

Automated and scalable weld and strip break classification in tandem cold rolling mills using Time Series AI



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**AM/NS
CALVERT**

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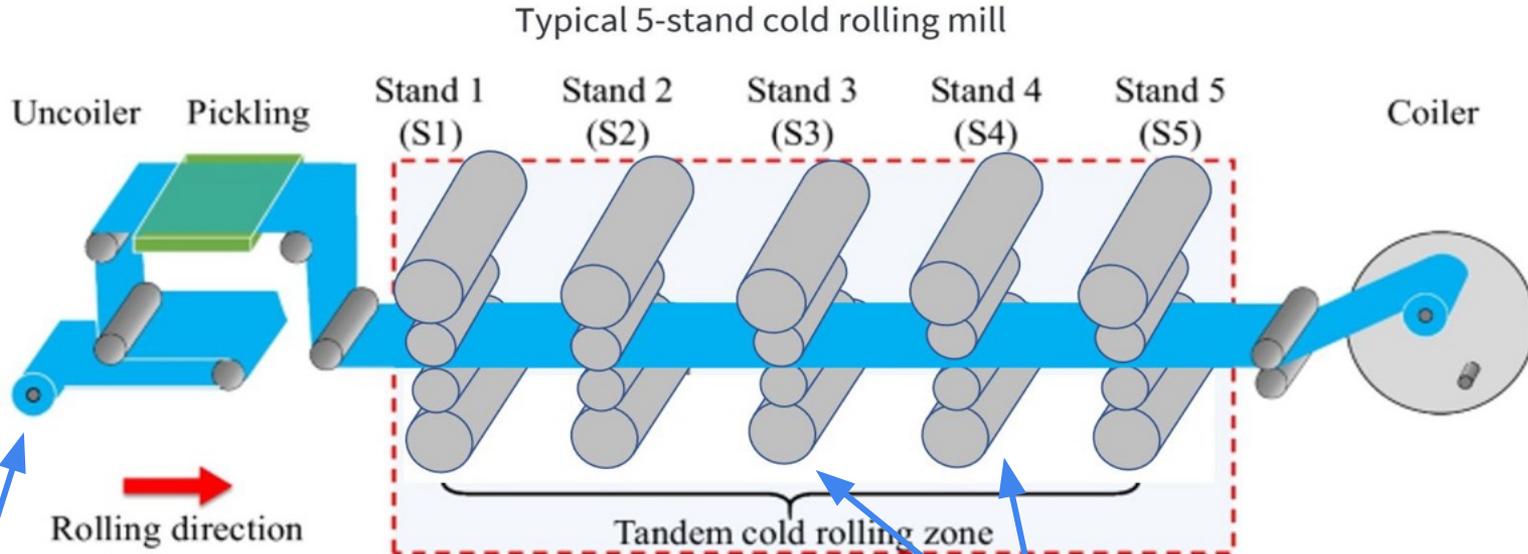


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Abstract

In this presentation, we showcase a novel methodology for automated strip break classification that uses Falconry's time series AI platform to classify the complex waveforms of tandem mill parameters associated with strip breaks. Strip breaks are unwanted yet common occurrences during cold rolling of steel. Strip breaks have various causes, such as weld breaks, material defects, or steering issues, and result in lost productivity, material scrap, and equipment damage. Today, analysis of strip breaks requires manual extraction of multiple time series parameters from SCADA systems or historians and extremely resource and time-intensive human interpretation of these parameters just before the strip break event. The resources and time required to analyze strip breaks are expensive, but more expensive is the lost time between events and diagnosis. Breaks are temporally indiscriminate. Human analysts are neither on-call nor capable of near-instant analysis — which is required for production teams to determine causes and actions in response to strip breaks. Automated classification allows low-latency automated classification of strip breaks for use by operations teams to understand underlying causal factors and implement corrective actions.

Tandem cold rolling mill



Coils are welded to be fed continuously through pickling & then tandem mill

The strip thickness decreases from stand to stand, and therefore the operating parameters (RPM, torque, current, tension), differ.

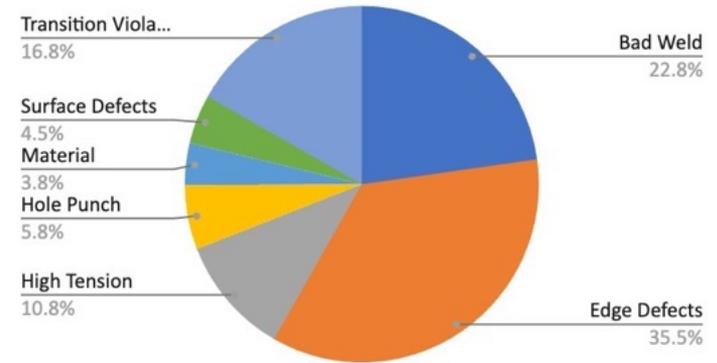
Impact of strip & weld breaks in cold mills

Strip break in tandem cold rolling mill causes productivity losses:

- Line stoppages, equipment damage and safety hazards
- Upto 15 days (3-4%) of lost productivity annually
- Upto USD 3.5mn financial losses every year

Dozens of break events every month. Common causes:

- Edge Defects
- Bad Weld
- Transition Violation
- Surface defects
- Hole Punch
- High Tension



Manual diagnosis of strip break is time consuming (~ 400 hrs / year) and less accurate, significantly delaying the corrective actions

Problem statement and solution overview

**AM/NS
CALVERT**

A joint venture between ArcelorMittal and
Nippon Steel & Sumitomo Metal Corporation



PROBLEM

Dozens of weld and strip break events each month causing **3-4% (10-15 days) of lost production** each year in 24x7 operation requiring weekly expert cause analysis requiring 20% FTE work

SOLUTION

Use **existing PLC** electrical and mechanical data at 100 Hz

Inline assessment of break causes to automatically **identify exact cause within minutes**

