Predictive Maintenance in Continuous Casting and Rolling (CCR) Plants

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The combination of multi-sensor monitoring, data analytics and predictive modelling provides a robust maintenance framework.

The metallurgical sector is increasingly adopting predictive maintenance systems to enhance the availability, reliability and lifespan of production assets. **Continuus Properzi** is carrying forward the development of a preventive and predictive maintenance program for the Continuous Casting and Rolling (CCR) lines producing copper and aluminium rod. The approach combines real-time sensor-based monitoring of temperatures, vibrations and radial/axial displacements with Industry 4.0 technologies such as big data analytics and cloud-based processing to anticipate possible failures and optimize maintenance planning. Case studies on rolling mill gear transmissions and coiler gearboxes demonstrate how early detection of mechanical anomalies reduces unplanned downtime, extends equipment lifetime, and decreases operational costs. Experimental validation on a MicroMill line confirmed the capability of early fault detection, enabling scheduled shutdowns, reducing spare parts consumption and improving operational safety.

1. Introduction

Continuous Casting and Rolling (CCR) lines (such the ones for copper, aluminium, zinc and lead) operate under extreme thermo-mechanical stress, involving high rotational speeds, heavy load cycles and long uninterrupted production runs. Components such as bearings, gearboxes and couplings are prone to wear mechanisms that may cause unplanned and unexpected, breakdowns, production losses, and safety risks.

Predictive maintenance offers a shift from time-based preventive strategies to data-driven, condition-based approaches, relying on continuous acquisition and analysis of machine parameters. This enables early detection of anomalies and informed maintenance scheduling, directly improving Overall Equipment Effectiveness (OEE).

In the Industry 4.0 context, predictive maintenance lets devices, machine learning and cloud platforms to collect, transmit and process operational data in real time. Such systems perform interventions only when actual fault risk is detected, optimizing both uptime and resource use.

2. Methodology

Data Analysis: Defect Recognition: localized defects: produce cyclic vibrations characterized by specific frequencies, and non-localized defects produce broad-spectrum noise. Phenomena that influence the generation of abnormal vibrations include the following:

- Variation in mesh stiffness, due to possible deformations of the gear teeth.
- Transmission error, the difference between the actual and theoretical gear positions.
- Eccentricity error.
- Shaft misalignment.
- Tooth collisions, due to deformations or alignment errors.
- Surface fatigue and wear of rolling elements (bearings).

The proposed system integrates three core monitoring domains:

- Vibration Monitoring
    1. Sensors: mono-axial and tri-axial accelerometers mounted at main bearing housings, gearboxes and motor interfaces.
    2. Standard: *UNI ISO 10816* for RMS vibration speed assessment.
    3. Thresholds: Alarm at 2.3 mm/s; shutdown at 4.5 mm/s (these threshold values can be varied depending on the application).
- Temperature Monitoring
    1. Sensors: type K thermocouples installed on bearing housings and lubrication oil circuits.
    2. Thresholds: Alarm at 80°C; shutdown at 90°C (values to be set according to the line).
- Radial/Axial Displacement
    1. Sensors: contact or non-contact displacement transducers to detect shaft misalignments or progressive deformation.

