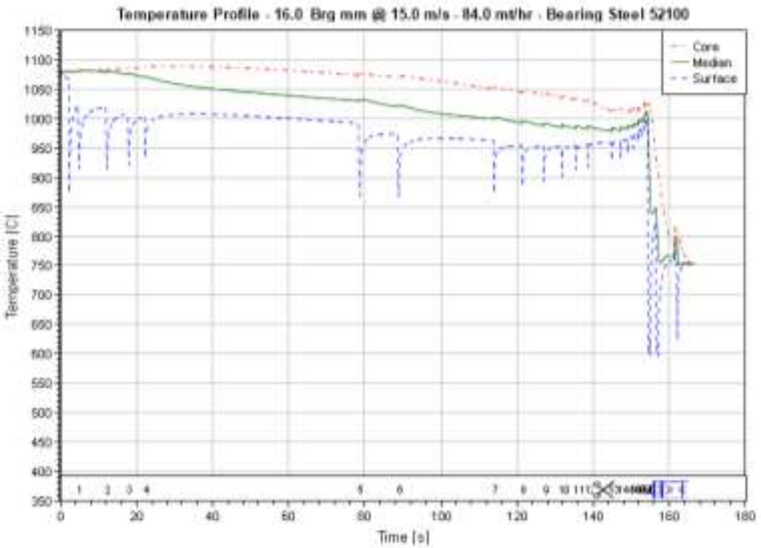
**625,000 T/yr example production calculation**

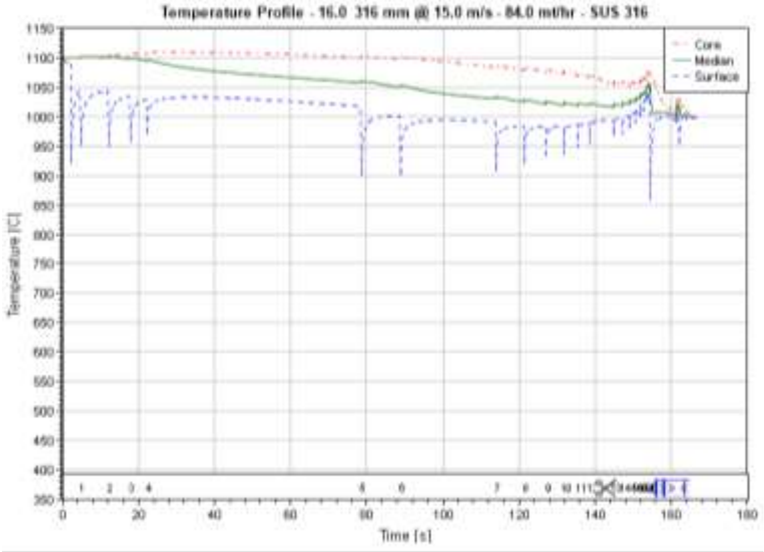
| Operating Time | | | Hours |
|---|---|---|---|
| Total Time Annually | 365 | Days | 8,760 |
| Annual Maintenance | 14 | Days | 336 |
| Guide/Roll Change Time | 5.0 | % | 438 |
| Weekly Maintenance 8 Hr/Week | 49 | Week | 392 |
| Unscheduled Delays (Mechanical) | 1.0 | % | 88 |
| Unscheduled Delays (Electrical) | 1.0 | % | 88 |
| Process Delays | 1.0 | % | 88 |
| Holiday | 10 | Days | 240 |
| Available Operating Time Annually | 295 | Days | 7,091 |

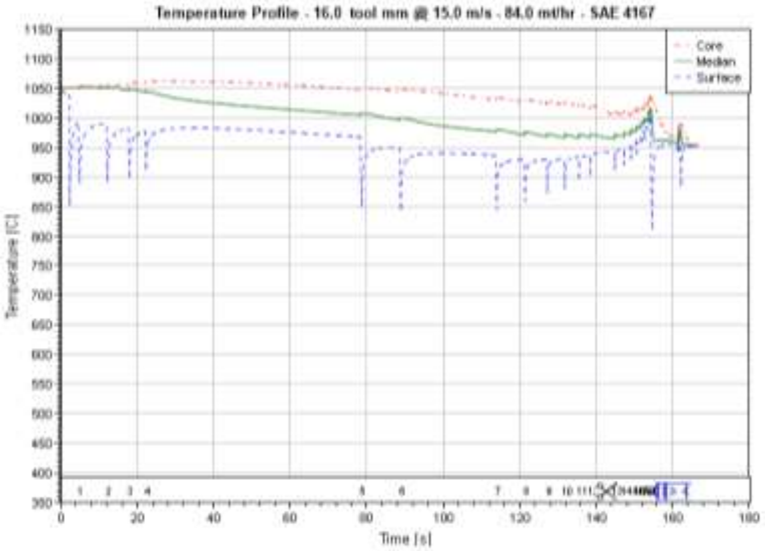
| Mill Utilization | | |
|---|---|---|
| **Operating Time** | 7,091 | Hours |
| **Rolling Time** | 5,756 | Hours |
| **Mill Utilization** | 81.2% | |
| **Charged Tons** | 644,330 | Tons |
| **Prime Tons** | 625,000 | Tons |
| **Yield** | 97.0% | |

# Process modeling - Temperature profiles
# Furnace drop out temperature to finish temperature on the cooling bed

- Determine the stand selections, gearbox and shear loading and motor powers needed for processing all steel grades and final rolled temperatures
- Determine overall distances for stands, water cooling boxes and troughs based on time and rolling rates
- Model grain size and structure to meet mechanical properties across various steel grades
  - Rolling at minimum temperatures for further grain refinement and optimized billet chemistries with minimum microalloying for minimum conversion cost to final products

