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A PROPOSAL FOR PRODUCTION DATA COLLECTION ON A HYBRID PRODUCTION LINE IN COOPERATION WITH MES

Jaroslav ZNAMENÁK, Gabriela KRIŽANOVÁ, Miriam IRINGOVÁ, Pavel VAŽAN

SLOVAK UNIVERSITY OF TECHNOLOGY IN BRATISLAVA,
FACULTY OF MATERIALS SCIENCE AND TECHNOLOGY IN TRNAVA,
INSTITUTE OF APPLIED INFORMATICS, AUTOMATION AND MECHATRONICS,
ULICA JÁNA BOTTU 2781/25, 917 24 TRNAVA, SLOVAK REPUBLIC
e-mail: jaroslav.znamenak@stuba.sk, gabriela.krizanova@stuba.sk, miriam.iringova@stuba.sk, pavel.vazan@stuba.sk

Abstract

Due to the increasing competitive environment in the manufacturing sector, many industries have the need for a computer integrated engineering management system. The Manufacturing Execution System (MES) is a computer system designed for product manufacturing with high quality, low cost and minimum lead time. MES is a type of middleware providing the required information for the optimization of production from launching of a product order to its completion. There are many studies dealing with the advantages of the use of MES, but little research was conducted on how to implement MES effectively. A solution to this issue are KPIs. KPIs are important to many strategic philosophies or practices for improving the production process. This paper describes a proposal for analyzing manufacturing system parameters with the use of KPIs.

Key words

MES, production line, KPI, manufacturing

INTRODUCTION

For every manufacturing facility to remain competitive (e.g. by low production costs, minimum lead time, or high quality of products) requires the improvement of its reactivity to adapt its production to the progress of technology (new production trends in manufacturing) hand in hand with the ability to cope with possible new risks and issues, which these technologies may create. Systems of production should thus be controlled in real time to, for instance, handle the frequent changes in the product and its demand. This control will be used to better anticipate and resolve interruptions in the future. This case of control is the ‘Reactive Control’ of the shop floor (1).

It is therefore invaluable to know the actual state of a manufacturing system (line), which can be observed by acquisition devices (e.g. sensors) and filing of real data by coupling the production shop floor software with MES.

MES is one of the software solutions used as a bridge between production planning and the equipment control system (2), (3). MES systems are very interesting for their ability not only to use fewer resources, but also to understand how those resources are being used throughout the production process, which can help to make the most efficient use of energy, equipment and raw materials, even before production orders are received (effective order scheduling). This is accomplished by providing mission-critical information about production activities across the enterprise and supply chain via bi-directional communications (4) and by scheduling equipment resources dynamically based on an order's requirements.

MES can be used for a variety of processing and manufacturing industries. For example in 2002 the MES system was used in the semiconductor industry, where integration of three systems via an integration model and system integration mechanism has helped to make the production of semiconductors more efficient, even though this technique made use of two types of databases, which led to the duplication of data and data updating problems (5).

Another type of MES application is in a cement industry. Here a MES module was used to integrate the information data between PCS and ERP and optimize the production process. MES functionality has been used to describe a three layer manufacturing integration model for the cement industry (6).

Aerospace is also an industry known to apply MES into its production, they are actually one of the major users of MES. Boeing enterprise provides a specific use case model for MES and its manufacturing activities (not all functionality of MES is covered, some functionality is outside the scope of MES) (7). The aerospace industry faces a problem in its rescheduling of production operations due to insufficiency of real time information of W.I.P. (work in process). MES can provide a solution to this problem (8).

The batch process industry requires comprehensive scheduling of manufacturing activities in its manufacturing process, therefore MES is implemented to launch and keep track of work orders or production activities and to quickly respond to random events (9).

THE MANUFACTURING EXECUTION SYSTEM

Definition of MES

Manufacturing Execution Systems (MES) is an information system application that enables the optimization of production from the launch of a production order to its completion in real time. MES serves as a bridge between the IS at the top level, namely enterprise resource planning (ERP), and IS at the lower levels, namely the automation systems (10).

MES is a production scheduling and tracking system used to report and analyze resource status and availability, collect data about W.I.P. parameters, resources, equipment status etc. in real time from the shop floor (real-time shop floor reporting). This data is then fed as activity data back to the ERP, with the aim of achieving a rapid response to the changing conditions, coupled with a focus on reducing non value-added activities. MES does hereby improve the on-time delivery of goods, cash flow, gross margin etc. during manufacturing operations.

Nowadays the Traditional MES (T-MES) has been replaced by Collaborative MES (C-MES), which merged and edited few T-MES functions, thereby describing MES as an integration enterprise platform.

