Exploring Opportunities and Challenges for PHM Technology Adoption by Small Manufacturers

*A Hybrid Numeric Data & TLP-based Approach*

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Since 1982, TechSolve has been focused on manufacturing and its emerging technologies

- Privately owned, not-for-profit 501(c)(3)
- State and Federal Manufacturing Extension Partnership (MEP) Center
- Broad Network of Academia and Industry
- Fully instrumented Smart Manufacturing Innovation Lab

**TechSolve's Highlights**

**Smart Manufacturing Expertise**

- Digital manufacturing
- Machine and process monitoring
- IIoT connectivity (MTConnect®)
- Advanced analytics
- Process modeling and simulation
- Smart machine technologies
- Predictive maintenance
- Automation, robotics
- Cybersecurity for IT & OT
- Additive manufacturing

**Manufacturing Process Solutions**

- Machinability Evaluation & Testing
- Manufacturing Process Development
- Problem Diagnosis & Resolution

**IIoT Solutions**

- MTConnect® Adapters
- Assessments & Installation
- Data Acquisition Solutions
- Protocol Translation Adapters
- Data Visualization

**Business Advisory**

- Process Optimization
- Growth Strategy

**Cybersecurity**

- Cybersecurity for IT & OT
- Plan of Action & Milestone Development
- Incident Response Planning

**IIoT Solutions**

- Cybersecurity for IT & OT
- Plan of Action & Milestone Development
- Incident Response Planning
TechSolve Equipment

- Instrumented CNC machines
  - 3, 4, and 5 axes CNC machining centers
  - Mill-turn machine
  - CNC Lathe
  - CNC Grinding machine
- Spindle test-bed
- Feed-axis test-bed
- Manual lathe, mill and drilling machines
- Collaborative Robots (UR3, UR10)
- 3D printers (CI SAAM, CreatBot)
- Laser scanner
- Coordinate Measuring Machine (CMM)
- Digital & optical microscopes
- Computer-based Tool Setter
- Minimum quantity lubrication (MQL) systems
- Scientific ovens
- Hardness tester
- Multiple metrology gages

Instrumentation & Data Acquisition

- Sensors:
  - Force dynamometers for turning, milling, drilling and grinding (Kistler)
  - Power sensors with IIoT connectivity
  - Current amperage sensors
  - Vibration sensors
  - Acoustic emission sensors and data acquisition system
  - Temperature sensors
  - Flowmeters
  - Pressure sensors
  - Precision measurement microphone
- Custom built data acquisition and analysis systems (LabView & Matlab)
- Bar code readers
- Tool condition monitoring systems
- MTConnect adapters and related software and hardware
- MTConnect to OPC UA converter
- All machine-tools connected to IIoT

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Assessment of Opportunities, Challenges and Performance Metrics for PHM Technology Adoption by Manufacturers
Project Scope

Conduct assessments and collect information/data associated with equipment and/or process health and performance at small and medium-size manufacturers, to

1) Understand and inform on the opportunities, challenges and performance metrics for PHM technology adoption

2) Explore the possibility of augmenting numeric data from sensors and control systems with human input, by integrating documented natural language reports with data collection technology
Opportunities, Challenges and Performance Metrics
Assessment Survey

• What maintenance practices do you employ and in what percentage?
• Who is running the Maintenance in your factory?
• Do you keep records of maintenance activities (text based)?
• Why do you capture maintenance work order (MWO) data?
• Do you process maintenance log data to extract analytics?
• Do you monitor any manufacturing assets and what is the main goal?
• What data do you use to determine your maintenance strategy?
• What could improve your day-to-day maintenance tasks?
• How would you want to improve your maintenance long term?
Performance Metrics

- Uptime
- Downtime
- Overall equipment effectiveness
- Repair cost
- Maintenance costs
- Failure frequency
Challenges

• The culture of some of the SMMs can create a barrier
• Insufficient awareness and education regarding the current digitalization trends and benefits of PHM technologies
• Limited guidelines/standards regarding the adoption and use of the PHM technologies
• Amount of management and tending for some of the PHM technologies on the market
• Complexity and cost of PHM systems vs. perceived benefits
• Lack of use cases and examples
• No rules or regulations requiring or motivating the manufacturers to collect data
Opportunities

• Green field for awareness creation, education and deployment of pilot solutions that could build momentum for accelerated adoption

• Genuine interest for guidelines and standards that would simplify the efforts in adopting more advanced practices and technologies supporting the maintenance area

• Openness to implementing advanced technologies that would align with current digitalization trends, providing the cost - benefits ratio justifies the investment
Technical Language Processing Experiment
Experiment

**Scope** – explore the capabilities and limitations of integrating and extracting actionable information from numeric data collected from manufacturing equipment, and the maintenance work orders (text-based maintenance logs) associated with that equipment.

**Goal** – explore and validate the relationship between observers’ natural language, quantified sensed values, and some ground truth knowledge about the state of the degrading component (i.e. the cutting tool).

**Approach** – limited and controlled accelerated aging setup where human observations were recorded at regular intervals alongside streaming sensor data.
Strategy

• Create a machining program that enables a long duration cut

• Modify the program such that some of the cuts exhibit chatter or higher than normal vibration – to create controlled and ‘random’ process failures

• While the CNC program is running, collect data from sensors and control, and have a technician, come to observe the test periodically (e.g. 15 min) to take notes relative to the status of the cut, tool and machine
Experimental Setup

**Machine:** Milltronics HMC35, instrumented with sensors and data acquisition system

**Cutting tools:** carbide end mill with 4 flutes, 0.5” diameter

**Metalworking fluid:** Water-based (Trimsol 206)

**Workpiece:** 4140 steel block of 6” x 4” x 4”
Human Recorded Process Characteristics

- Test No. and Workpiece No.
- Various Test and Observation Times
- Test Status
- Layer No.
- Tool Gauge length (in)
- Type of observation
- Process condition
- Tool condition

- Tool flank wear - END (in)
- Tool flank wear - LATERAL (in)
- Tool wear - RAKE FACE (in)
- Surface finish - face (μ in)
- Surface finish - lateral (μ in)
- Did you hear chatter?
- Anything out of ordinary?
- Out of ordinary description
- General Notes/Comments
Concluding Remarks

• This study has been revealing with regard to the current state of adoption of PHM technologies by the small manufacturers

• Opportunities and challenges for PHM technology adoption have been identified on a sample of small manufacturers

• The interactions with manufacturers were leveraged to create awareness / educate about PHM technologies and their benefits

• A first exploratory step focused on integrating data coming directly from the equipment and the human-generated text data has been made

• The findings are useful for future standards development activities associated with PHM for Manufacturing
Thank you!

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