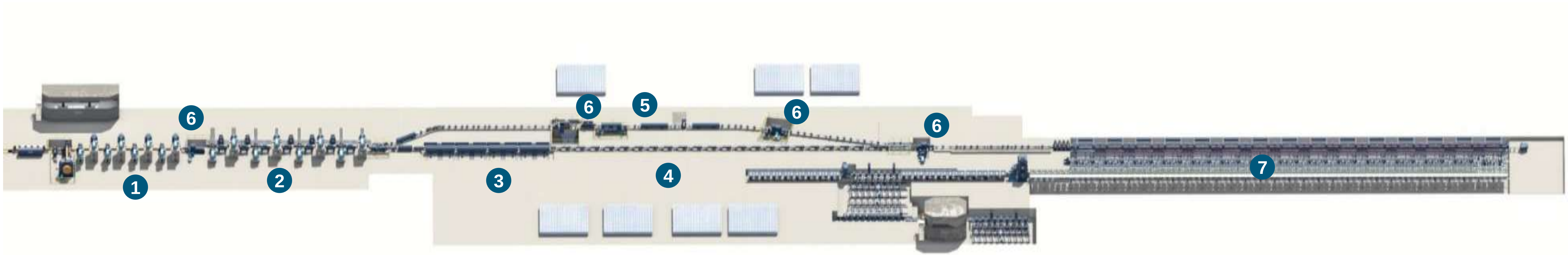


PRIMETALS TECHNOLOGIES

# Building the mill to support the process – Bar mill




| | |
|---|---|
| 1 | Roughing mill train – Critical to start the grain refinement but introduce rolled in defects |
| 2 | Intermediate mill train – Start to further lower temperatures and start to build mechanical properties |
| 3 | Thermal processing of bars - Enhanced process control, recipe driven based on steel grade, size and speed |
| 4 | Equalizing zone for final grain structure – Allow for consistent temperature gradient for all steel grades, sizes and speeds |
| 5 | High-speed outlet with No-Twist® Mill with eDrive – Can finish on the cooling bed, bar in coil line, spooler line or full rod outlet<br>• Long-life finishing passes for long production runs with virtual gearbox capability, (no roll families needed)<br>• Quick product changes and precision product tolerances<br>• Post rolling thermal processing of bars with enhanced process control at increased speeds |
| 6 | Mill Shears – Optimization via vision systems and laser speed gauges for maximized yield |
| 7 | Cooling Bed Outlet – Bed length, layer wide and discharge system defined by size range, finishing speed and production rate |

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# Building the mill to support the process – Rod mill / Combination Mills

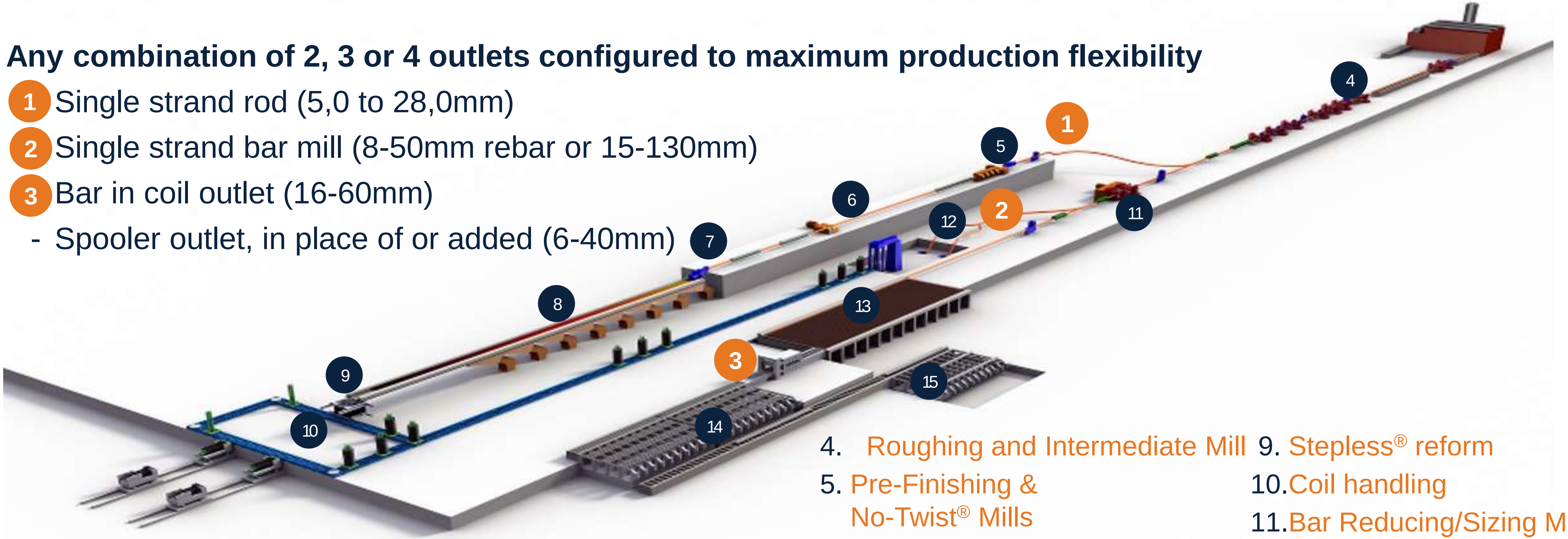
**Any combination of 2, 3 or 4 outlets configured to maximum production flexibility**

1 Single strand rod (5,0 to 28,0mm)

2 Single strand bar mill (8-50mm rebar or 15-130mm)

3 Bar in coil outlet (16-60mm)

- Spooler outlet, in place of or added (6-40mm)

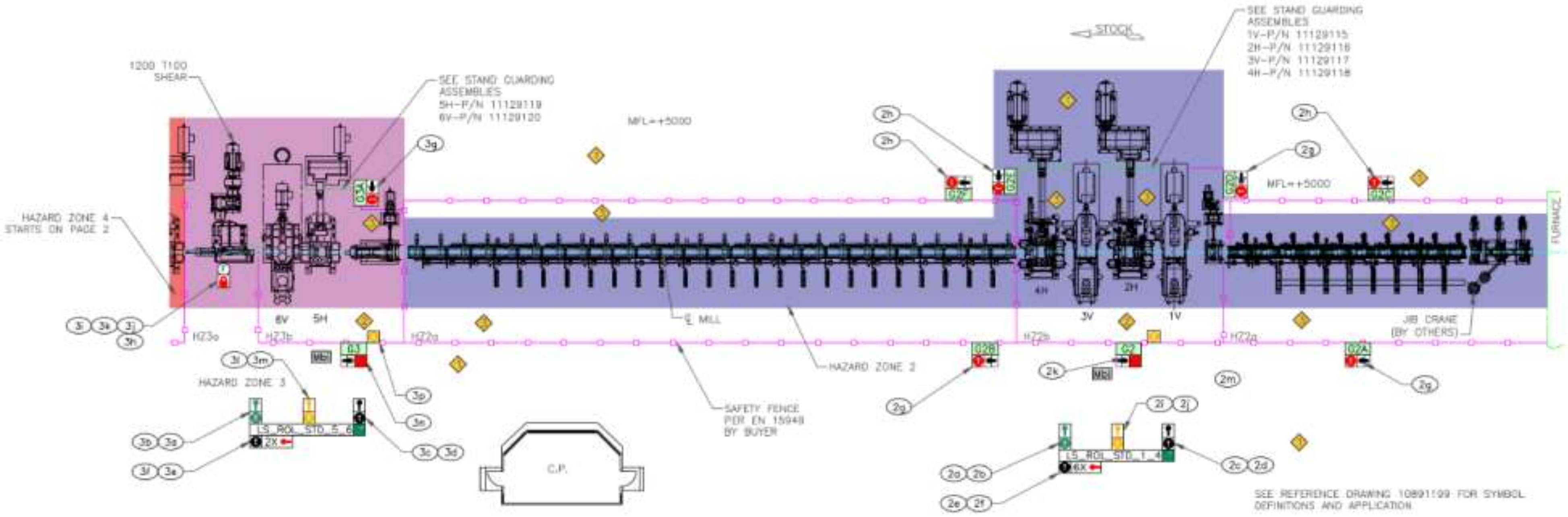



4. Roughing and Intermediate Mill
5. Pre-Finishing & No-Twist® Mills
6. Reducing/Sizing Mill
7. Intelligent Pinch Roll and Laying Head
8. Stelmor ® conveyor
9. Stepless® reform
10. Coil handling
11. Bar Reducing/Sizing Mill
12. Pouring Reels
13. Straight bar cooling bed
14. Bar bundling
15. Bar handling

