A Model Based Condition Monitoring System for Rotary Machinery

by

Shaun Ghafari  Ph.D, P.Eng

GCM Tech

Predictive Maintenance Technology

www.gcmtech.ca
Agenda

• Model based fault diagnosis
• Motor Condition Monitor (MCM)
• Benefits
• Case study
• Conclusion
Electrical Motors

More than 60% of all electricity generated worldwide powers industrial motors

Compressor  Gearbox
Fan  Pump
Conveyor
Model Based Fault Diagnosis

- No Correlation between input and output
- Incapable to diagnose variable input states
- Non-expandable system
- Diagnoses electrical or mechanical faults
Technology Overview (US Patent 6,393,373 B1)

✓ Input and output are known (V-I signal)
✓ $H(s)$ is constructed based on actual measurement and mathematical model of motor
✓ Model handles variable input states
✓ Diagnoses mechanical and electrical faults
Monitoring Flow Diagram

Motor

Input Voltage

$H(s)$

Trained Model

Mathematical Model
reconstructed by
Actual Measurement

Fault Detected?

Yes

No

Analysis of Fault Parameters

Fault Classification
MCM – Motor As a Sensor

Developing Faults

Air-gap & Tensional Dynamics

Input (Voltage) - Output (Current)

\( L \frac{di}{dt} + Ri + k\omega i = V \)

\( j \frac{d\omega}{dt} + f\omega = ki^2 - T_L \)
Motor Condition Monitor (MCM)
System Configuration
Process

Install → Train → Monitor

- Install
- Train
- Monitor

Icons and labels for different stages of the process.
Range of Faults Covered

**Mechanical**
- Loose foundation
- Unbalance
- Misalignment
- Bearing damage
- Loose component
- Belt & Coupling

**Electrical**
- Insulation
- Capacitor breakdown
- Unbalance phase
- Rotor bar damage
- Winding problem
Advantages

- **Continuous** Monitoring
- Simple to **install**
- **No Sensor**
- Self training
- Simple diagnosis report
- Integrate with other systems
- Electrical and Mechanical fault diagnosis
- Monitors most 3 phase motor driven systems
Saving **Energy / Reduce Production Costs**

- Power factor monitoring (Over size motor 10-12%)
- Mechanical problem (such as unbalance & misalignment) 10-15% higher energy consumption
- Electrical problem (such as loose connection) 5-10% energy waste

- Reduce the risk of **downtimes**
- Minimize the **catastrophic failures**
- Reduce the **spare parts inventory**
Case study – Exhaust fan (MCM)
Case study – Exhaust fan (routine vibration analysis)
Case study – Exhaust fan  (High Ferq. vibration analysis)

HFRT Spectral Analysis

Sample rate: 52k
Sample size: 0.5 M
Band pass frequency [2.5 k 7.5 k]
Hilbert Transform
Low pass frequency 500 Hz
Case Study – Automotive Industry

Challenge
Conveyor failure in all three major lines due to damage of bearing and insulation on drive motors – Significant reduction of productivity

Solution
Installation MCM on all the conveyor driver motors. Low cost solution, simple to install, provide diagnostic information before catastrophic failure.

Results
• Cut unplanned shutdowns to less than 1%
• Meeting the requirements of the ISO TS 16949 quality certificate
• A class supplier rating from Daimler Chrysler
• System re-paid in first year
Case Study – Compressor bearing damage

Application: Monitoring critical compressor
Intermittent Alarm: September 13th
Service alarm: December 16th
Lead time: 91 days
In January 2006 during regular seasonal service it was found the Motor bearing is damaged
Case Study- Tower fan loose bolt

Application: Monitoring
Inaccessible tower fan
Intermittent Alarm: October 16\textsuperscript{th}
Alert alarm: November 14\textsuperscript{th}
Vibration and inspection: Feb 14\textsuperscript{th}
Lead time to failure ~ 120 days
Conclusions

• Model base condition monitoring benefits analysis of both input and output of the system. This approach is more sensitive to early defects rather than the routine predictive maintenance approach.

• MCM is a low cost, easy to install, sensor less system for online and continuous and remote monitoring of systems driven by 3 phase motors.

• MCM reduce downtime and increase productivity.

• Saving Energy.
Thank You

Question?

Shaun Ghafari  Ph.D.,  P. Eng

4-195 Clayton Dr.
Markham, Ontario

shaun.ghafari@gcmtech.ca