Technical Decision Document – Predictive Maintenance Analysis

1. Data Quality Issues & Handling Decisions

During exploratory analysis of the machine sensor logs, several data quality problems were identified and addressed as follows:

a) Physically Impossible Sensor Values

Some temperature and vibration readings were outside realistic operational limits:

- Temperature values below –20°C or above 200°C
- Vibration values below 0 mm/s or above 100 mm/s

These values are physically implausible for industrial bearings and indicate sensor errors or transmission glitches. Instead of deleting entire rows (which would discard valid data from other sensors at the same timestamp), only the faulty values were replaced with NaN and later interpolated. This preserves time-series continuity while removing corrupted measurements.

b) Missing Sensor Readings

After cleaning invalid values, gaps appeared in the time series. Since machine behavior changes gradually rather than abruptly, missing values were filled using time-series interpolation per machine. Dropping rows would have created artificial breaks and distorted rolling statistics used for condition monitoring.

c) Timestamp Consistency

Timestamps were converted to proper datetime format and sorted per machine. Rolling window features depend on strict chronological ordering; without this step, trend and instability calculations would be incorrect.

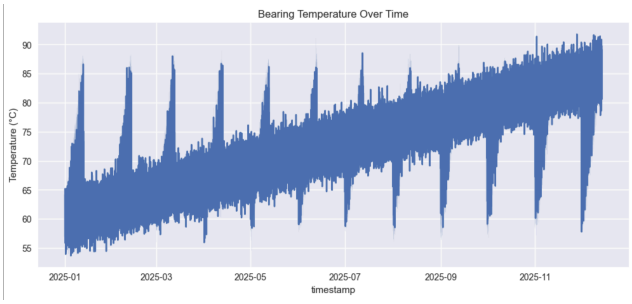
d) Missing Status Labels

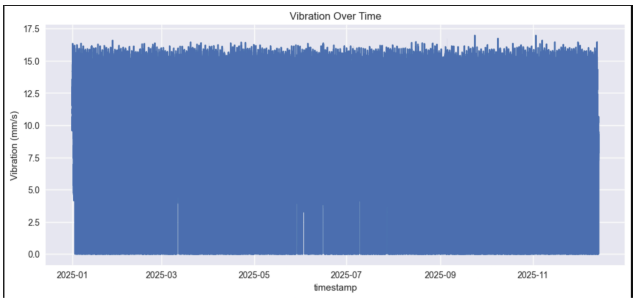
Some `status_code` values were missing. These rows were retained and labeled “UNKNOWN” rather than dropped, because sensor behavior is still informative even when dashboard labels are absent.

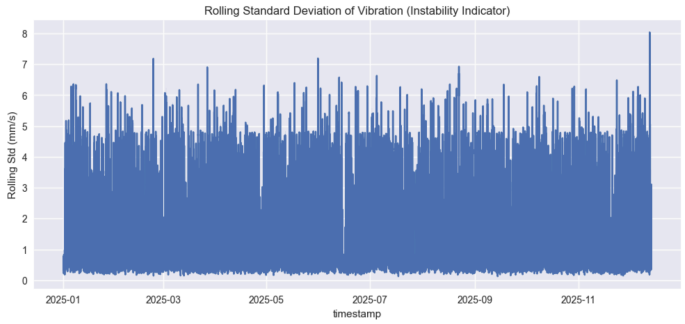
2. What Is Happening to the Machine?

Analysis of temperature and vibration signals shows gradual mechanical degradation, not a sudden failure.

- Temperature Trend: The baseline bearing temperature steadily increases over time (55°C → 90°C). This indicates rising friction, likely due to lubrication breakdown or bearing wear.
- Vibration Behavior: While average vibration levels remain relatively stable, variability increases over time.
- Rolling Vibration Standard Deviation: The rolling standard deviation of vibration — a proxy for mechanical instability — rises progressively. This pattern is consistent with developing looseness, imbalance, or surface damage inside the bearing.







3. Biggest Risk for Production Deployment

The most significant risk is label reliability.

The `status_code` does not reflect the true mechanical condition of the machine. If this dataset were used to train a predictive model with status labels as ground truth, the model would learn that degraded behavior corresponds to “normal” operation. This would produce a system that fails to detect real failures, giving a false sense of safety.