Contents

# Safety Layout – For mill control, operations and maintenance safety
# EN15949 – Safety requirements for bar mills, structural mills and wire rod mills

- Hazard Zones for:
  - Operator access to equipment
  - Power control for operations and maintenance
  - Interlocks and checks for mill stops and mill starts and mill adjustments
  - The rolling mill is a “machine” and a component of the whole plant





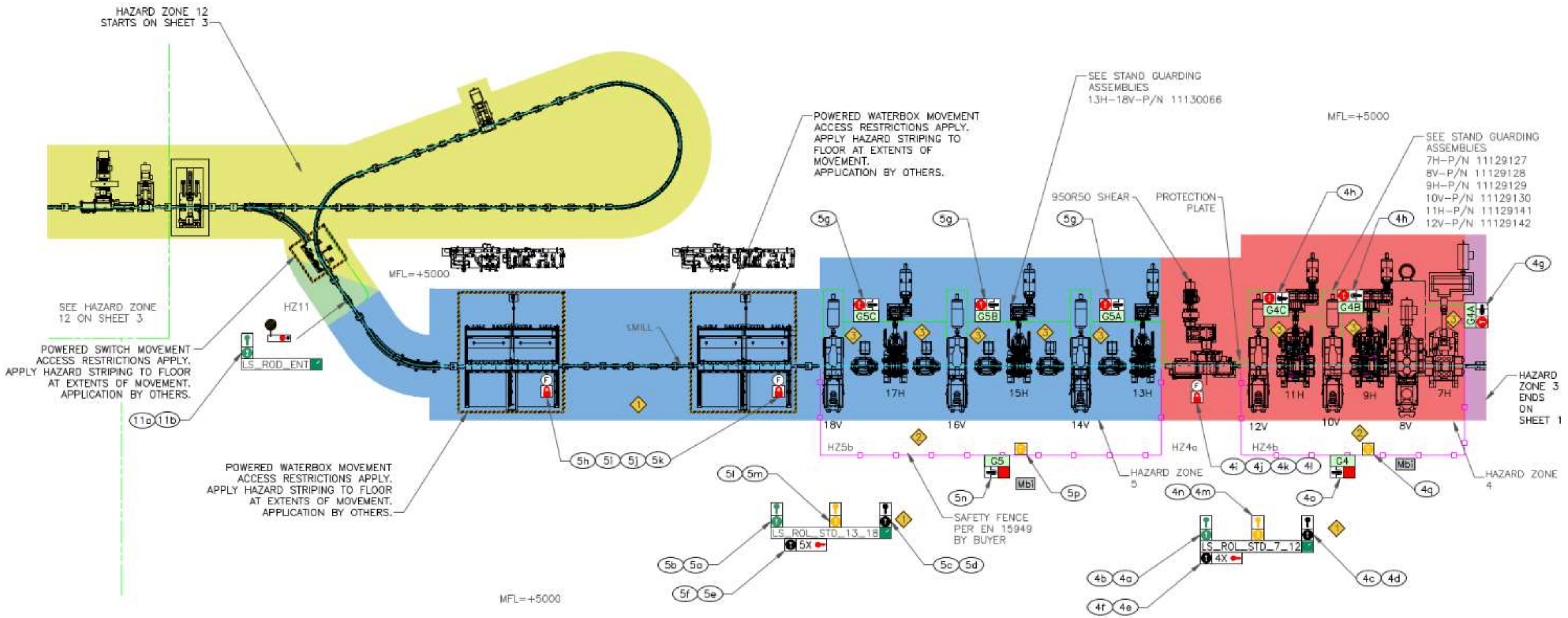
| MACHINE ACCESS MATRIX | | | | |
|---|---|---|---|---|
| MACHINE OPERATING MODE | | MACHINE STATUS | MACHINE ACCESS LEVEL | EN 15949 CLAUSE |
| P | PRODUCTION | NORMAL PRODUCTION | DENIED | 5.1.6.8 |
| IUL | INSPECTION (UNDER LOAD) | CONTROLLED PRODUCTION | WITH CONDITIONS | 5.1.6.4<br>5.1.6.7 |
| A | ADJUSTING | JOG MODE | WITH CONDITIONS | 5.1.6.3<br>5.1.6.7 |
| I | IMMOBILIZATION | NO MOVEMENTS POSSIBLE | WITH CONDITIONS | 5.1.6.3<br>5.1.6.7 |
| M | MAINTENANCE | OFF (LOTO) | ALLOWED | 5.1.6.8 |

| MILL AREA ACCESS MATRIX | | | | | | |
|---|---|---|---|---|---|---|
| MILL AREAS: AUTHORIZED PERSONNEL ACCESS TO AREAS PER OPERATING MODE. | | MILL OPERATING MODES | | | | |
| | | P | IUL | A | I | M |
| 1 | ROLLING MILL WORKING PLACES | ✓ | ✓ | ✓ | ✓ | ✓ |
| 2 | INSPECTION UNDER LOAD – SEGREGATED AREAS | ✗ | ✓ | ✓ | ✓ | ✓ |
| 3 | ADJUSTMENT ACCESS | ✗ | ✗ | ✓ | ✓ | ✓ |
| 4 | IMMOBILIZATION ACCESS | ✗ | ✗ | ✗ | ✓ | ✓ |
| 5 | MAINTENANCE ACCESS | ✗ | ✗ | ✗ | ✗ | ✓ |
| ROLLING MILL AREAS, "X" IS NUMERIC I.D. | REQUIRES PRESENCE SENSING IN THE PULPIT | ✓ ACCESS ALLOWED | | | | |
| | PRESENCE SENSING NOT REQUIRED | ✗ ACCESS NOT ALLOWED | | | | |