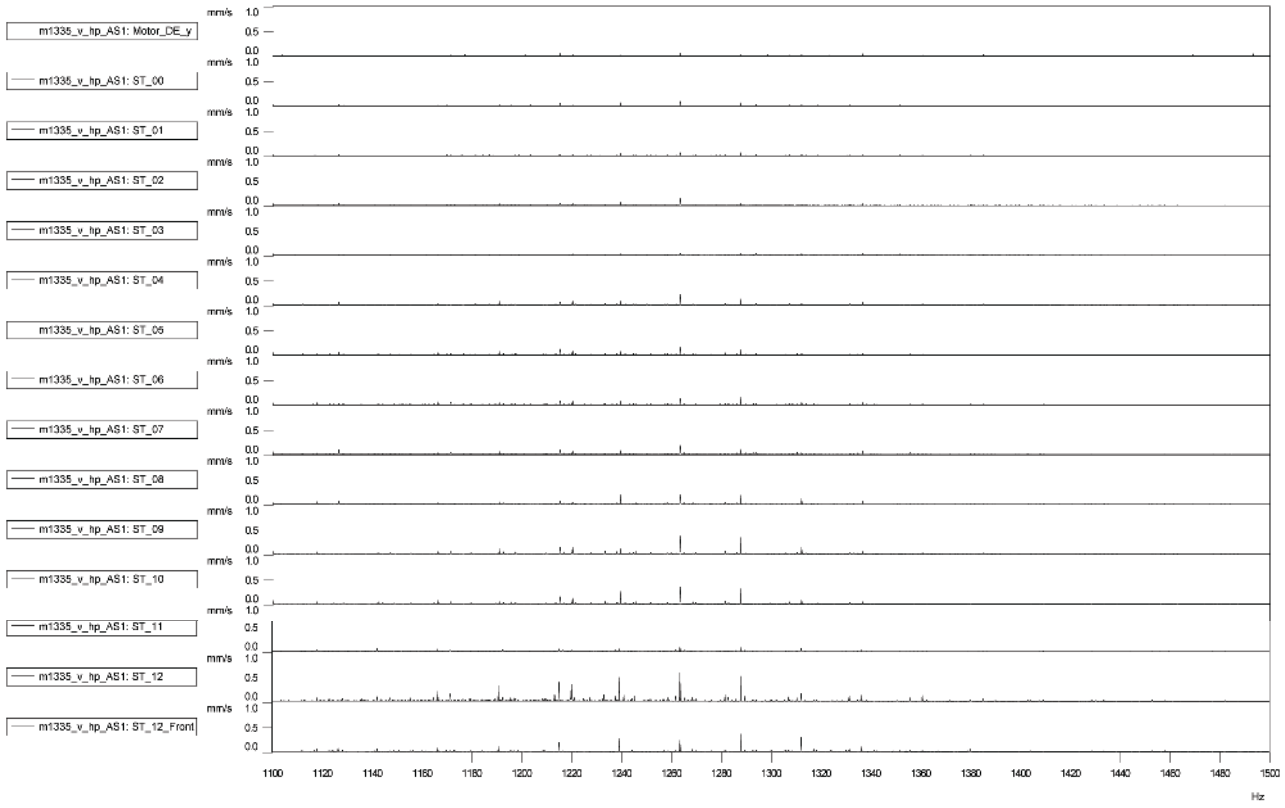
Data Acquisition and Analysis: signals are collected continuously, logged in a historical database and analysed using both time-domain trends and frequency-domain spectral analysis. Alarm generation is based on fixed thresholds and pattern recognition models developed from historical data.

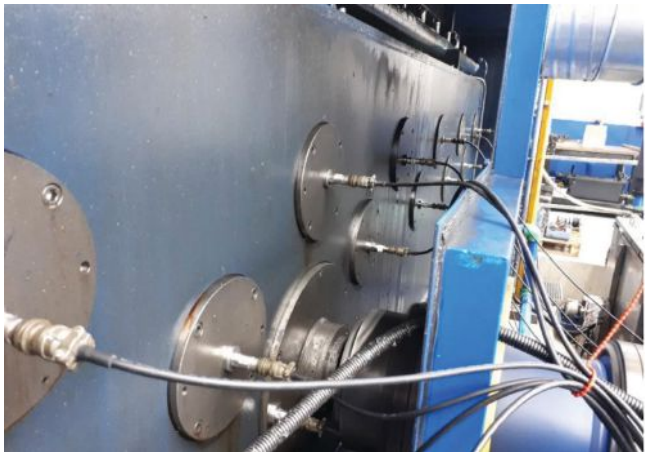
3. Case Study – MicroMill CCR Line

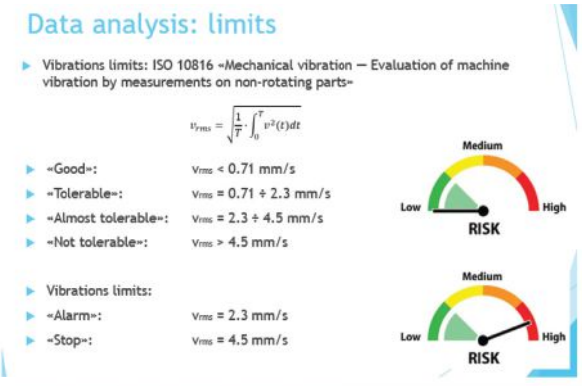
A test campaign on an aluminium alloy MicroMill line (10 stands, 3 mm wire, 16 m/s, 1100 kg/h) was initiated following increased noise levels and perceptible vibrations. Accelerometers (mono-axial and tri-axial) installed on transmission gearbox, shafts, motor hub and machine basement with highest readings recorded at the inlet transmission shaft.