Functions of MES

The core functions of MES are defined by the organization MESA as (4):

- Resource allocation and status – managing of production resources (machines, tools, labor skills, materials, documents, other equipment), providing detailed history information of resources and monitoring of real time resource status information.
- Dispatching production units – managing of production unit flow (jobs, orders, batches etc.), changing the shop floor schedule and handling the rework and disposal of the items during manufacturing.
- Data collection – serving as an interface link between the production data and the parametric data of the production unit. The data may be collected either manually or automatically from equipment in real time (including the data analysis for quality management).
- Quality management – analysis of product measurements in real time in order to guarantee proper product quality control.
- Maintenance management – ensuring the availability of equipment and tools for manufacturing (via preventive maintenance) and handling of the schedule.
- Performance analysis – providing performance analysis reports of manufacturing operations (including information about process, quality parameters, product cycle time etc.)
- Operation/detail scheduling – using attributes, priorities and production rules to sequence production operations.
- Document control – controlling of production records.
- Labor management – controlling and allocation of workers, analysis of their productivity and capability for relocation.
- Process management – continuous monitoring and correcting of the production activities.
- Product tracking and genealogy – providing real time equipment, material or tool tracking and history records for each product.

Different production scope and application situations in individual manufacturing companies or plants requires various combinations of MES to be implemented into production, which can lead to the development of functionality that is outside the scope of the above mentioned core functions of MES.

PROBLEM DEFINITION

The introduction of a MES system into a production process, may bring upon itself many challenges. One of them is the type of data objects, which should be acquisitioned for each entry object. Depending on the type of use, other data entry objects will be of interest: the plant and equipment manufacturer will be interested in time data and hardly at all in quantities while the repetitive manufacturer regards process speed at the machine as the essential factor. Quality inspections, on the other hand, will have equal importance for both target groups (11).

Another challenge is the implementation of MES itself. Connecting all the manufacturing system components in an efficient way takes time and lots of planning. This issue has been partially addressed by an industry standard ISA-95. This standard specifies the MES sub-systems and defines the boundaries between ERP systems, MES, and other automation systems.

A great variety of input data (different in form and content) from manufacturing and their automated identification also poses a problem for MES, if it should optimally fulfill its objectives. Input data is used as a fundamental stone for individual analysis, as well as for utilization analyses or OEE reports.

All of the mentioned challenges have to be taken into consideration in the planning and implementation phase of MES integration into the production process. This paper is aimed at defining and choosing the measurement parameters for the evaluation of performance of the manufacturing system. These performance indicators have not yet been defined for the given manufacturing system. The calculation of these performance indicators will involve the analysis of the acquired process data.

HYBRID PRODUCTION SYSTEM DESCRIPTION

For this paper we have chosen to work with an AFB System from the company FESTO. This system (depicted in Fig. 1) consists from the following stations:

- Transport system – the material flow is implemented by a pallet transport system, which is used for transporting of pallets (each with its own identifier) to 4 production stations.
- AS/RS station – an automatic warehouse, it can hold up to 16 six-packs on 4 levels each with 4 bays.
- Unpackaging station – unloading of filled trays (each tray is filled up to 6 bottles), where a gripper takes one line of bottles from the tray and moves them to the conveyor of the station. Bottles are separated at the end of the conveyor for transport to the next station.
- Recycling station – exhausting liquid and bulk goods from bottles by a robot, which separates the cover of the incoming bottle, if one is mounted (sensor detects and sends a signal to the robot). The content of the bottle is sucked out of the bottle.
- Filling/bottling station – dosing, filling and capping the incoming bottles on a rotary indexing table. Filled and capped bottles are forwarded by conveyor to the next station.
- Packaging station – 2 by 3 bottles are packed into a six-pack, the bottles are carried on conveyor belts to the handling station.
- In/Out station – placing of full six-packs on one of the two outgoing goods ramps for shipping.
- Distribution station – separating of work pieces, up to eight work pieces are stored in the magazine tube of the stacking magazine.
- Buffer station – storing and separating of up to five work pieces.
- Handling station.

Fig. 1 *The AFB system*

THE PROPOSAL OF PERFORMANCE MEASURING OF THE HYBRID SYSTEM

A big amount of data can be collected from the hybrid production system in real time. Choosing the right data to effectively measure the performance of the system, leads to a decrease in the implementation difficulty level of MES. The type of data objects is also smaller and more flexible for each entry object. The performance indicators for manufacturing processes, are divided into three types according to (13) (depicted in Fig. 2):