PRIMETALS TECHNOLOGIES

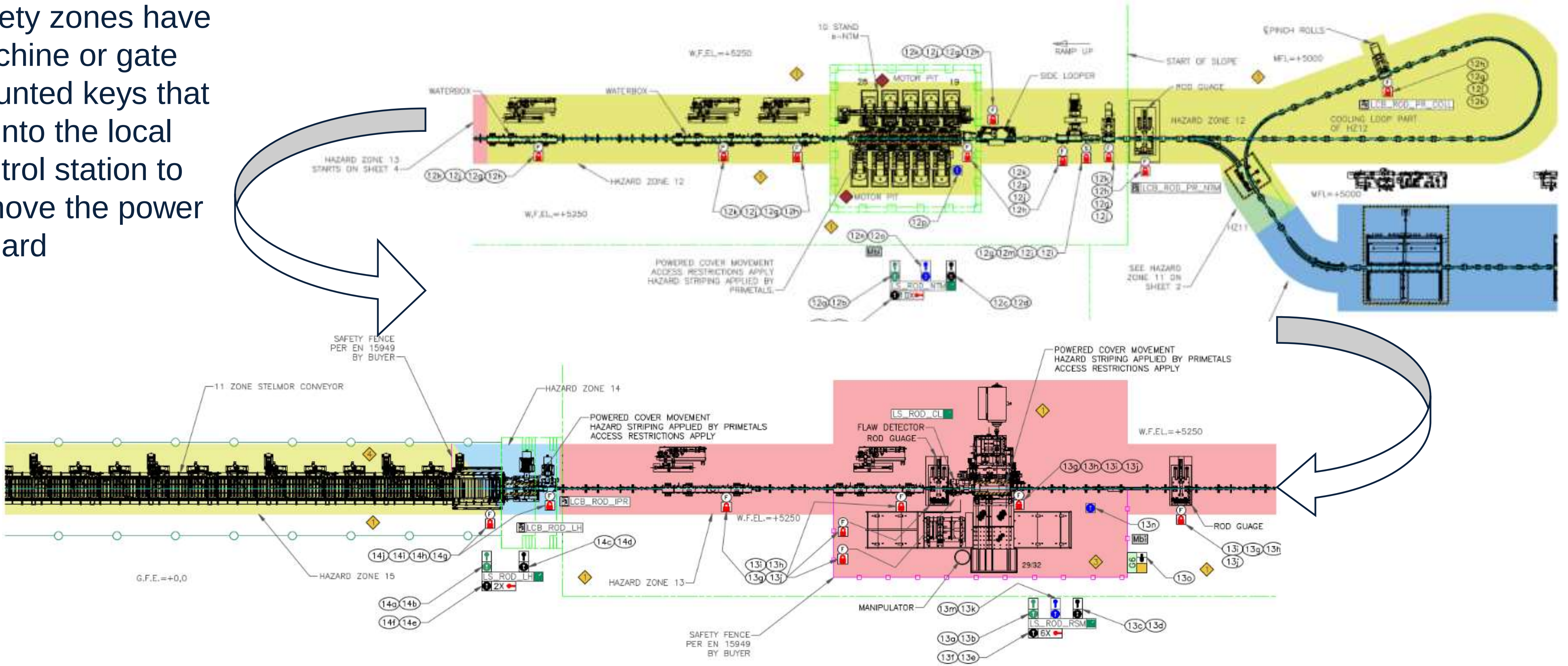
# Safety Layout – For mill control, operations and maintenance safety
# EN15949 – Safety requirements for bar mills, structural mills and wire rod mills

- As speeds increase, different rules influence different levels of machine and area guarding or fencing
- Some areas only have locked guards on the machine (like a machine tool in the roll shop)



# Safety Layout – For mill control, operations and maintenance safety DIN EN15949 – Safety requirements for bar mills, structural mills and wire rod mills

- Safety zones have machine or gate mounted keys that go into the local control station to remove the power hazard



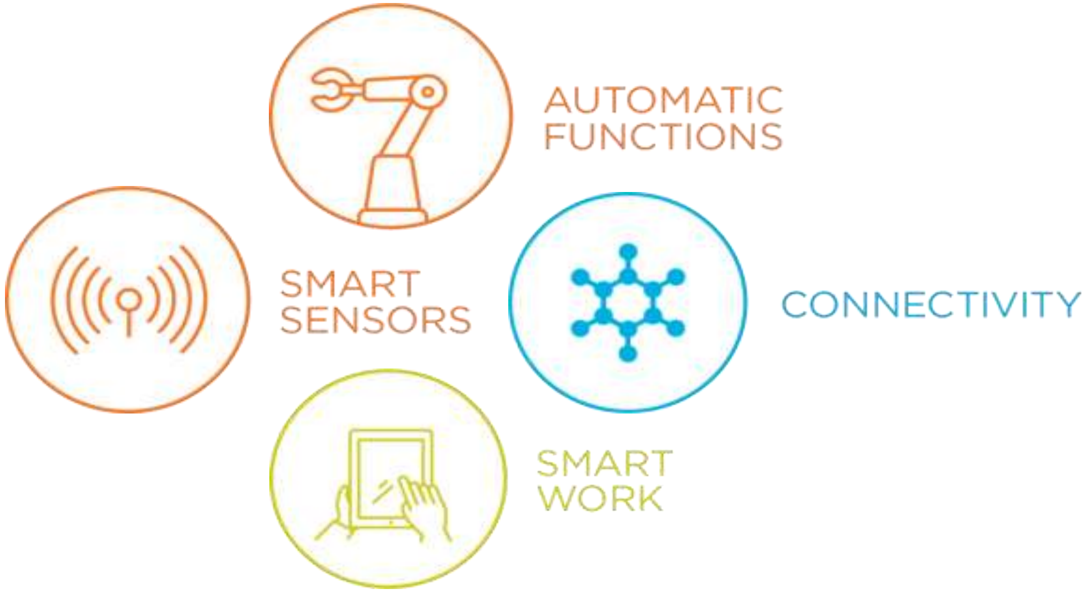
# Safety Layout – For mill control, operations and maintenance safety
# DIN EN15949 – Safety requirements for bar mills, structural mills and wire rod mills

**Local stations made for each hazard zone**

- Color coded keys at the equipment (or safety gates) and at the local control station
- Key release interlocks ensure operator safety during maintenance or for immobilization/mill adjusting modes
- Key are engraved and cut per safety zone and machine for ease of replacement
- Ensures consistent operations and maintenance practices, regardless or crews/shifts


# Product development driven by safety

- Primary goals of safety solutions:
  - Prevention of cobbles – Zero failure
  - Increase yield – Production flexibility and profitability
  - Keep people away from the process – Zero reportable
- Focus mill area solutions:
  - Main mill stands stock measurements via Digital Optical Caliper or Advanced guiding solutions
    - Advanced guiding for bearing and roller monitoring
    - Pass wear monitoring for stand adjustments
  - High-speed rod or bar outlets; speed measurement for tension control of equipment
  - Mill Shears for crop optimization
  - Vision system for Laying Head adjustments
  - Wire rod coil handling for ring trimming



