REAL TIME PRODUCTION MONITORING SYSTEM IN SME

Snatkin, A.; Karjust, K.; Eiskop, T.

Abstract: The main objective of the current study is to analyse real time production monitoring systems (PMS) and to offer better solutions for small and medium sized production companies. PMS is the alternative to manual data collection and should capture most of the required production data without human intervention.

Practical part of the study is focused on selection of suitable PMS, its adaption and mapping manufacturing process (determining key factors, etc.).

Key words: production monitoring system, remote monitoring, real time information, manufacturing execution system.

1. INTRODUCTION

The objective of the paper is to give an overview of advantages and possible drawbacks of a PMS before starting to implement such system in a specific SME. SMEs are more flexible comparing to larger companies and can faster implement a new way of doing business. Also the result of changes can be seen earlier that simplifies the research.

In a fiercely competitive market, companies cannot afford the waste of time and resources to perform work that can be done in a better and faster way with advanced solutions. One of the advanced solutions can be a real time PMS. It is a production tool that collects and distributes necessary data when various events occur in a shop floor. The main aim of a PMS is to prevent small disturbances having large effects. In this way a PMS will decrease the number of unscheduled production stops, improve cost-efficiency and simplify the production planning.

2. PRODUCTION MONITORING SYSTEM

The task of a PMS is to collect and distribute real time data of events on the shop floor. This data must be understandable and useful for decision making. Monitored data should help the production team to respond timely on the events that may affect the desired result. Such system should also alarm and inform respective department concerning all recognized faults.

PMS is not just display boards that show production data, it also has a reporting and administration module, where stored data can be analysed to find trends, estimations and projections for easier decision making and production planning.

Proactively detected faults will decrease wasted time and improve overall equipment effectiveness.

2.1 Manufacturing Execution System

Production monitoring and machine data collection is one of a Manufacturing Execution System’s (MES) functions. Historically, each software editor had their own definition of an MES which was generally based on the capacities of their own tools or on the expectations of their customers [1].

Several of the major automation providers offer now MES solutions, including Emerson, GE, Honeywell, Invensys, Rockwell and Siemens.

MES integrates separate data collection systems. It is like a linkage between the
shop floor and office. It should solve the problems of the lack of integration between the Enterprise Resource Planning (ERP) systems and the control systems on the plant floor.

MES position in the factory automation system can be described in different ways. To understand on what enterprise automation level it is positioned, a pyramid diagram can be used. Please see Figure 1.

Fig. 1. Automation Pyramid [7].

The standard of International Society of Automation ISA S 95 best describes the architecture of a MES into more detail, covering how to distribute functionality and what information to exchange internally as well as externally.

MES is overlapping with the Product Lifecycle Management (PLM) system in the production phase [2,3,4]. It means that changes made by MES during the production (machine adjustment, tolerance change etc.) may have influence on the PLM workflow (changes in drawings and CAM).

From e-manufacturing point of view, a MES is the lower level of factory automation and communication systems [7]. Please see Figure 2.

2.2 Real time information handling and classification

The idea of a real time PMS is not to give some information simultaneously as the event occurred, but provide the production team, as fast as possible, with the accurate and meaningful data. But it should be enough time to respond timely on these events.

It will always take some time (seconds, minutes or even hours) to analyse monitored data and respond on it. And the goal is to try to decrease this time.

Real time production monitoring information can be classified into two main groups. One group is related to the status of resources and another one to the status of jobs. Information on actual or potential disruptions may relate to resources or jobs.

Machine breakdowns, material or tool shortages and longer-than-expected processing times give resource problems. Job related disturbances arising from planning systems and customers include changes in priority, reassignments of jobs to orders and the emergence of new jobs. Quality problems may relate to both resources and jobs [6].

Classification of real time information helps to understand how the desired PMS should be structured.

The first step of real time data in the monitoring process is detection. Data can be detected by sensors, operators, barcode scanner etc. Understanding the detection process will lead to effective use of real time data capture devices, and removal of
unnecessary and useless devices. Then data should be classified and identified. For example, transferred to respective department or handled automatically. And the last step is diagnosis and analysis [9]. There is no reason to store all collected data in the database. Good decision will decrease running costs and improve performance of the database.

3. CONCEPT OF A PRODUCTION MONITORING SYSTEM

Production data collected on the shop floor may be incorrect, mostly due to human intervention or improper production monitoring system. The human factor is more common in this case. That is why a PMS should capture most of the required data without human intervention. When an unscheduled outage does happen, time is spent notifying support resources that a problem has occurred, time is spent for the support resource to respond to the issue, time is spent troubleshooting and finally time is spent to resolve the problem. But predictive nature of continuous remote monitoring more often avoids unscheduled outages by addressing the issues before they affect machine operation and product quality [7].

The benefit of installing an efficient real time PMS is the immediate access to all required production related information by the relevant personnel. And it should be enough data to clearly identify the reasons of production stops, time loss etc. At the same time, presenting too much information can confuse or even distract operators.

The most important requirements of any PMS are that the system is economical, accurate and easy to set up on a production line. And it has to be capable of providing straightforward connectivity to switches, sensors, PLC outputs and other common industrial equipment. If the true production data can be automatically captured and presented in a simple, understandable way to the operators, they will become a more integral part of the improvement process [8].

Relatively simpler systems may have greater potential for real-time control [9]. An effective production monitoring system should be at least comprised of the four elements: collection, display, analysis and data storage (see Figure 4).

![Fig. 4. PMS modules.](image)

Alarm system is also one of the basic capabilities of a PMS. Fault annunciation should be properly understood by the personnel to act in a timely manner. And an advanced PMS should provide the possibility to review historical site alarm activity.