Alert the line personnel to accelerate recovery

ADVANTAGES

Off the shelf makes for faster deployment

Records tacit knowledge of subject matter experts

Versatile, leads to competency development

1% production improvement

20% FTE work reduction

Objective and approach

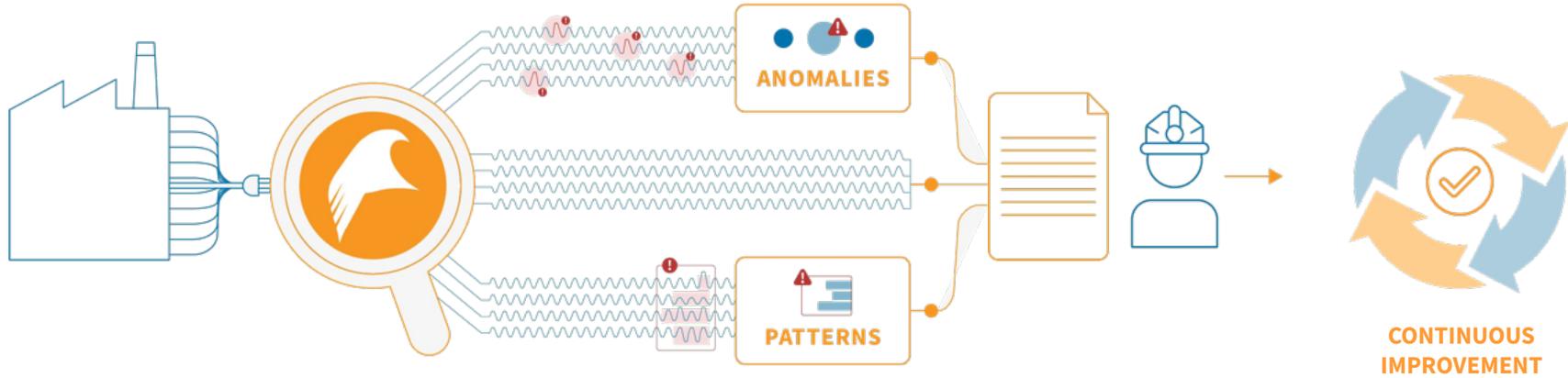
Improve productivity in a cold mill by:

1. Instantaneously classify the accurate reason for weld and strip breaks
2. Relay the classification of the reason to the operations team to reduce time to recover

Use off-the-shelf technology to:

- Ascertain the right PLC parameters to use for automated classification
- Connect to the plant historian for those parameters
- Classify break events in the cold mill
- Validate automated classification against expert classification
- Convey break classification to line users by email

Time Series AI approach to automated classification



READY

Connect existing lines or fleets to find anomalies.

LEARN

Semi-supervise learn labels for multivariate trends.

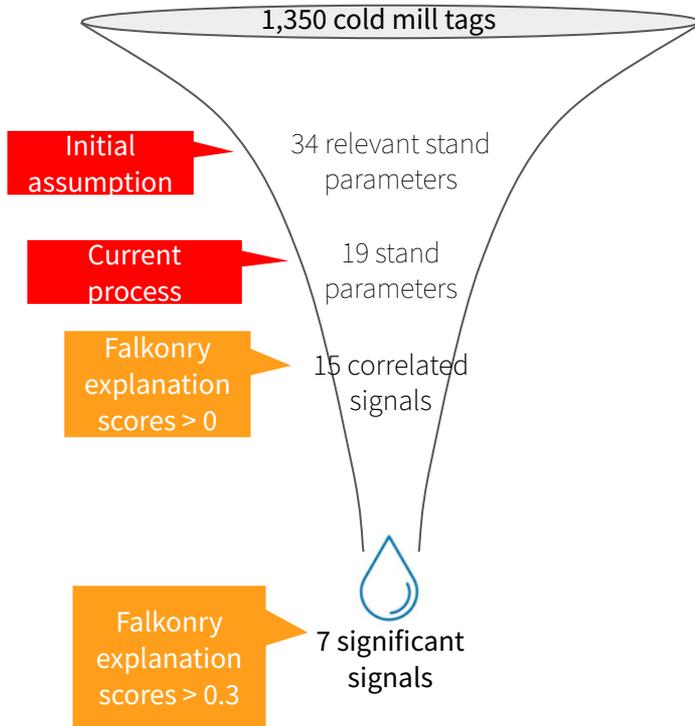
SET

Validate results for inline assessment.

GO →

Data driven decisions and continuous improvements.

Narrowing the problem down

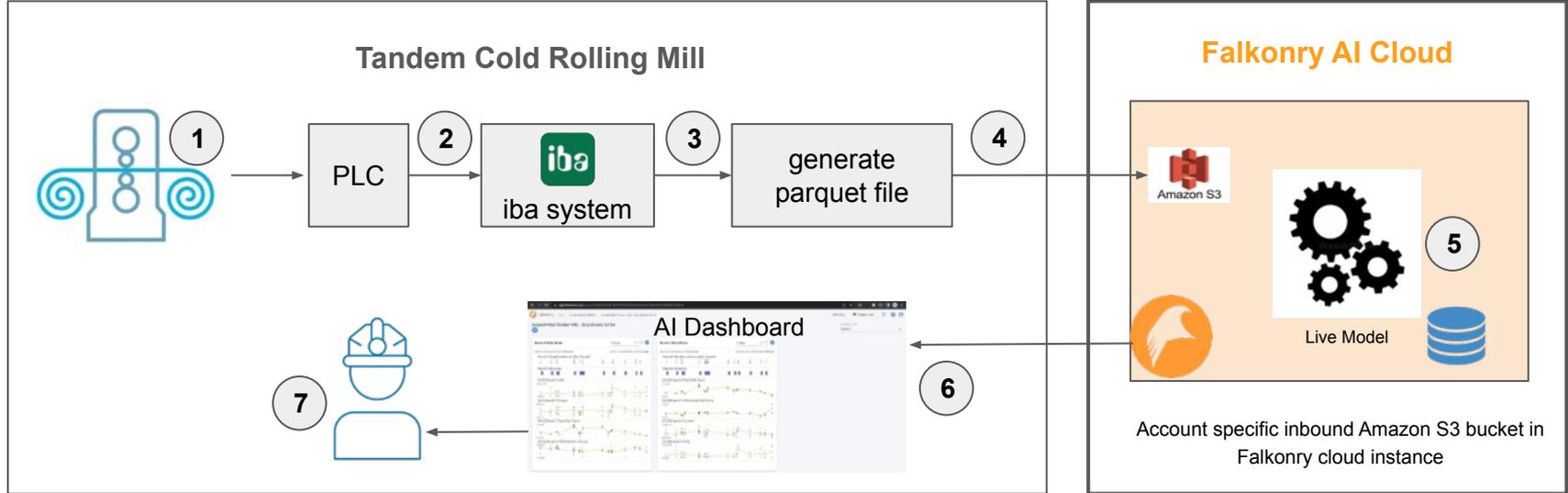


The relevant electromechanical operating parameters determined by Falkonry are:

1. Current
2. Voltage
3. Differential roll force
4. Tension feedback
5. Tension stress feedback
6. Torque
7. Torque Roll force

Strip break classification cannot be performed by same model as weld break classification

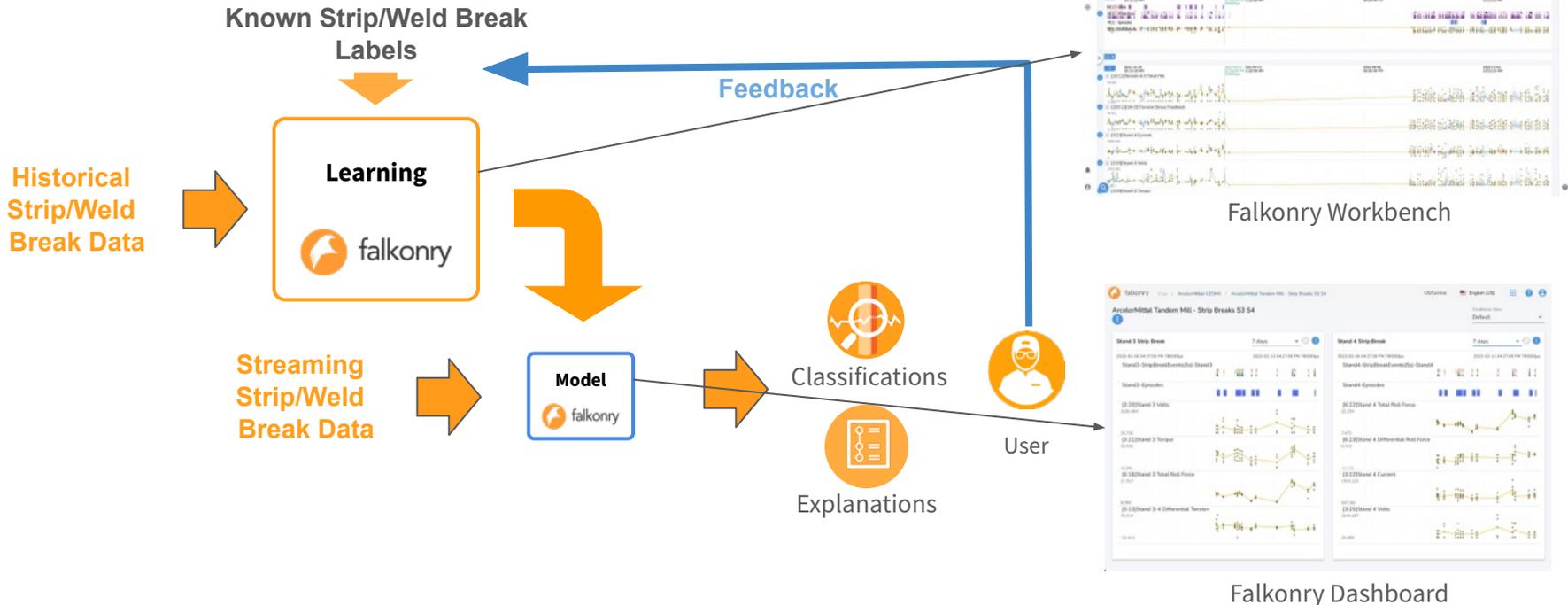
Strip break classification system diagram



1. Mill Stand data is being collected by PLC
2. It is sent to **iba** data historian
3. When a strip break occurs, sensor data 10 seconds prior to the break and 5 seconds after the break are packaged and exported as parquet file automatically
4. The parquet file is copied to Falkonry Cloud instance

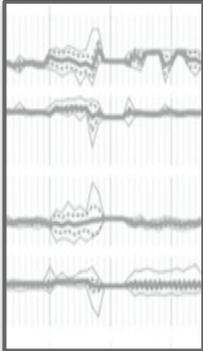
5. Falkonry Live model receives, processes the data and produces break classification.
6. The classification is rendered in Falkonry Live digital twin.
7. ArcelorMittal user visits the digital twin corresponding to the stand where the break occurred for the classification

Strip & weld break classification workflow

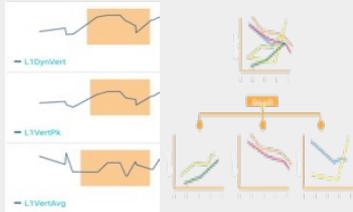


Inside Falconry's classification and explanation analysis

Operational data

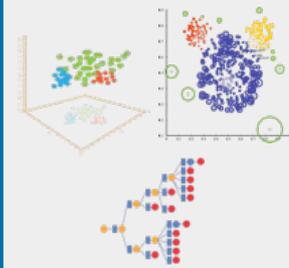


Signal Processing & Feature Recognition



Automated Feature Learning
(Segmentation, featurization)

Generalized Classification



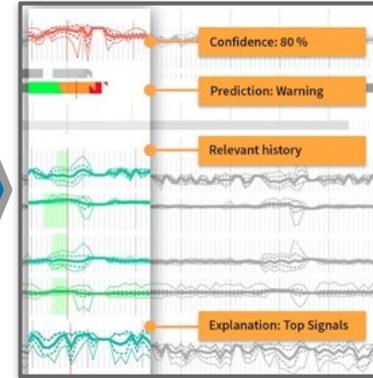
Condition Prediction
(Unsupervised & Semi-supervised ML)

