IMPROVING A PLASTICS INJECTION PROCESS BY USING AN EFFICIENT PRODUCTION MANAGEMENT SYSTEM

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ABSTRACT: In the actual automotive industry context, in order to remain competitive on the market, all companies are constantly looking for solutions and tools to help increase productivity and improve the production process. The operational optimization through continuous improvement is the solution of this need. The paper describes how an injection process can be improved by implementing an MES- Manufacturing Execution System. This system provides visibility on process indicators, key data that reflect the operational performance. Through continuous monitoring and measurement of indicators, directions for continuous improvement can be addressed. MES Systems offer also a number of short and long-term benefits including reduced time, higher production volumes, improved yields, lower operating costs, increased compliance.

Keywords: Improvement; injection process; indicators; MES.

1. Introduction:

Optimizing the production process is an essential aspect in all the companies. The processes are becoming more complex, the requirements are more varied and in order to fulfill them, it is necessary to improve each step in the process.

Automatic control and permanent monitoring of the process allow access to essential data that must be analyzed in order to obtain favorable results and to improve production efficiency. Analysis of process data leads to a clear image of the aspects that need to be improved.

The profitability of companies is built more and more starting from the reduction of losses. Currently, most production processes are automatically controlled and monitored, which contributes to the identification of inefficient or repetitive processes, the correct analysis of process components and the search for optimization solutions.

Production management involves planning, coordinating, monitoring, administration, and judgment about the inputs and outcomes of a production process.

An extremely important foundation for process optimization is data analysis, perhaps even in real time that allows managers to understand changing conditions, system flow and how the system, process or line can be used to increase productivity. Companies must use this information to improve the production process or system.

MES (Manufacturing Execution System) is a software system intended for factories, which manages and controls the entire production process, from placing the order to obtaining the finished product, with the aim of optimizing all activities and resources in the production process.

The system provides real-time information on the status of each order, on which machine it is, at which stage in the production process, on machine parameters or on availability, performance, productivity and quality indicators. This solution helps to collect, measure and analyze the most important production performance indicators in a factory, to generate reports for efficiency analysis, anytime during the production process.

Such software has direct electronic connections to the planning system and control systems, collects and provides information and direction within the production activities thus proving an innovative industrial solution in the field.

2. The actual stage

There are many definitions for MES but they are all focused on the same direction: production improvement through the efficient management of all stages and the collection and analysis of real data from the process: "Manufacturing execution systems (MES) are computerized systems used in manufacturing to track and document the transformation of raw materials to finished goods. MES provides information that helps manufacturing decision-makers understand how current conditions on the plant floor can be optimized to improve production output."[1]

"A Manufacturing Execution System (MES) is a dynamic information system that drives effective execution of manufacturing operations. Using current and accurate data, MES guides, triggers and reports on plant activities as events occur. The MES set of functions manages production operations from the point of order release into manufacturing to the point of product delivery into finished goods. MES provides mission critical information about production activities to others across the organization and supply chain via bi-directional communication." [2]

With the help of this solution, managers can: permanently access the current situation of the machines in the entire factory; create an optimal production plan taking into account the situation of the machines and the tact; track in real time all machine stops, cycle times, speeds, production capacity utilization; calculate the OEE indicator based on data collected in real time from each machine.

The key factor of informed decisions, at the executive level, are the quality/performance indicators. Knowing and improving indicators can lead to increases in productivity by improving the use of equipment and increasing discipline in production. "An industry contains numerous types of equipment and processes that are a challenge to control and maintain in order to achieve highest performance and profit for the plant. Key performance indicators (KPIs) are fundamental in measuring the performance and its progress. KPIs can provide information about the performance in different areas such as energy, raw-material, control & operation, maintenance, planning & scheduling, product quality, inventory, safety, etc." [3]

The indicators provide specific information measured at a precise moment; they provide the image of the evolution and anticipation of the performance of an organization. Performance indicators allow performance measurement for each action taken, in order to achieve a proposed objective. They are therefore quantitative data, which measure the efficiency or effectiveness of a precise action. "Today, only modern Manufacturing Execution Systems (MES) offer real-time applications. They generate current as well as historic mappings of production facilities and thus they can be used as basis for optimizations." [4]

An organization can only effectively improve what it can measure and compare. By implementing and using a Manufacturing Execution System the most important indicators can be available anytime and for any period. "Manufacturing Execution Systems (MES) play a key role in the factory of the future" [5].

