Determination of OEE and Analysis of Time Losses in the Production Process

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Abstract: *The aim of this paper was to focus on time loss analysis and to evaluate OEE in the manufacturing process. OEE is mainly evaluated to see how efficiently the production lines are used. OEE was evaluated on the production line. OEE is evaluated from the collected data. Data collection is fully automated. The data that has been collected for analysis is from the calendar year 2022. The resulting OEE percentage is obtained by multiplying availability, performance and quality. The results show that the production line does not yet meet the achievement of an OEE of 80%. The production line achieves an OEE of 59.2% without industrialization. The time losses are analyzed focusing on planned and unplanned stops. Specific improvements are proposed to improve the overall OEE results. These suggestions for improvement would provide a better resulting percentage OEE.*

Keywords: *OEE, production line, downtime, losses, quality*

INTRODUCTION

OEE is a key KPI for organizations that focus on how efficiently a manufacturing operation is used (Luptak, 2021). OEE identifies and tracks losses; it is a measure that finds the potential of a facility; it identifies gaps and opportunities in production (Stamatis, 2010).

The main objective of OEE is to reduce cost, increase productivity, increase awareness of the need for machine productivity, increase machine life (Stamatis, 2010).

The first problem occurs when using OEE when the inefficiency of the equipment being evaluated does not fall within the benchmark six large losses. This situation occurs frequently when analyzing production data logs of complex equipment (Carlo, Arleo and Tucci, 2014).

Jeong and Phillips point out that OEE is not well suited to capital-intensive sectors. In an area where these devices are to be used to get an immediate return on their investment, these devices should be used to their maximum potential. Therefore, it is advisable to consider every type of loss, for example, those related to planned preventive maintenance or plant-wide shutdowns (Jeong and Phillips, 2001).

Quality refers to manufactured parts that do not meet quality control standards, including those that need to be corrected. Performance takes into account the number of slowdowns or short stops in production. A perfect performance result under OEE conditions means that the plant produces as fast as possible. Availability takes into account planned and unplanned downtime. Perfect availability results are obtained when, the plant runs continuously during scheduled production times (Trout, 2022).

The downtime is the total sum of the times when the equipment is not operational until it is brought back into service. The downtime is the total time, which does not include only the net time to repair the equipment. We divide downtime into planned and unplanned (Bujna, Prístavka, Čičo, 2020). In the manufacturing sector, once OEE is in place, it also depends on the level of OEE. OEE can be divided as follows into the following four levels: paper-based OEE, Excel-based OEE, automated non-integrated OEE, automated integrated OEE (Clarke, 2020).

The key phases for the new OEE improvement framework are set out as follows in the five points above:

- In the first phase, the project is initiated and the team is assembled;
- in the second phase, data collection and evaluation is underway;
- in the third phase, it focuses on priority losses;
- In the fourth phase, root cause analysis and implementation of OEE improvements is underway;

In the fifth phase, the implemented improvements are checked, verified and maintained

(Cheah, Prakash, & Ong, 2020).

The aim of the work is to determine the OEE on a selected equipment within the manufacturing process. After determining the OEE, the time losses in the manufacturing process are analyzed.

MATERIALS AND METHODS

Production line

The production line (Fig. 1) is semi-automated in nature, as the loading of blanks, tool changes and removal of finished products are not fully automated. It consists of conveyors, equipment for cleaning blanks with brushes, robotic arms (manipulators), presses.

The production process on the line is as follows. Semi-finished products are prepared in front of the entrance gate and are placed on conveyors, which are placed on rails in front of the entrance gate. There are two such entry gates, and behind these gates is an area called the semi-finished goods bin. There are two of these trays because when the blanks in one tray run out, the robotic arm can smoothly start removing material from the other tray without interrupting production, and in between the tray fills up while the robotic arm is removing blanks from the other tray. The blanks are removed by the robotic arms onto a conveyor belt which is directed towards the cleaning machine. Subsequently, the semi-finished products are taken from the cleaner by the robotic arms to the presses. Robotic arms are also used between these presses, so that after the required operation has been carried out on one of the presses, the material is continuously transferred between the presses to the end of the line on the conveyor belt by means of the robotic arms. During the transfer of the semi-finished product between the presses, the product achieves the desired shapes. At the end of the production line there is a conveyor belt from which the finished products are removed manually by operators who inspect the products and then place them on transport racks.