Correlation



Explanation
(Correlate signals with resulting predictions)

Operational insight



Prediction Outcomes

- Classification label
- Per label classification confidence
- Per instant explanation score

Data prerequisites

Time series data from the mill stand is collected by the PLC and stored in iba historian

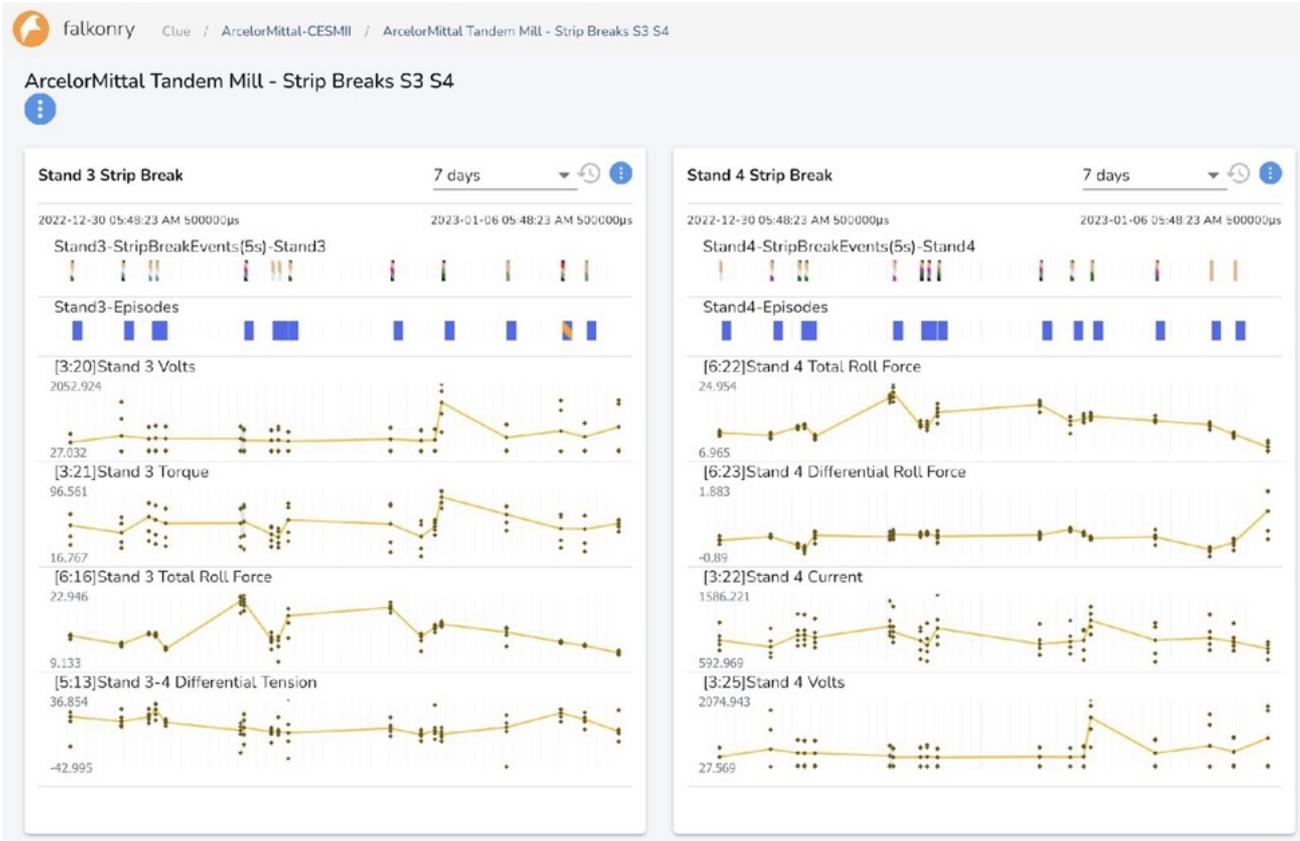
~4 months of mill data:

- 430 operational & non-operational signals
- Typical operational parameters (electromechanical) are current, voltage, differential roll force, tension stresses and feedback, torque roll force, etc
- Timestamp of known strip-break and weld-break events

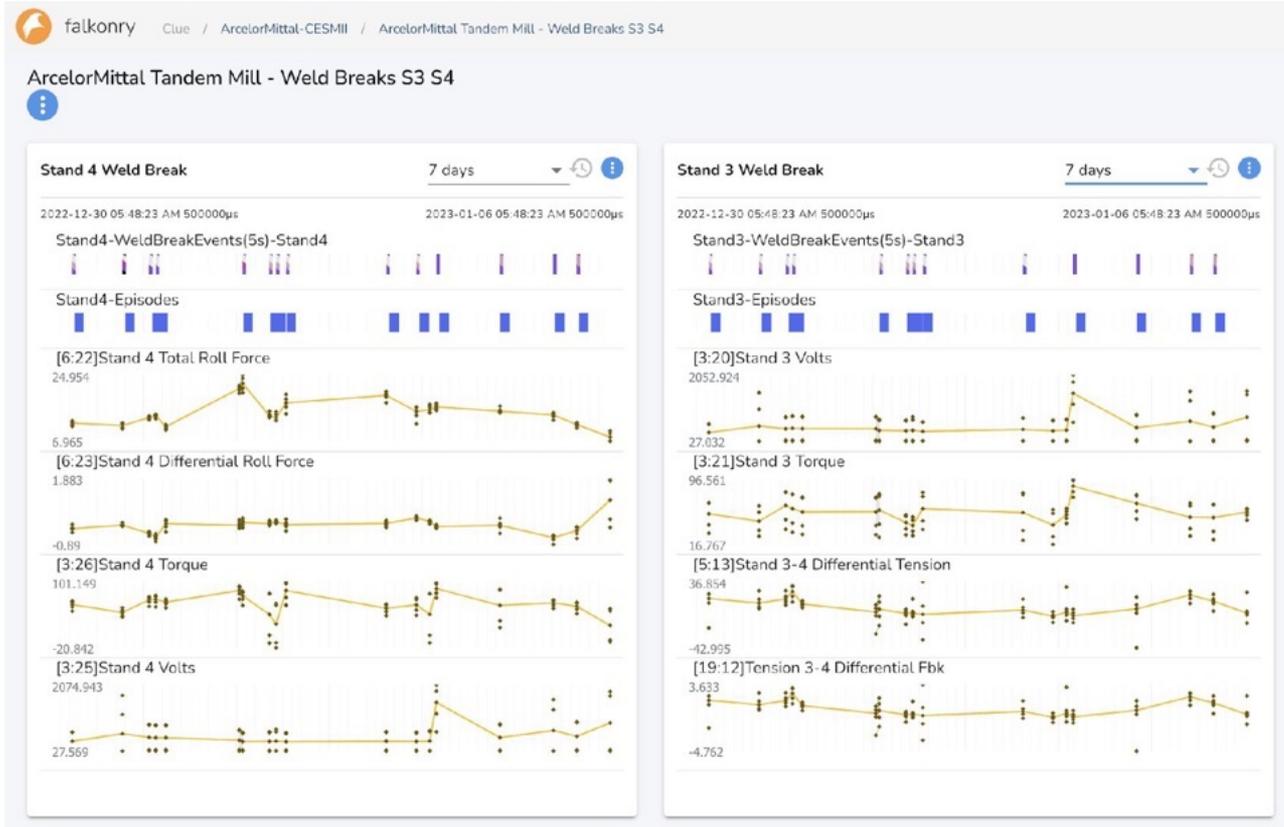
Most breaks occurred on Stand 4 (73%) followed by Stand 3 (24%). Stand 1 & 2 have very few breaks