# Product development driven by safety
# Prevention of cobbles - Stock measurement and monitoring solutions

**Digital Optical Caliper (fixed or portable) Accuracy: +/- 0.1mm (0.004")**

- Portable unit for spot checking of stock size (to replace wood burning)
  - Typically used for 2-3 bars in a location for mill calibration
  - Measures rounds, flats and squares
  - Reduces setup and change times with immediate feedback
- Fixed unit for continuous measurement
  - Accurate real time section control that can be linked to iba
    - Tension effects can be captured and analyzed
  - Integrated with tension monitoring for true tension free rolling
  - Monitor pass wear to prevent cobbles and surface defects
  - Automated or semi-automated section control implementation
  - Data analytics can be used to improve quality and production
  - Measures rounds, ovals, squares, and flats

# Product development driven by safety
# Prevention of cobbles - Stock measurement

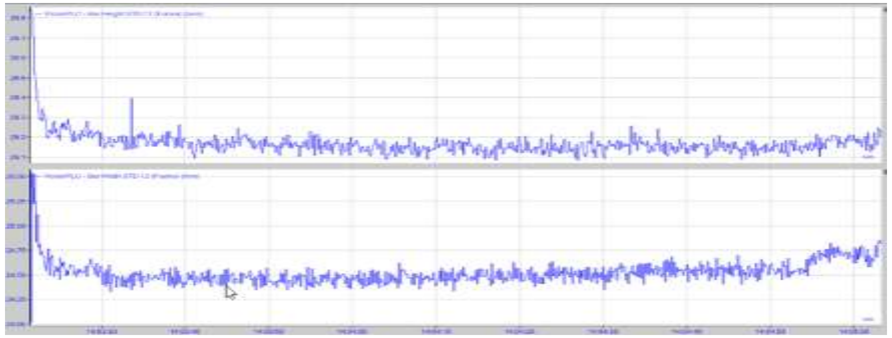
## Digital Optical Caliper graphical user interface

- Simple and intuitive
- Imperial and Metric system and bar shape selections
- Individual images for bar width and height displaying
  - Live measurement
  - Minimum/maximum and Average
- Screen sharing on portable unit for larger smart screen display outside of restricted zone
  - Typically used for 2-3 bars in a location for mill calibration
  - Measures rounds, flats and squares
  - Reduces setup and change times with immediate feedback

## Camera and enclosure

- Cameras mounted on rail system for flexibility of adjustment and positioning
- IP67 enclosure suitable for water and steam applications

**Fixed Caliper example**



Average Height & Width Measurement in data acquisition system


GUI

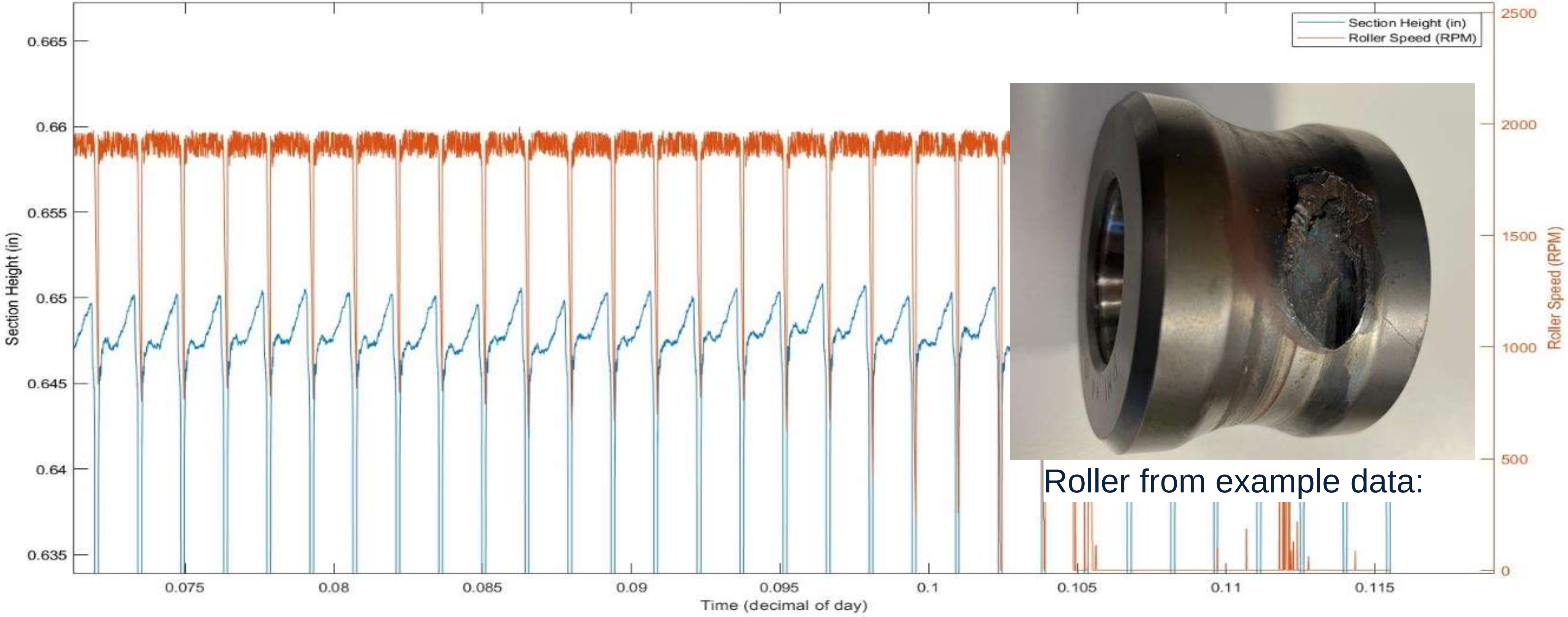
# Product development driven by safety
# Prevention of cobbles - Stock measurement and monitoring solutions

**Advanced Guides for process monitoring**

- Section height measurement
- Remote symmetrical roller gap adjustment
- Roller speed measurement
- RMS vibration measurement
- Wireless data transmission
- Internal condition monitoring
- Interchangeable control modules
- Convertible to standard guide with dummy plate
- User friendly HMI
  - Real-time predictive failure analysis with alerts
  - Up to 6 guides per HMI station
  - Ability to feed data into IBA