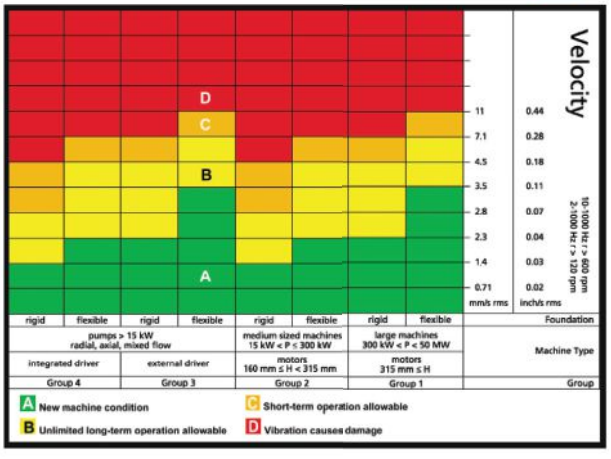
Key findings include the following:

- Dominant vibration peak at 1263 Hz, corresponding to the inlet shaft's secondary frequency.
- Additional peaks observed at 1263 Hz ± n·24.3 Hz.
- Maximum vibration speed recorded: 0.70 mm/s (below *ISO 10816* alarm limit).
- Bearing hub temperature rise from 48°C (idle) to 63°C (operation).
- Root cause: dry and seized motor-to-gearbox coupling, lead-









ing to loss of flexibility and increased load on the inlet shaft.

Recommendation: Immediate coupling replacement, followed by post-intervention monitoring to confirm vibration reduction.

4. Results and Discussion

The integration of vibration and temperature monitoring allows:

- Identification of early-stage defects (e.g., misalignments, gear tooth errors and bearing fatigue).
- Correlation between vibration amplitude and thermal anomalies, which reinforces diagnosis reliability.
- Optimization of maintenance planning by anticipating failures (e.g., seized coupling) and scheduling shutdowns.

The implementation of the predictive maintenance system yielded the following measurable outcomes:

- Availability: net increase in annual productive hours.
- Planned Maintenance: interventions aligned with production shutdowns.
- Cost Reduction: significant savings on spare parts and

labour from avoiding catastrophic failures.
- Safety: more stable operating conditions and lower risk of mechanical accidents.

The creation of a structured database enables progressive refinement of predictive models, particularly when integrating spectral analysis with AI-based diagnostic tools.

5. Conclusions and Future Work

The combination of multi-sensor monitoring, data analytics and predictive modelling provides a robust maintenance framework for CCR plants.

Planned Enhancements:
- Advanced frequency-domain analysis for automated fault-type recognition.
- Machine learning algorithms for anomaly classification.
- Integration with Manufacturing Execution System for joint production and maintenance optimization.
- Cloud-based dashboards for real-time KPIs, active power monitoring and remote diagnostics — aligning with Industry 4.0 digitalization strategies.

Minimal modifications (e.g., threaded sensor ports near bearings) make CCR machinery predictive-maintenance-ready, ensuring long-term competitiveness in copper and aluminum rolling plants.

6. References

Standards
- *UNI ISO 10816*: Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts.
- *ISO 13373*: Condition monitoring and diagnostics of machines — Vibration condition monitoring.
- *ISO 17359*: Condition monitoring and diagnostics of machines — General guidelines.

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Company Profile:

Continuus-Properzi**, Milano, Italy, is an engineering company, promoter and inventor of the continuous casting method and direct rolling of non-ferrous metals to produce wire rod/wire. It is also involved in the design, sale, construction, installation and start-up of plants for recycling copper scrap to obtain ingots and wire rod. In addition to its core business, which has a history of more than 75 years, Continuus-Properzi has a furnace division and can also supply flue gas treatment plants to complete its offerings, always with a view to providing its customers with tailor-made solutions.* ***www.properzi.com