ROHINI

COLLEGE OF ENGINEERING AND TECHNOLOGY

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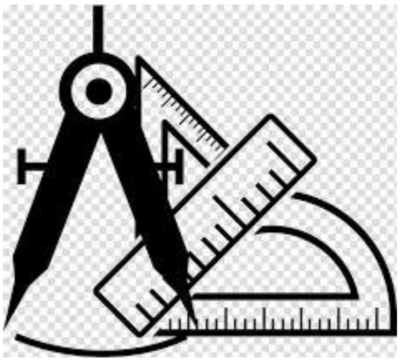
DEPARTMENT OF MECHANICAL ENGINEERING

24ME403 - METROLOGY & MEASUREMENTS

Dr. A. ARUL MARCEL MOSHI,

ASSOCIATE PROFESSOR / MECH.



UNIT V: ADVANCES IN METROLOGY

CO5: To inspect the quality control in Manufacturing Industries with advances in Measurement.

Working principle of Tool condition monitoring

The need for Tool condition monitoring:

In automated and unmanned manufacturing environments, a tool failure can be catastrophic, leading to scrapped workpieces, damaged machine tools, and costly downtime. Traditional scheduled tool changes are inefficient, as tools are often replaced before the end of their useful life, or worse, fail before the scheduled change.

Tool Condition Monitoring (TCM) is a technology that addresses this by continuously assessing the state of the cutting tool (wear, breakage, chipping) during the machining process. It acts as the "nervous system" for the cutting process, enabling the machine to react intelligently to the tool's actual condition rather than relying on estimates.

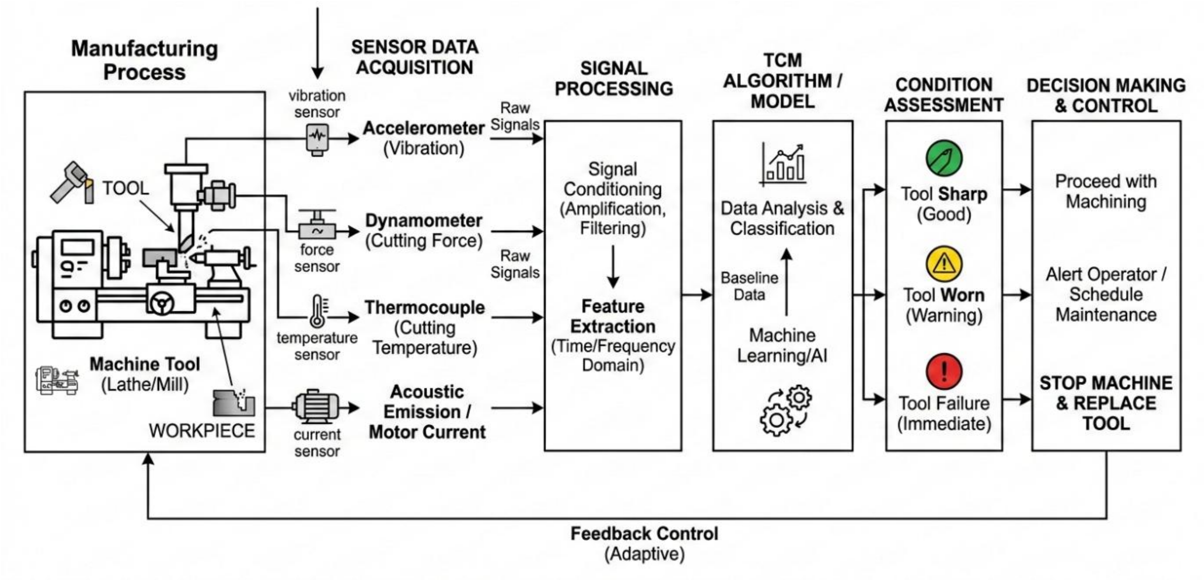
Working principle of Tool condition monitoring:

The fundamental working principle of TCM is based on an indirect measurement approach. Since directly observing the tool-chip interface during a cut is impractical, TCM systems monitor process variables that are correlated with the tool's condition. The system operates in a closed-loop manner, as illustrated below.

The process involves four key stages:

i) **Sensor selection and signal generation:**

Principle: As a tool wears or breaks, the physics of the cutting process changes. Sensors are used to capture these physical changes.



Common sensors and their correlation to tool condition:

a) **Acoustic emission (AE) sensors**: Detect high-frequency stress waves generated by crack propagation and plastic deformation. An increase in AE signals often correlates with tool fracture or severe wear.

b) **Accelerometers (vibration)**: Measure machine tool vibration. An increase in amplitude at specific frequencies can indicate chatter or a deteriorating tool condition.

c) **Power / current sensors**: Monitor the spindle or feed motor load. As a tool wears, friction increases, requiring more power to cut. A sudden power drop can indicate tool breakage.

d) **Dynamometers (force)**: Directly measure cutting forces. Flank wear causes a gradual increase in cutting forces, while chipping causes sudden force fluctuations.

ii) <u>Data acquisition and signal processing (Feature extraction)</u>:

Principle: The raw sensor signals are a complex mix of information and noise. Signal processing techniques are used to extract meaningful features that are sensitive to tool wear but insensitive to other process variations (e.g., changes in depth of cut).

Techniques:

a) **Time-domain analysis:** Calculating statistical parameters like the Root Mean Square (RMS), mean, or variance of the signal.

b) **Frequency-domain analysis:** Using Fast Fourier Transforms (FFT) to identify changes in the signal's frequency spectrum related to tool condition.

c) **Time-frequency analysis:** Using Wavelet Transforms to capture transient events like tool breakage.

iii) Decision making (Pattern recognition):

Principle: The extracted features are compared against pre-established "signatures" or "thresholds" representing a sharp tool, a worn tool, and a broken tool.

Methods:

a) **Thresholding:** Simple comparison of a feature (e.g., power level) against a preset limit.
b) **Artificial Intelligence (AI) / Machine Learning:** Advanced systems use neural networks or fuzzy logic trained on historical data to classify the tool's state based on multiple features simultaneously. This is more robust and can adapt to different cutting conditions.

iv) Control action (Feedback):

Principle: Based on the decision made, the system initiates an appropriate action to protect the workpiece, tool, and machine.

Typical Actions:

a) **Alarm:** Notify the operator.
b) **Tool change:** Automatically command the machine to swap the tool for a new one from the magazine.
c) **Machine stop:** Emergency stop to prevent catastrophic damage if a tool breaks.
d) **Process adaptation:** Slightly reduce feed rate or speed to prolong the life of a worn tool until the end of the cut.

Benefits of Tool Condition Monitoring in Manufacturing:

Implementing a robust TCM system offers significant economic and operational advantages.

- **Reduced downtime:** By preventing catastrophic tool failures, TCM eliminates unplanned stops for cleaning up damage and replacing broken tools. This maximizes machine utilization.

- **Improved product quality:** By detecting tool wear before it negatively impacts surface finish or dimensional accuracy, TCM ensures consistent part quality and reduces scrap and rework rates.
- **Optimized tool life:** TCM allows tools to be used for their entire effective life, rather than being changed prematurely based on a conservative timer. This directly reduces tooling costs.
- **Enhanced machine safety:** Preventing tool breakage protects the machine tool's precision components (spindle, guides) from damage, reducing maintenance costs and preserving machine accuracy.
- **Enabler for unattended manufacturing:** TCM is a critical technology for "Lights-Out" manufacturing, where machines run for extended periods without human intervention, confident in their ability to react to tool problems.