# Product development driven by safety
# Prevention of cobbles - Stock measurement and monitoring solutions

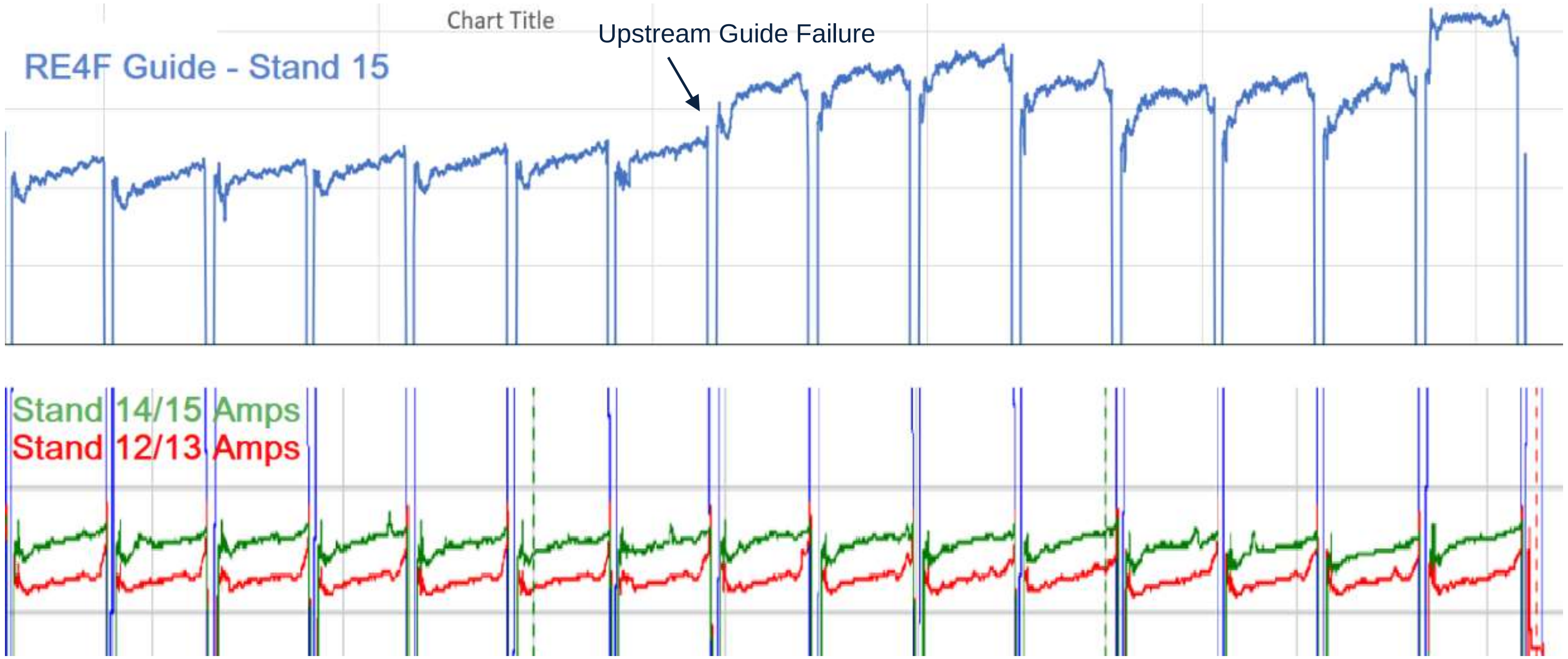
## Section height and roller RPM monitoring



# Product development driven by safety
# Prevention of cobbles - Stock measurement and monitoring solutions

### Upstream (non-Advanced) Guide Failure Example

- Section height measurement can help to identify upstream guide failures or setup issues.
- Detection of exact billet that failure or issue occurred streamlines quality inspection for defects.
- Failure not clearly visible in stand amperage data




# Product development driven by safety
# Prevention of cobbles and Yield optimization – Speed measurement

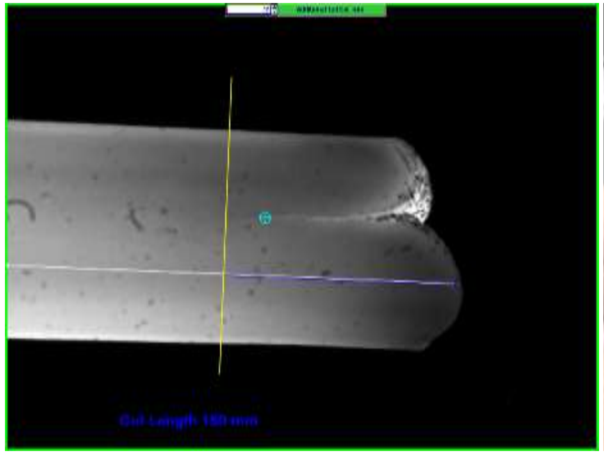
## Bar speed gauge for process optimization

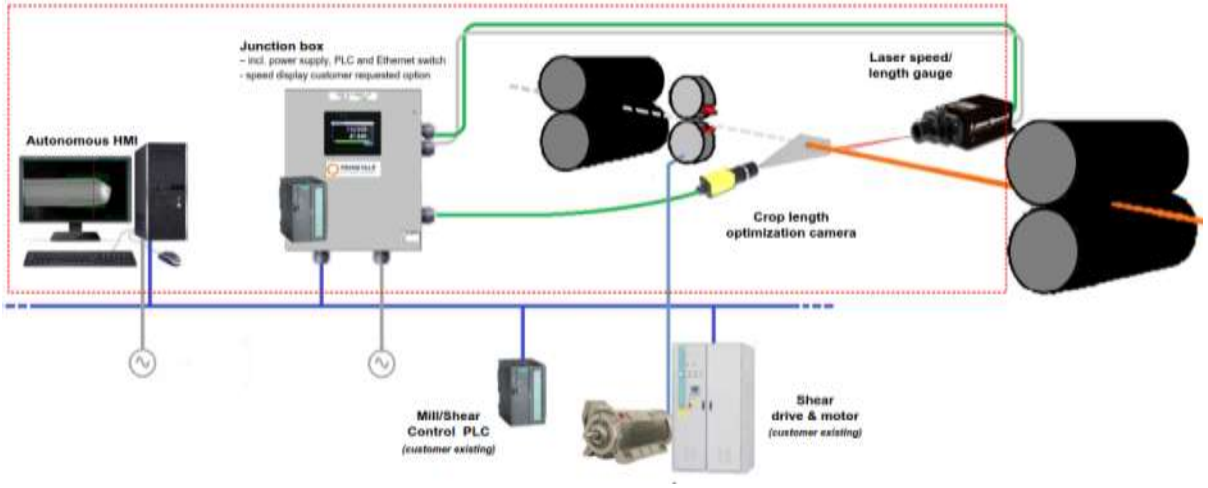
- Dopler laser measurement of actual bar speed
- Non-contact with no moving parts and requires no calibration
- Can be installed anywhere, not impacted by bar movements
- Measure length of the billet and length of finished product for direct yield calculation
- Tension regulation between stands at high-speeds
  - Continual and instant true product speed of the sections being rolled independent of work diameter calculations or motor RPM’s
  - Speed measurement is accurate within 0,03% (0,033 m/s @ 110 m/s)
- Shear crop optimization to minimize heat crops to maximize yield