Each mill stand is modeled for separate strip and weld break events

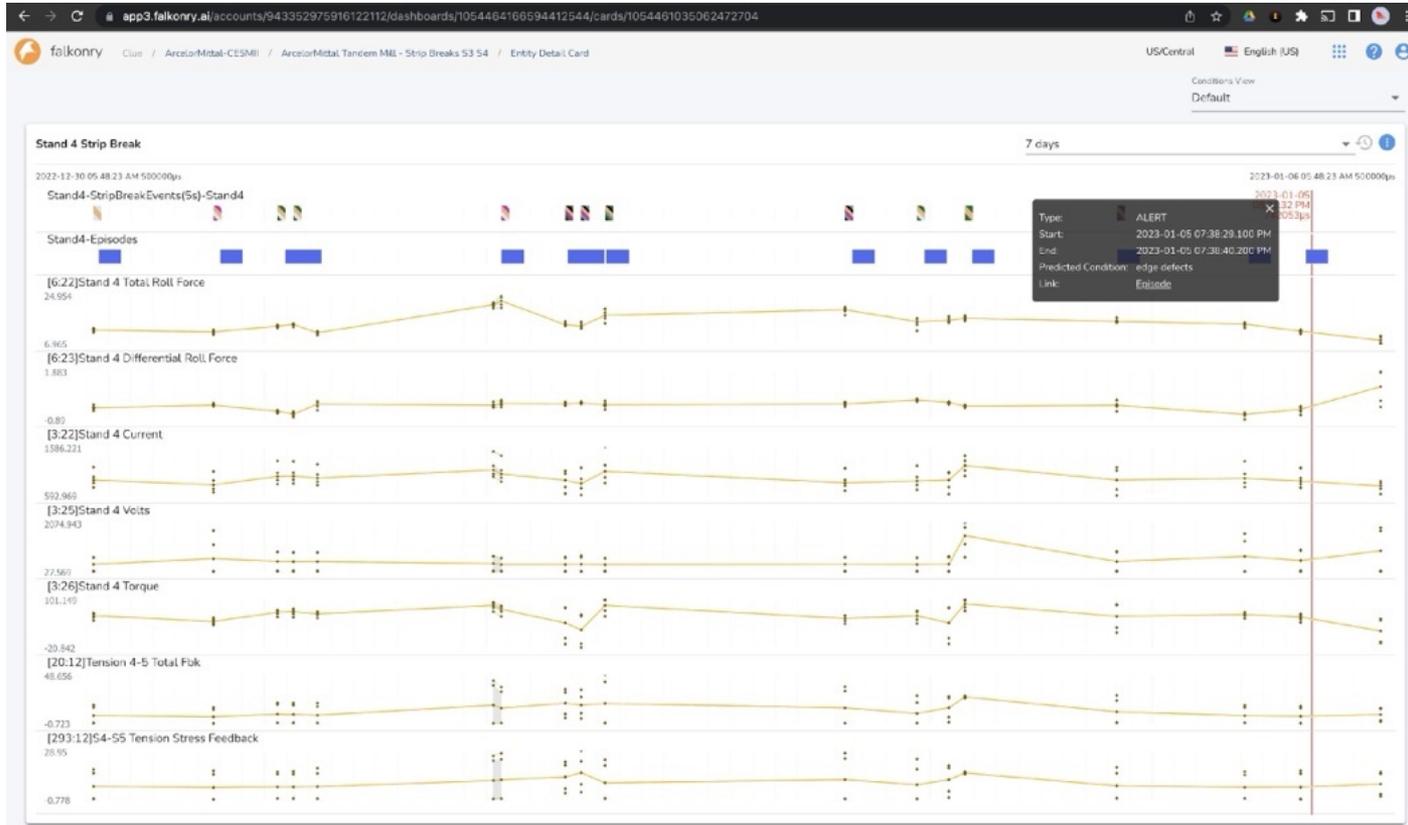
Strip breaks - Stand 3 and 4