1. *Key result indicators (KRIs)* – often mistaken for KPIs, are measures, covering a longer period of time (they are not being reviewed on a daily basis), thus representing the performance of an organization over time, they are invaluable resource for the organizational governance reports. They include for example: customer satisfaction, net profit before tax, profitability of customers, employee satisfaction, return on capital employed.
2. *Performance indicators (PIs*) – PIs lie beneath KRIs, are more detailed, but only give information of what to do, to satisfy elementary manufacturing objectives to a certain degree, that is insufficient to make them KPIs, they are defined in (12). They can include: profitability of the top 10 % of customers, net profit on key product lines, an increase in sales for the top 10 % of customers, number of employees participating in the suggestion scheme.
3. *Key performance indicators (KPIs)* – KPIs represent a set of measures focusing on organizational performance aspects that are most critical for the current and future success of the organization (13). KPIs tend to vary by organization, but they are always being reviewed on a daily basis, because they can have a dramatic impact on the production performance. KPIs have to be very precise and work with 'fresh' data (real time data at best). These performance measurements are commonly used to evaluate success in relation to goals and objectives and therefore are very valuable for production management as a source of data for reports. Seven Characteristics of a KPI (13):
    1. Nonfinancial measures (not expressed in dollars, yen, pounds, euros, etc.)
    2. Measured frequently (e.g. daily or 24/7)
    3. Acted on by the CEO and senior management team
    4. Understanding of the measure and the corrective action required by all staff
    5. Ties responsibility to the individual or team
    6. Significant impact (e.g., affects most of the core critical success factors and more than one BSC perspective)
    7. Positive impact (e.g., affects all other performance measures in a positive way).

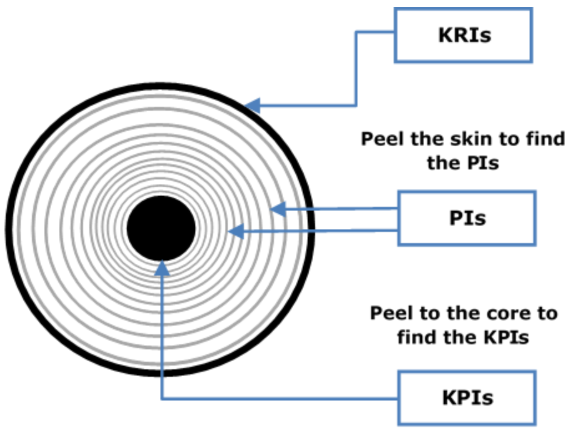

Fig. 2 *The relationship of performance indicators (13)*

The proposed KRI, PIs and KPIs

To cope with the given problems, according to the above mentioned categorization, the following KRI has been chosen:

1. *Costs per part unit* – a financial measure, it is defined as a key result indicator (KRI) according to (13), minimizing of costs per part makes it possible to decrease the price of the particular part on the market.

PIs chosen for the evaluation of the hybrid system performance (measured in short time production periods) include:

1. Number of finished products – *a shop floor metric relating to the overall amount of produced products*, maximizing the overall production increases the position of organizations on the market.
2. *Number of scrapped products* – a metric relating to the overall amount of scrapped products during production, minimizing of scrapped products decreases costs for each produced unit (product).
3. *Flow time* – a time interval representing the actual time of a product in the production process from launching of the order until its completion (placing of product into the *In/Out station)*, minimizing of this metric yields quicker production of goods.

The following KPIs have been proposed by the authors (for the sake of high precision, their measurements will occur in a very short time period during production):

1. *Reject Ratio* – a ratio of scrap taken from the overall produced goods, minimizing scrap helps organizations meet profitability goals.
2. *Work in process (W.I.P.)* – a factory floor metric relating to the overall amount of products (semi-finished products), minimizing of W.I.P. decreases storage costs in the production process.
3. *Capacity utilization* – a metric indicating the utilization of production equipment in a given time period (during production), higher utilization should increase the effectivity of production.
4. *Lead time* – a time interval representing the actual time of order placement to its completion, minimizing of this time interval is important for quicker order completion.
5. *Overall Equipment Effectiveness (OEE)* – a metric multiplying the availability of equipment by its performance and quality of produced goods to determine resource utilization, maximizing of this metric leads to a more efficient utilization of available personnel and machinery.
6. *Downtime* – one of the most important metrics caused by breakdowns or machinery setups during production time, minimizing downtimes is an easy way to increase profitability.
7. *First Time Through (FTT*) – metric representing the percentage of finished goods that meet the quality guidelines for the first time (no reruns are needed), improving this metric should decrease costs for reruns and the number of scrapped products.

CONCLUSION

This paper deals with the connection of a hybrid production system with MES. During the planning phase, several challenges had arisen and had to be resolved immediately. A solution to the given challenges has been proposed by the definition of proper KPIs, which are being calculated from the MES input data. The MES can usually contain a big amount of input data, therefore the real-time data for KPIs had to be appropriately chosen.

The proposed KPIs are used as a measure for performance, which opens up new possibilities that are in accordance with two of the strongest trends given for MES these days: integration of MES into a digital factory (as part of an automated manufacturing line) and the support of parallel online simulators for MES.

The future of this research work is to create a simulation model able to evaluate and optimize a production plan automatically in the case of a defined production event occurence, with the aim to use this online simulation to support throughout the lifecycle of MES.

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