# Product development driven by safety
# Yield optimization – Shear crop length

## Vision systems for crop and divide shears

- Head end position detection
- Head and tail end condition detection
  - Shear the bar decision or change the length of the shear cut based on the actual head and tail condition
  - Potential to reduce cobbles from head end splits
  - Potential to reduce cobbles from tail end tension overfill removal
- Potential to optimize furnace control though cold zone detection through the bar

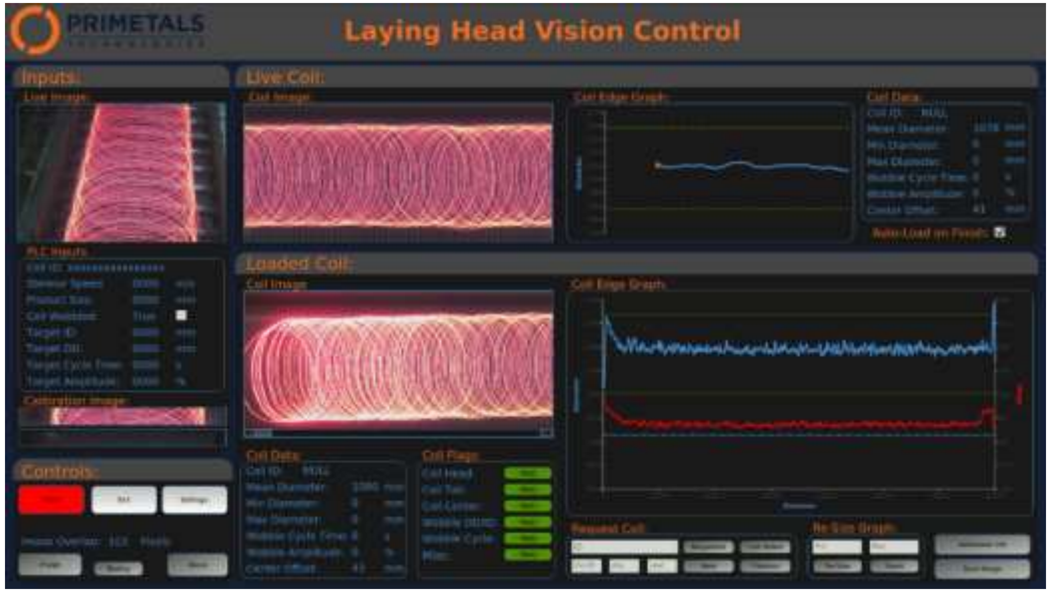




# Product development driven by safety
# Operator safety – Keep people away from the process

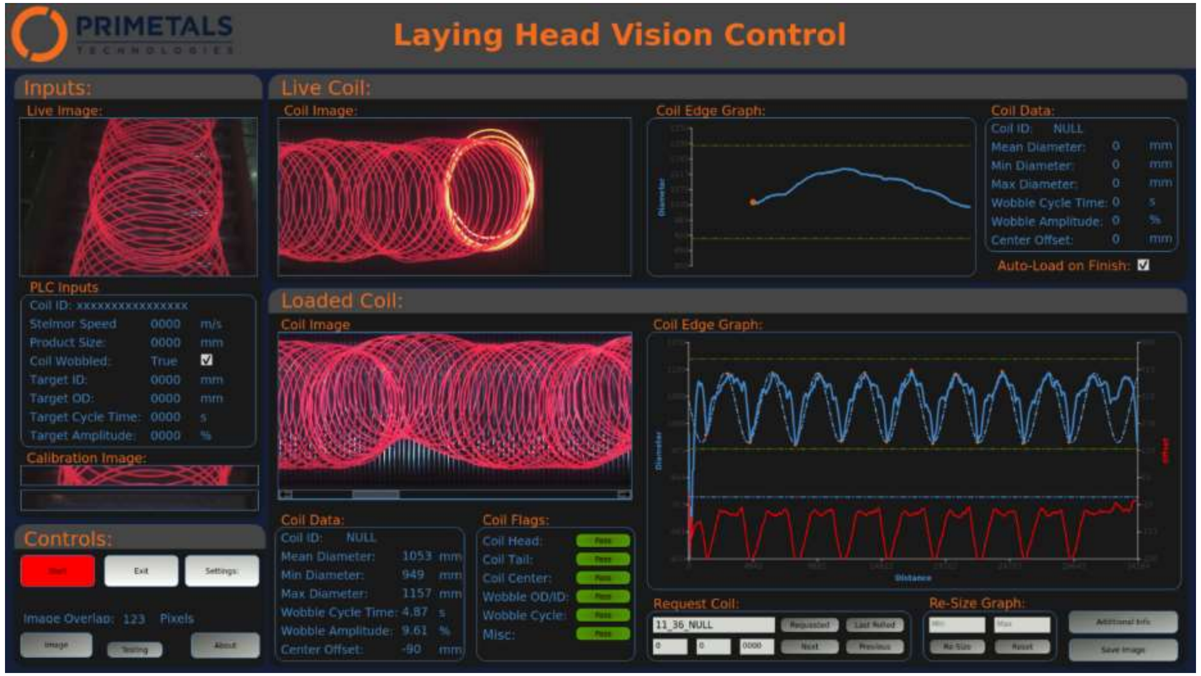
## Vision systems for Laying Head adjustment

- Optimize laying head speed and pattern to remove an operator from the Stelmor® area
- Measures, identifies, and/or records:
  - Off-center coil on the conveyor
  - Ring diameter average for a coil, as well as maximum and minimum diameter during wobble
  - Wobble amplitude and frequency
  - Coil edge formation consistency
  - Ring spacing from entry zone speed feedback
  - Tail and head formation for speed adjustments and wear monitoring
- Recognizes issues as they occur and offers operators corrections
- Stores coil images and accompanying data for 30 days
- Provides images for operators to determine head ring trim count