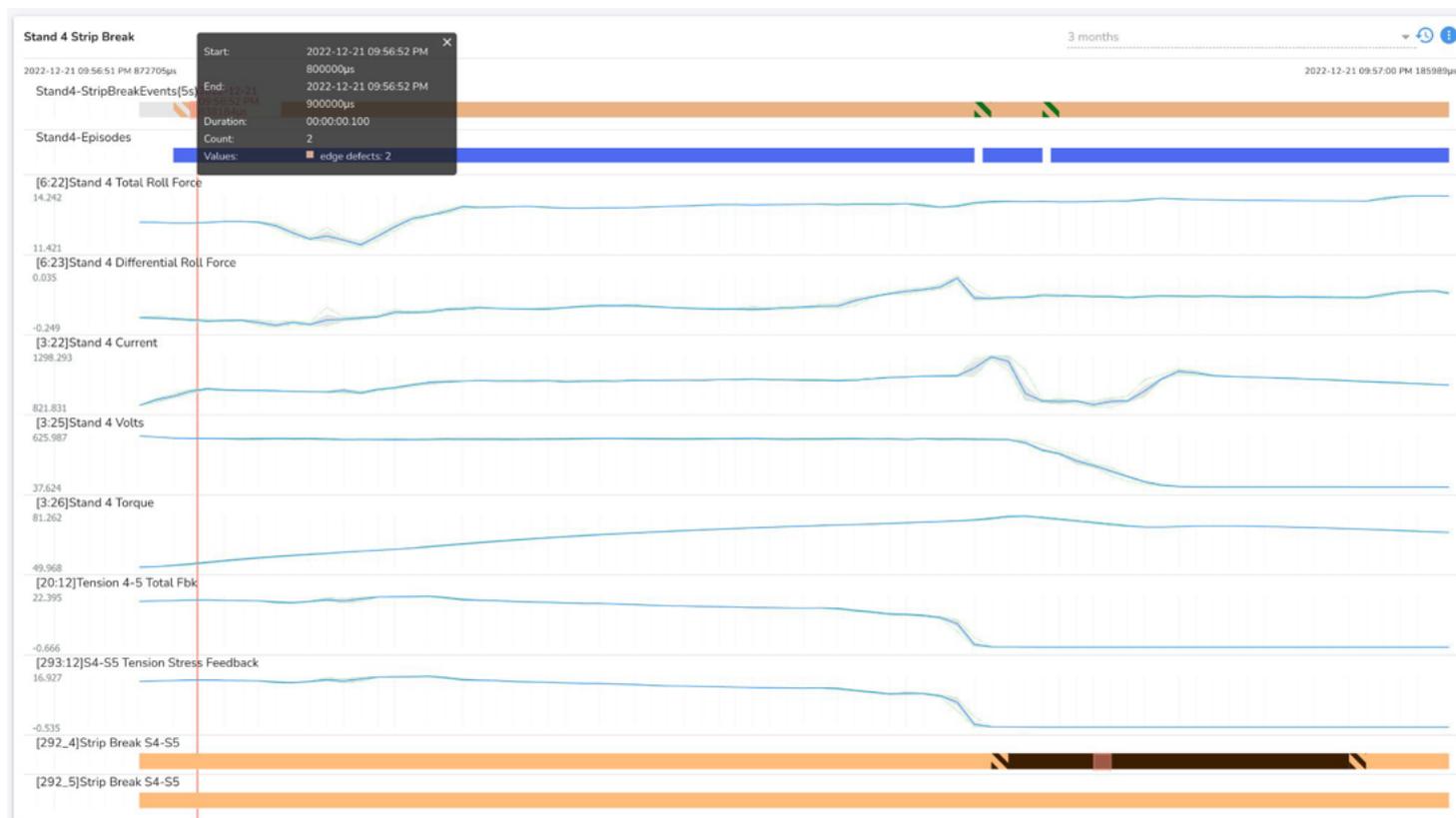
Weld breaks - Stand 3 and 4



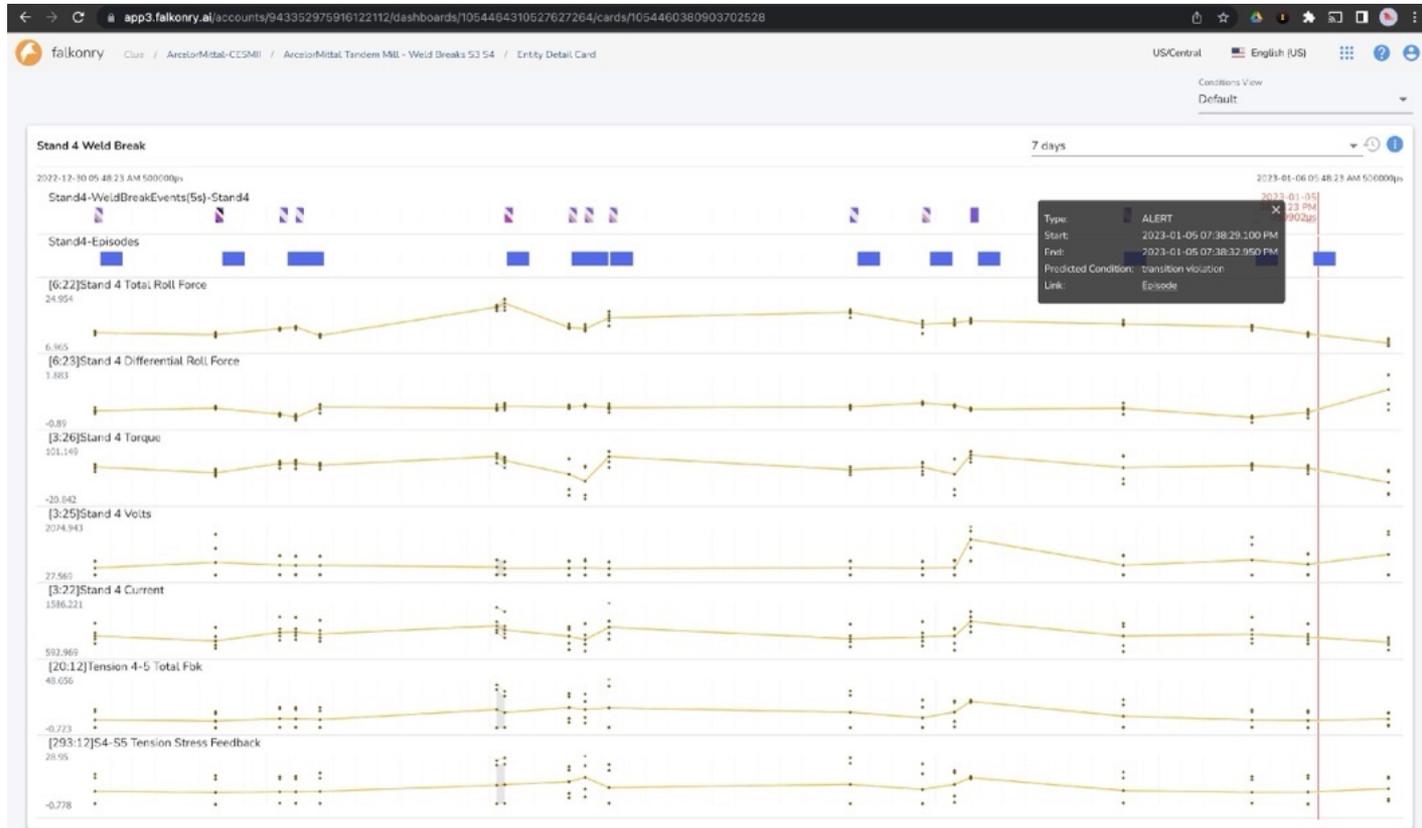
Strip break - Stand 4