Visualisation of data can be made through displays, andon boards and mobile solutions, like smart-phones etc.

4. PMS INTEGRATION ON THE SHOP FLOOR

Because of the high cost of deployment of automated manufacturing systems, machines are not integrated on most shop floors [10]. Production industry still gathers most of the data in the shop floor through manual inputs.

Despite the fact that number of automation providers offer MES solutions, such systems are mostly monolithic, insufficiently configurable, and difficult to modify.
Installing such software and integrating it with current systems is found to be a challenging and costly undertaking \([11]\). Localized solutions can be more affordable and even more strengthen the advantage of an automated production monitoring. Especially during the economic recession, companies are more precisely weigh the pros and cons of investing money in a new production system. And faster return on investments can be the decisive moment when choosing a production monitoring system, though alternative MES systems can offer a wide range of additional functions. When calculating costs of a PMS, not only software and hardware investments should be calculated. Possible consultation and support costs must be taken into account. If system is developed and integrated in cooperation with the production team, these costs can be decreased. In case of modern manufacturing equipment, a monitoring system is assumed to be a part of the machinery. Installing wireless sensors (so called “smart dust”) on machinery can be one of the solutions. Before that, models should be developed that reflect the correlation between the state of the machine and the monitored parameter. All these will enable the detection of failures and critical modes of operation. Installing a monitoring system, based on wireless sensor nodes, is relatively cheap and it can be fitted to both old and modern manufacturing equipment \([12]\). Wireless sensors eliminate the cost of cables that also simplifies the install. In real life wireless monitoring is used infrequently in shop floors \([13]\).

**5. TRENDS**

The trends of PMS solutions can be summarized as follows:
- Standardized plug & play connectivity
- Real time performance
- Web-based architecture
- Scalability and re-configurability

It is evident that the amount of information collected from control systems increases tremendously with the degree of increased automation on the shop floor. Manufacturing systems grow because of the need for more complex processes to meet the needs of increased product functionality \([1]\). It means that PMS has to be connected to more equipment and process more data at the same time. In addition to these trends, there is future direction to self-learning and decision making system that maximally eliminate human intervention. General trend is to use PMS for improvement of the production processes by applying: statistical process control, mathematical modelling and optimization of the production process \([14-18]\).

**7. CASE STUDY**

The monitoring systems are designed for four workbenches in Tallinn University of Technology (TUT) and for two work lines in private company JELD-WEN Estonia. The data collection and display modules are completed, but the development of the analysis module is in progress. Measuring devices will be assembled on a controlled machinery to conduct measurements. It will provide early warnings of machine degradation or impeding accident. The characteristics chosen for monitoring and the measurement equipment selected are outlined in Tables 1-5.

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical / Hall effect sensor</td>
<td>Spindle speed</td>
</tr>
<tr>
<td>Acclerometer / piezoelectric sensor</td>
<td>Spindle vibration</td>
</tr>
<tr>
<td>Infrared temperature sensor</td>
<td>Bearing temperature</td>
</tr>
<tr>
<td>Clip-on ammeter</td>
<td>Current</td>
</tr>
<tr>
<td>Magnet / Hall effect sensor</td>
<td>Carriage mechanism position</td>
</tr>
</tbody>
</table>

Table 1. Metalworking lathes, 1K62B and 16A20 (TUT)
### Table 2. Milling machine DYNA MECH. EM3116 (TUT)

<table>
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<tr>
<td>Infrared temperature sensor</td>
<td>Belt friction point temperature</td>
</tr>
<tr>
<td>Clip-on ammeter</td>
<td>Current, load</td>
</tr>
</tbody>
</table>

### Table 3. Wire-cut machine AGIE AC 50/120H (TUT)

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature sensor</td>
<td>Coolant temperature</td>
</tr>
<tr>
<td>Accelerometer / piezoelectric sensor</td>
<td>Working table vibration</td>
</tr>
<tr>
<td>Optical / magnet sensor</td>
<td>Wire feed speed and brake</td>
</tr>
<tr>
<td>Conductivity meter</td>
<td>Water (coolant) salinity</td>
</tr>
<tr>
<td>Clip-on ammeter</td>
<td>Current, load</td>
</tr>
</tbody>
</table>

### Table 4. Output of planer line Weinig 141 (JELD-WEN Estonia)

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotary encoder</td>
<td>Line speed</td>
</tr>
<tr>
<td>Optical sensor</td>
<td>Material availability on the line</td>
</tr>
</tbody>
</table>

### Table 5. Input of the painting line Makor (JELD-WEN Estonia)

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical sensor</td>
<td>Count of material from the in-feed</td>
</tr>
<tr>
<td>Optical sensor</td>
<td>Count of material reaching machine</td>
</tr>
</tbody>
</table>

Thus, in TUT the milling, wire-cut and lathe machines are set up for monitoring.

### 8. FURTHER RESEARCH

Each production SME has differences in manufacturing processes, equipment, priorities and capital resources. That is why such questions still need to be answered:
- Which data should be collected first?
- Which data have to be saved and for how long in the PMS database?
- Is it possible to design a “plug and play” PMS solution that is suitable for most of the production SMEs?
- What is the easiest way to connect different data formats and communication interfaces?
- How to visualise the production data to make it clear to all personnel?

### 9. CONCLUSION

The real time PMS systems designed for TUT and JELD-WEN Estonia enables to continuously acquire data from the shop floor with regard to efficiency, malfunctions and productivity. This leads to improved production capacity and cost-efficiency, helps to achieve desired production goals. Development of the data analysis module has been foreseen as next task in improvement of PMS system.

### 10. ACKNOWLEDGEMENTS

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