For the plastic injection process analyzed, the most important indicators are: availability, performance, quality and OEE. Others important indicators for this process are: down-time rate, scrap rate, cycle time deviation.

Further, I described the main indicators of the injection process together with the calculation method for each indicator and, in order to exemplify the way in which the MES system calculate the indicators and offers visibility on production data, I extracted and presented the main indicators results obtained in the first 3 months of 2023 year, for 8 injection machines.

3. Injection process indicators

3.1. AVAILABILITY (uptime)

Machine Availability in the context of the manufacturing industry- also referred to as uptime- is the first of the three key performance indicators that are taken into account for the calculation of the OEE. It takes into consideration all of the events that could have interrupted planned production time, whenever it has been stopped for a significant period of time.

The availability refers to the production time and indicates the percentage of time of actual production during the loading time. This performance indicator is therefore based on the time duration of the production.

Losses in effectiveness due to non-production during the loading time are called availability losses.

The formula for calculating this indicator is:

$$Availability\ (in\ \%) = \frac{production\ time}{loading\ time} \times 100 \qquad (1)$$

Machine Availability is presented in a percentage form and is measured by analyzing all of the equipment on the factory floor's uptime, which refers to the amount of time it takes machines to conduct their work (run time), and dividing it by the maximum time it would be available if there were no downtime for repair or unplanned maintenance. And in order to capture the actual availability, it's important to highlight each instance of downtime, whether planned or unplanned.

Loading time (operation time during the period under observation) = calendar time minus generally production -free times (weekends, plant holidays) minus scheduled availability gaps (shift changeovers etc.) minus order-independent scheduled down-times (maintenance etc.)

Production time = scheduled loading time minus order-contingent non-production times (machine set-up, calibration etc.) minus unscheduled down-times (malfunction, equipment breakdown, no staff, no material etc.)

3.2. PERFORMANCE (productivity, process rate)

The performance- also referred to as productivity or process rate- is the second of the three key performance indicators that are taken into account for the calculation of the OEE.

The performance refers to the production quantity and indicates the percentage of quantity produced, based on the quantity that theoretically could have been produced during the production time. This performance indicator is therefore based on the speed of the production, measured as a percentage of its designed speed, during the actual production time. In contrast, losses in effectiveness from unscheduled down-times (that is, from a reduced production time, as opposed to a reduced production speed) are taken into account in the availability.

Losses in effectiveness due to reduced production speed are called performance losses or speed losses.

$$Performance\ (in\ \%) = \frac{produced\ quantity}{target\ quantity} \times 100 \qquad (2)$$

Produced quantity = total produced quantity (yield + scrap)

Target quantity (order) = Target yield for the order

3.3. QUALITY (first pass yield)

The quality- also referred to as first pass yield- is the third of the three performance indicators that are taken into account for the calculation of the OEE.

The quality refers to the production quantity and indicates the percentage of yield in the total quantity produced. This performance indicator is therefore based on the quality of the production. Losses in effectiveness due to poor quality are called quality losses.

$$Quality\ (in\ \%) = \frac{yield\ quantity}{produced\ quantity} \times 100 \qquad (3)$$

$$= \frac{yield\ quantity}{yield + scrap} \times 100 \qquad (4)$$

3.4. Overall Equipment Effectiveness (OEE)

Fig 1. OEE indicator components.