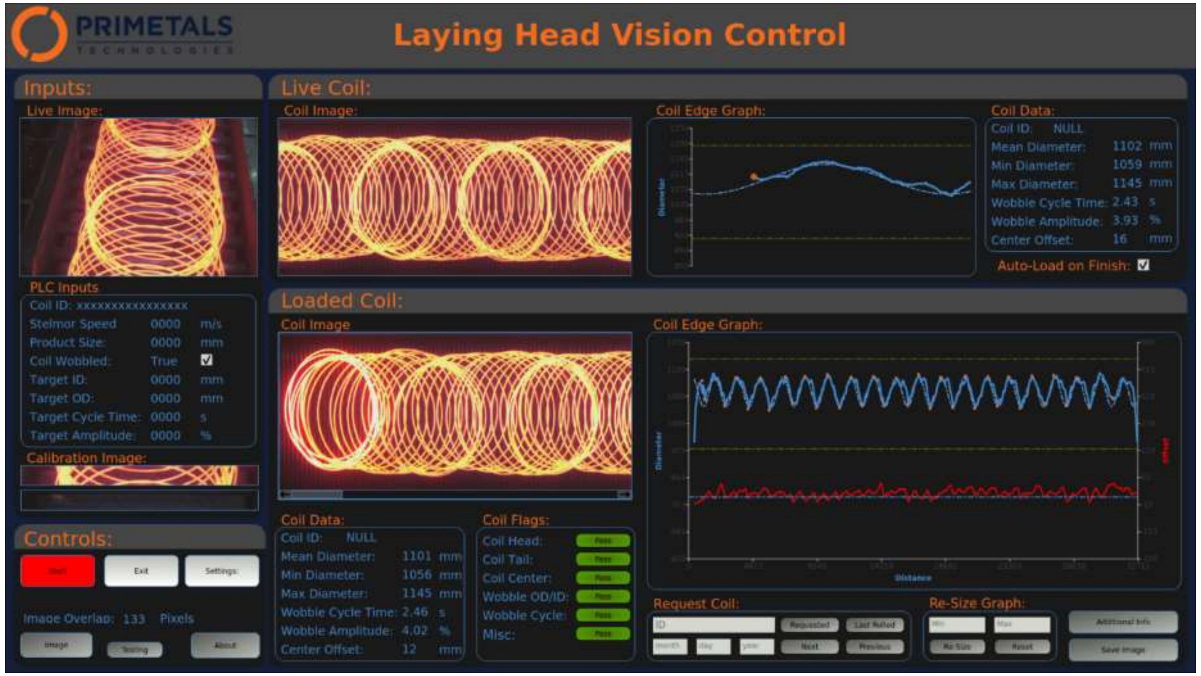


5,5mm natural cooled product

# Product development driven by safety
# Operator safety – Keep people away from the process




15,1mm – Natural cooled high wobble




15mm rebar - low period wobble

- Optimized wobble settings to achieve target coil density and compacted coil heights
- Maintains wobble limits and coil centrality offset limits
- Minimizes reform cobbles and related production delays and yield losses

# Product development driven by safety
# Operator safety – Keep people away from the process

## TrimRob - Vision system/robotic solution for wire rod coils

- Remove the operator from manual trimming of non-uniform metallurgically processed head and tail rings based on waterbox control settings
- Trimming rocess is very labor-intensive, inaccurate, and has a high rate of injuries
  - Many production people are reluctant to take on the task of manual trimming
  - Highly repetitive process and operator contends with ergonomic issue considered unsafe working conditions
  - Location for the trimming task in a hot and dusty environment
- The robotic system simulates the manual trimming process without the inherent risk of inaccurate ring counts, too few or too many rings, and the risk of operator injury from repetitive movement of ring removal from the C-hook

# Product development driven by safety
# Operator safety – Keep people away from the process

## TrimRob - Coil trimming steps

Ring notches and vision identifying where to trim

Location to trim is identified and tool inserted

Locating tool between the pinch tools to start the cut

# Product development driven by safety
# Operator safety – Keep people away from the process

## TrimRob reference installation – trimming and sampling



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# Product development driven by safety
# Operator safety – Keep people away from the process

## TrimRob - Production testing results

| size | Grade | Cycle time | | Trimming Setpoints | |
|---|---|---|---|---|---|
| | | Standard | with sample | targets | tolerance |
| [mm] | | [sec] | [sec] | # | # |
| 5.0 | Low Carbon<br>Medium Carbon<br>High Carbon<br>Boron Steel<br>Alloy Steel<br>Spring Steel<br>Bearing Steel<br>Welding Steel<br>Free Cutting Steel<br>Mild Steel<br>Cold Heading Grades | 60 | 72 | >3 ; < 10 | +5 |
| 5.5 | | 60 | 72 | >3 ; < 10 | +5 |
| 6 | | 60 | 72 | >3 ; < 10 | +4 |
| 7 | | 60 | 72 | >3 ; < 10 | +4 |
| 8 | | 60 | 72 | >3 ; < 10 | +4 |
| 9 | | 60 | 72 | > 2; < 10 | +3 |
| 10 | | 60 | 72 | > 2; < 10 | +3 |
| 11 | | 60 | 72 | > 2; < 10 | +3 |
| 12 | | 60 | 72 | > 2; < 10 | +3 |
| 13 | | 60 | 72 | > 2; < 7 | +3 |
| 14 | | 60 | 72 | > 2; < 7 | +2 |
| 15 | | 60 | 72 | > 2; < 7 | +2 |
| 16 | | 60 | 72 | > 2; < 7 | +2 |
| 17 | | 60 | 72 | > 2; < 7 | +2 |
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| 21 | | 60 | 74 | > 2; < 5 | +2 |
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| 23 | | 60 | 74 | > 2; < 5 | +1 |
| 24 | | 60 | 74 | > 2; < 5 | +1 |
| 25 | | 60 | 76 | > 2; < 5 | +1 |
| 26 | | 60 | 76 | > 2; < 5 | +1 |
| 27 | | 60 | 76 | > 2; < 5 | +1 |
| 28 | | 60 | 76 | > 2; < 5 | +1 |

5,5mm to 7mm software enhancements in process to manage interlaced coils

Larger sizes manage interlaced coils within cycle time and accuracy targets

Operator training completed to improve coil formation from the reform station

Contents

# Focus areas for future advancements

### Rolling Mill Evolution

- Operator safety
- Advanced process modeling
- Maximum utilization, flexibility and productivity
- Minimum OPEX

### Smart Sensors

- Advanced integration within maintenance and operation systems
- Process quality control
- Integrated warehouse solutions

### Vision Systems

- Billet storage
- Billet dimensional condition
- Furnace charging/monitoring
- Stelmor transformation tracking

### Robotics

- Removing repetitive, repeatable functions
- Roll changing
- Coil and bundle tagging
- Bar sampling

# Evolving the long rolling mill design process and driving new solutions

Long rolling processes are rooted in fundamentals dating back over 250 years

The modern rolling mill design starts from these core fundamentals now applying new tools and technologies for the highest levels of productivity, quality and safety not imaginable a few decades ago

If problems suddenly start to occur when they did not occur before, check to ensure the rolling fundamentals are being followed

New technologies can be utilized via systematic planning and implementation, you don’t need a new rolling mill

Advancements in vision systems, smart sensors, AI learning models, robotics and digital systems will drive the industry to new limits not yet imagined

The industry ultimate goal - Zero Cobbles and Zero Operators when the mill is producing

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# THANK YOU