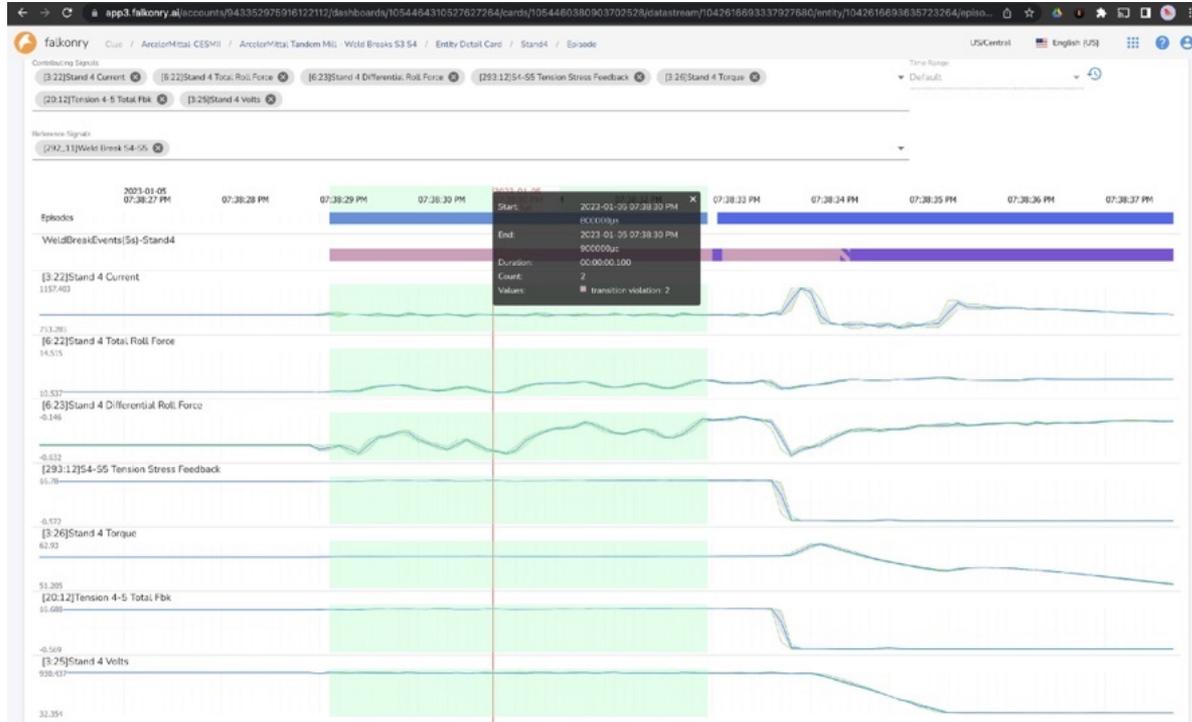
Strip break - Stand 4 (detailed view)



Weld break - Stand 4



Weld break - Stand 4 (detailed view)