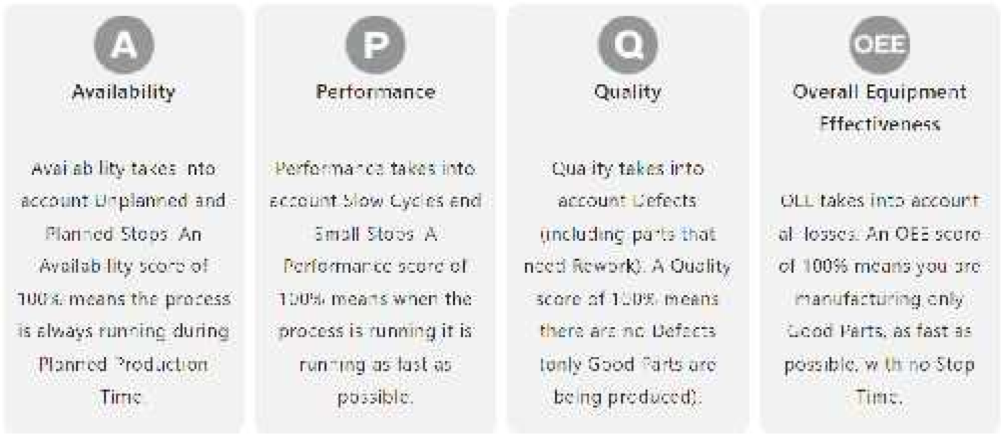
OEE (Overall Equipment Effectiveness) is the gold standard for measuring manufacturing productivity. Simply put it identifies the percentage of manufacturing time that is truly productive. An OEE score of 100% means that the factory produces only good parts, as fast as possible, with no stop time. In the language of OEE that means 100% Quality (only Good Parts), 100% Performance (as fast as possible), and 100% Availability (no Stop Time).

Measuring OEE is a manufacturing best practice. By measuring OEE and the underlying losses, management obtains important insights on how to systematically improve the manufacturing process. OEE is the single best metric for identifying losses, benchmarking progress, and improving the productivity of manufacturing equipment.

The OEE is a measure for the effectiveness of single machines or whole plants; it measures the relation of produced yield to the theoretically possible yield during the loading time. The OEE incorporates effectiveness losses due to (insufficient) duration, speed and quality of the manufacturing process.

$$OEE\ (in\ \%) = \frac{availability}{100} \times \frac{performance}{100} \times \frac{quality}{100} \times 100 \qquad (5)$$

The 3 major indicators that are taken into account when calculating the OEE and described above, are briefly presented in the figures below:



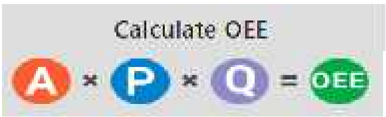


Fig. 2. OEE calculation formula

For the chosen period and machines, the results are presented below:

OEE machines

Timespan	from 01/01/2023 until 03/31/2023 (Shift Timespan from 01/01/2023 00.00.00 until 03/31/2023 08.00.00)
Machines	M1; M2; M3; M4; M5; M6; M7; M8;
Shift types	Early shift-not in use; Productie pe weekend : Late shift-not in use; Night shift-not in use; L-V ora 08h00-16h00; L-V ora 16h00-00h00; L-V ora 00h00-08h00; Extra shift-not in use;
Downtime reason	According to mastercate

Device	Availability	Performance rate	Quality rate	OEE
M1	70 %	97 %	98 %	67 %
M2	86 %	100 %	99 %	85 %
M3	85 %	99 %	99 %	84 %
M4	91 %	98 %	98 %	88 %
M5	88 %	100 %	99 %	87 %
M6	84 %	100 %	99 %	84 %
M7	89 %	100 %	100 %	90 %
M8	87 %	81 %	99 %	70 %

