NSF Engineering Research Center for
Reconfigurable Manufacturing Systems
University of Michigan

Prediction of Unscheduled Factory Downtime

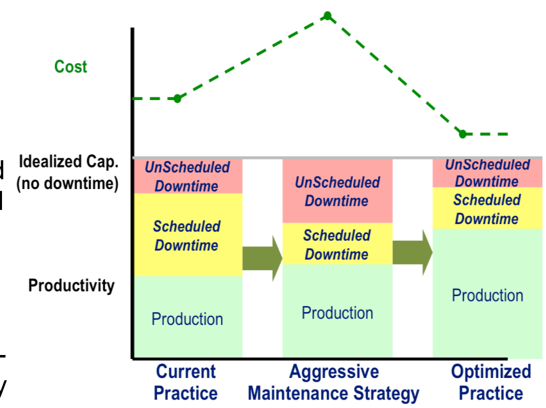
MOTIVATION AND CHALLENGE

Preventative maintenance on machines in a manufacturing system is an essential element in modern factory operation. As Howard Cooper comments in his SME editorial: "The cost of unscheduled equipment downtime in lean manufacturing environments…. results directly and immediately in lost opportunity, failed shipped schedules, and lost sales". Due to this fact, maintenance scheduling is now progressively moving from a reactive to a proactive strategy. Under the new paradigm of *predictive maintenance*, instead of reacting to a problem when a machine experiences failure, data collected from machines is used to predict when a machine is about to fail so it can be maintained proactively. The benefits of predictive maintenance are three fold (1) it reduces the costs associated with unscheduled downtime (e.g., cost of consumables, lost-productivity, and damage to machines and product), (2), it increases mean-time-between-failure (MTBF) and reduces mean-time-to-repair (MTTR), and (3), it reduces the occurrence of unnecessary preventive maintenance events. As shown in the figure to the right, a strategy that performs maintenance as it is needed reduces the total cost of factory operation.

A major problem in introducing a predictive maintenance scheme is the lack of data that could indicate when a machine is likely to fail. Sensor systems are expensive and require an acute knowledge of the failure modes on each machine in order to be used in preventive maintenance. However, factory records documenting events that occur on each machine (or "event data" as it is called) is widely available in many modern manufacturing plants and provides a means by which a machine's likelihood of failure can be approximated. Utilizing event data provided by one of our partners, GEMA (Global Engineering Manufacturing Alliance) as a case study, we are creating a statistical model that will allow engineers to implement maintenance procedures proactively to reduce both their incidence and cost.

BENEFITS

- ✓ Reduction of unscheduled downtime
- ✓ Reduction of MTTR
- ✓ Improved understanding and practice of data collection
- ✓ Improved maintenance/tool change scheduling
- ✓ Improved data visibility
- ✓ Definition of data consolidation approach
- ✓ Scalable solution that can be applied to other control scenarios



Predictive maintenance minimizes factory operating cost

OVERVIEW OF THE WORK

Our group at the ERC is focused on exploring means by which factory event data can be used to predict unscheduled downtime thereby reducing the factory operating costs. By mapping the relationships between factory events and unscheduled downtime, the project aims to minimize the cost of preventive maintenance by allowing engineers to target the machines most likely to experience failure. We incorporate three strategies to pursue reduction of unscheduled downtime:

- analysis of relationships between factory events
- determination of how failure predictions can improve maintenance scheduling
- exploration of data quality as a barrier to failure prediction

Utilizing these strategies, manufacturers such as those at GEMA can identify which types of machine failure can be inferred from existing event data and which failures need additional data quality improvement to be effectively predicted.

GOALS

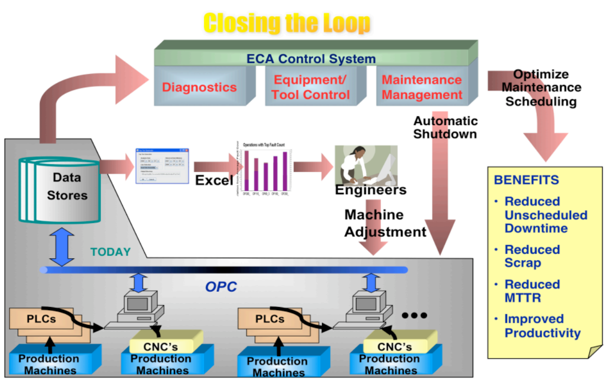
Develop and demonstrate an open-architecture event-driven software control system that links equipment data collection, equipment control and equipment & tool maintenance capabilities

- Increase MTBF and decrease MTTR within a manufacturing system
- Provide prediction solutions for the reduction of unscheduled downtime occurrences; test and validate in an industrial setting leveraging our GEMA partnership
- Provide algorithms and methodologies for increasing data quality on consolidated factory data systems.
- Demonstrate benefit of solutions through technology transfer to GEMA
- Provide statistical tools for improving decision making in reject analysis and maintenance scheduling

PRELIMINARY RESULTS

- Automated mechanism for finding trends in process data
  "*Gives us a combined picture of the line on one page from a faults perspective*" (quote from sponsor)
- A Pareto user interface for viewing top 10 faults on plant floor
  "Shows us how the data really relates to line operations and faults," (quote from sponsor)
- Report on potential ROI improvement and success metrics
- Best Practices document for Maintenance Management
- Automated mechanism for finding trends in process data
- Analysis scripts to find anomalies on the plant floor
- Study on OPC data collection for data quality analysis
- Correlation plots and methods for improving signal to noise ratio in correlations
- A user manual on system requirements, installation instructions and user instructions for the Pareto user interface and the associated Java script
- A MATLAB user interface for viewing plots of faults vs. maintenance
- Historical data study indicating potential improvement

Event based prediction system allows the factory to proactively schedule maintenance.



CURRENT STATUS

- Implementing UML plan to increase data quality in databases by creating an extensive data layer for all event data.
- Working with regression data to improve root-cause analysis of engine rejects.
- Incorporating end-of-line discrete and continuous test stand data into prediction model for unscheduled downtimes

DELIVERABLES

- Software to display the top ten anomalies in event data
- Internships at GEMA for Summer of 2007 and 2008
- User interface to track relationships between event data and unscheduled downtime
- UML consolidated data scheme for improving data quality
- General methodology for data consolidation to support unscheduled downtime reduction

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FUTURE MILESTONES

- Develop unifying factory-wide data model at GEMA and use the process to identify a general methodology for data consolidation for downtime prediction.
- Work with industry sponsors to implement an extensive data layer above various data systems
- Study correlation of process and quality data to identify quality affecting process parameters
- Develop methodology for determining optimum maintenance and tool change scheduling
- Improve scheduling of maintenance and tool changes via prediction metrics
- Investigate methods for increasing productivity of test stand analysis using statistical methods.
- Improve data quality and develop specifications for improvements in data collection systems