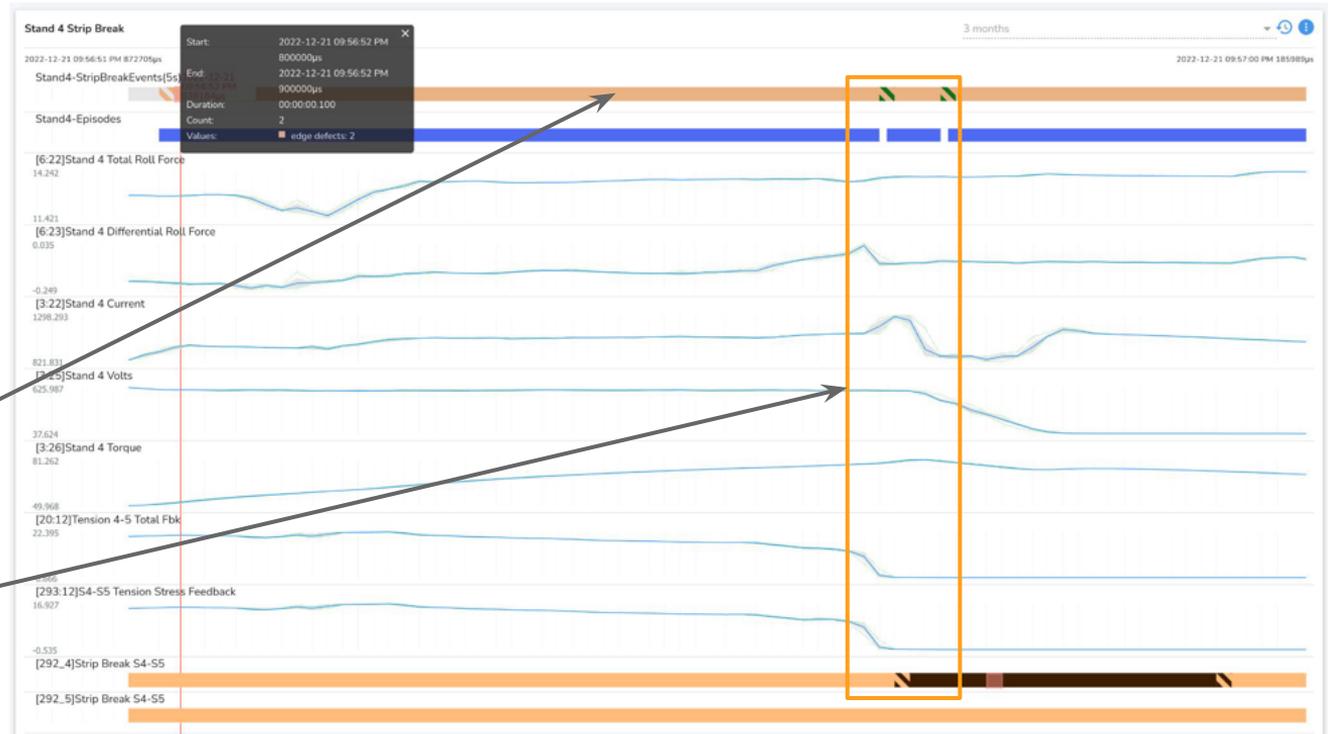


Reviewing individual classified break - Strip Break Stand 4

Episode view where more details about a single strip/weld break classification are available.

Classification

Strip Break

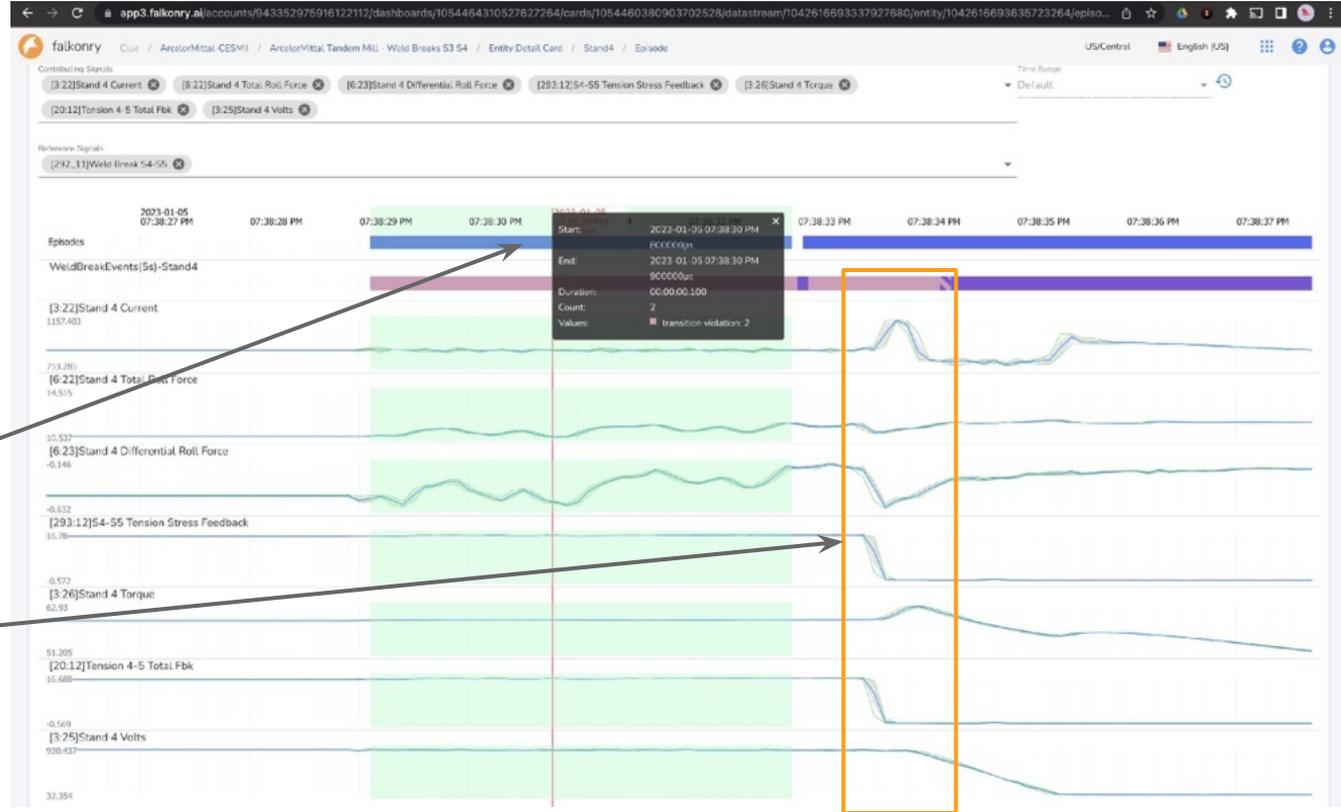


Reviewing individual classified break - Weld Break Stand 4

Episode view where more details about a single strip/weld break classification are available.

Classification

Weld Break



Model accuracy and solution performance

| RESULTS MATRIX | | | | |
|---|----------|-----------------|------------------|--|
| KPI Type | Baseline | Original Target | Actual Value | Human Productivity Improvement (% FTE) |
| Coverage | 95% | 50% | 75-78% | - |
| Accuracy | 90% | 80% | 85.6% | - |
| Routine weekly process engineering effort | 8 hours | 4 hours | Under 30 minutes | 20 |

Lessons learned

- 1) Multi-class classification for weld and strip break with off-the-shelf technology against PLC parameters
 - provides good accuracy
 - Can achieve good accuracy with fewer parameters than were used for expert classification
 - Same parameters are used for classification of both strip and weld breaks
- 2) Rule of thumb: 10 samples per label for high classification quality
 - 10 samples generally cover major variations for the label
 - 70/30 split for training/validation
- 3) Need to simplify the automated classification output for ongoing operations at the cold mill
- 4) Off-the-shelf multivariate classification can improve inline assessment of part and production quality across process and discrete manufacturing