Fig 3. Values for 3 months- 8 injection machines

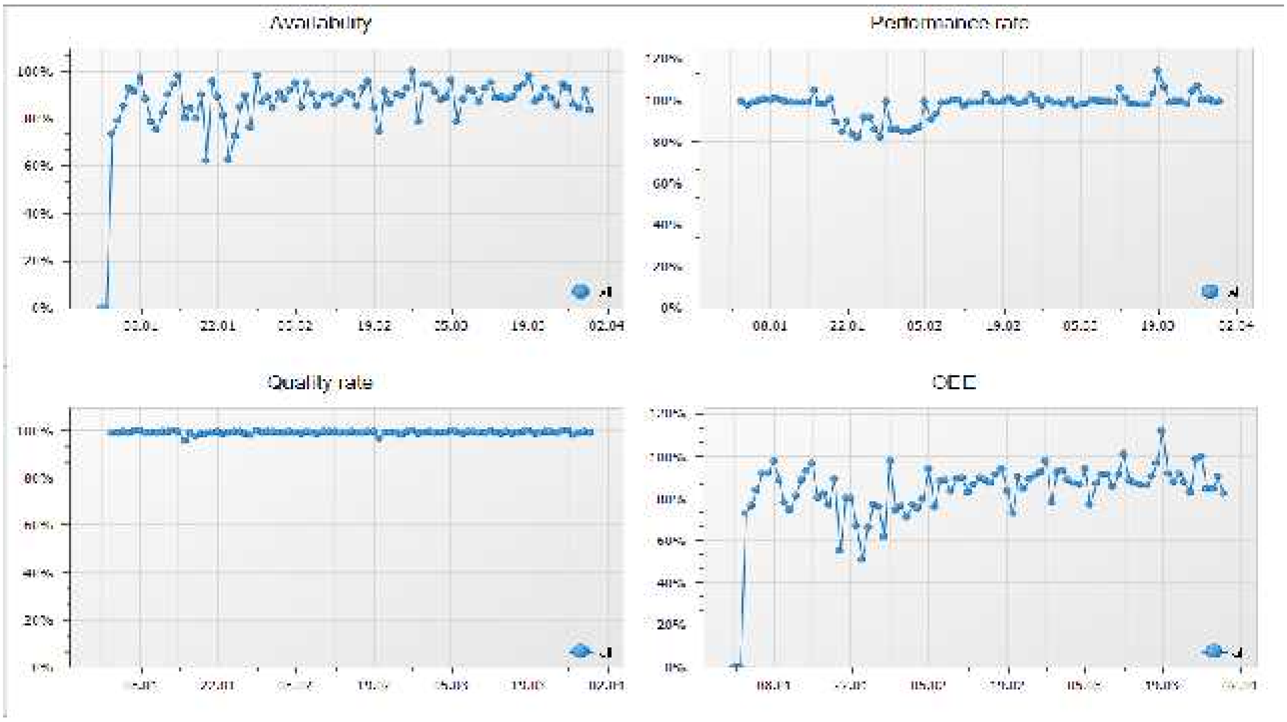


Fig 4. Values/each day

These indicators are automatically calculated by the MES system and can be available for one machine, for several machines or for the entire chain of injection machines at any time and for any period.

An ideal process, equipment, or system would operate at: 100% uptime, 100% capacity, and 100% proper parts quality. However, in real life, this situation is rarely encountered. The difference between the ideal situation and the current one is due to losses. If there is a gap between the daily production process and the ideal situation, the analysis must focus on this gap and find ways to overcome it. Losses can be classified into 3 main categories: non-functioning losses, speed losses and quality losses.

3.5. DOWN-TIME RATE

The down-time rate refers to the loading time and indicates the percentage of unscheduled down-times during the scheduled production time.

The down-time rate measures the availability losses.

$$Down - time\ rate\ (in\ \%) = \frac{non - production\ time}{loading\ time} \times 100 = 100 - availability \quad (6)$$

Non-production time= order-contigent non-production times + unscheduled down-times= loading time- production time.

If the various down-time reasons are assigned a resource type, the down-time rates can be calculated for each resource type individually.

3.6. SCRAP RATE (reject rate, defect production rate)

The scrap rate refers to the total production quantity and indicates the percentage of bad or defect products in the total quantity produced. The scrap rate measures the quality losses.

$$Scrap\,rate\ (in\ \%) = \frac{scrap\ quantity}{produced\ quantity} \times 100 = 100 - quality \qquad (7)$$

3.7. CYCLE TIME DEVIATION

The cycle time deviation refers to the target cycle time; it could reach a maximum of plus 100 percent (in the theoretical case the actual cycle time was zero) and can take any negative value.

$$Cycle\ time\ deviation\ (in\ \%) = \left(1 - \frac{actual\ cycle\ time}{target\ cycle\ time}\right) \times 100 \qquad (8)$$

If the actual cycle time is shorter than the target value (that means the production is running faster than planned) the deviation value is positive. If the actual cycle time exceeds the target cycle time (that means that the production is running slower than designed), the deviation value turns negative. An actual cycle time that is 50 percent longer than the target cycle time means that the cycle time deviation is minus 50 percent. An actual cycle time of twice the target cycle time results in a deviation value of minus 100 percent.

4. Conclusions

Machine monitoring was adopted in this era of smart technology to rise above competitors with optimal control. With real-time monitoring, the management can instantly detect when the machines or equipment are running, when they are abruptly stopped due to issues, and in which way they are exactly used. Reducing errors saves money, access to data keeps the team in the know, and complete transparency of the operations increase team morale. Real-time Machine Monitoring empowers manufacturers by gathering relevant data that helps them perfect overall production and ensure a fully productive time.

Manufacturing optimization is the result of a deep analysis of the entire process, analysis that can only be achieved using clear and real, quantifiable data. These data can be collected with the help of production control and management systems like MES.

This interactive tool helps management to act promptly and efficiently in case of any situation encountered in production. Thus, resources are used at maximum capacity, processes are accelerated, elimination of dead times or production stoppages is favored. Monitoring is easily and permanently carried out over the entire process, from sourcing to product delivery. Process optimization thus leads to cost optimization and increased process performance.

Reducing costs by optimizing resources is a requirement that modern manufacturing companies must face today in order to better survive in a world in continuous digitalization.

Production execution systems as MES thus play a key role in the factory of the future.

V. Bibliography:

[1]. McClellan, M. *Applying Manufacturing Execution Systems*, 1st ed. CRC Press, Boca Raton, Fl,1997.
[2] What is MES?: A & D Tech Eng. (n.d.). Retrieved December 2, 2019, from http://www.techeng.com.au/mes/what-is-mes
[3] May, G., Taisch, M., Prabhu, V. V., Barletta, I. (2013). Energy Related Key Performance Indicators – State of the Art, Gaps and Industrial Needs. IFIP International Federation for Information Processing 2013. pp. 257–267, 2013.
[4]. Jürgen Kletti, *Manufacturing Execution Systems* — MES, 2007

[5]. TIG authentig – TIG hard- and software solutions (tig-mes.com)
6. Scholten, Bianca (2009). *MES guide for executives: why and how to select, implement, and maintain a manufacturing execution system.* Research Triangle Park, NC: International Society of Automation.
7. *Enterprise-Control System Integration Part 1: Models and Terminology*. Research Triangle Park, North Carolina, USA: International Society of Automation. 2000.
8. *Enterprise-Control System Integration Part 3: Activity Models of Manufacturing Operations Management*. Research Triangle Park, North Carolina, USA: International Society of Automation. 2005.
9. *A Reference Model For Computer Integrated Manufacturing* (CIM) Purdue Research Foundation, 1989
10. O. Sauer, "Trends in Manufacturing Execution Systems," no. 2, pp. 685–693, 2010.
11. R. Govindaraju and K. Putra, "A methodology for Manufacturing Execution Systems (MES) implementation," IOP Conf. Ser. Mater. Sci. Eng., vol.114, no. 1, 2016
12. T. Hänel and C. Felden, "Limits or Integration? – Manufacturing Execution Systems and Operational Business Intelligence," AMCIS 2011 Proc, 2011.
13. E. L. Itskovich, "Basics of MES construction concept for production industries," Autom. Remote Control, vol. 77, no. 11, 2016
14. B. S. De Ugarte, A. Artiba, and R. Pellerin, "Manufacturing execution system - A literature review," Prod. Plan. Control, vol. 20, no. 6, 2009.
15. MESA White Paper #01: The Benefits of MES: A Report from the Field," vol. 3, MESA International, 1997
16. I. Mahmoud, H. H. Ammar, M. M. Hamdy, and M. H. Eissa, "Production operation management using Manufacturing Execution Systems (MES),"
2015 11th Int. Comput. Eng. Conf. Today Inf. Soc. What's Next?, ICENCO 2015
17. J. Kletti, Manufacturing Execution Systems – MES. Springer Berlin Heidelberg New York, 2007.
18. H. Meyer, F. Fuchs, and K. Thiel, Manufacturing execution systems : optimal design, planning, and deployment. 2009
19. F. Almada-Lobo, "The Industry 4.0 revolution and the future of Manufacturing Execution Systems (MES)," J. Innov. Manag., vol. 3, no. 4
20. D. Romero and F. Vernadat, "Enterprise information systems state of the art: Past, present and future trends," Comput. Ind., vol. 79
21. Hamlin, C. and N.F. Thornhill (2008). "Integration of control, manufacturing and enterprise systems", Control IChemE Industry Session, Manchester, Sept 3rd.
22. MESA International Website: www.mesa.org