Fig. 1 Production line

Data collection

Data collection for OEE evaluation is fully automated through a software that collects data from the line and performs the necessary calculations for OEE percentage evaluation.

Determination of OEE

The resulting OEE percentage is determined according to mathematical relationships 1-4 above.

$$Overall\ efficiency\ of\ the\ device = Availability/Performance/Quality \quad (1)$$

$$Availability = \frac{Net\ operating\ time\ of\ the\ device}{Available\ time\ for\ production} \quad (2)$$

$$Performance = \frac{The\ net\ operating\ time\ of\ the\ device}{The\ net\ operating\ time\ of\ the\ device} \quad (3)$$

$$Quality = \frac{Number\ of\ good\ pieces}{Total\ number\ of\ pieces} \quad (4)$$

RESULTS AND DISCUSSION

In Figure 2 we can see a graphical representation of the OEE for the calendar year 2022. From the individual values we can conclude that the percentages are fairly constant, with small percentage differences. The only exception is the month of July. In July, the OEE percentage was only at 51% and due to frequent breakdowns on the instruments, this was reflected in the quality. Due to these breakdowns, greater time losses were incurred, which was reflected in the resulting OEE.

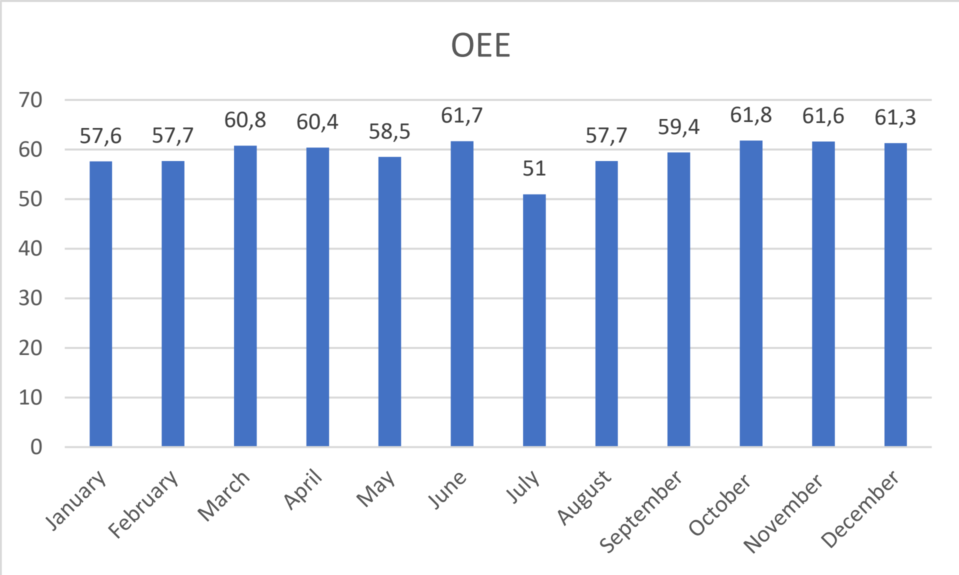

Fig. 2 Bar chart of OEE for production line 1 in 2022

The total OEE on the production line for the calendar year 2022 (Figure 3) was:

- an average percentage of 59.2%;
- Time losses for the full year amounted to 40.8%.

Unscheduled stops due to breakdowns are mainly responsible for time losses on the production line:

- machines;
- Instruments;
- robots;
- errors in the production process;
- quality.

The production line is kept just below the typical OEE value. This means that there is room for improvement.

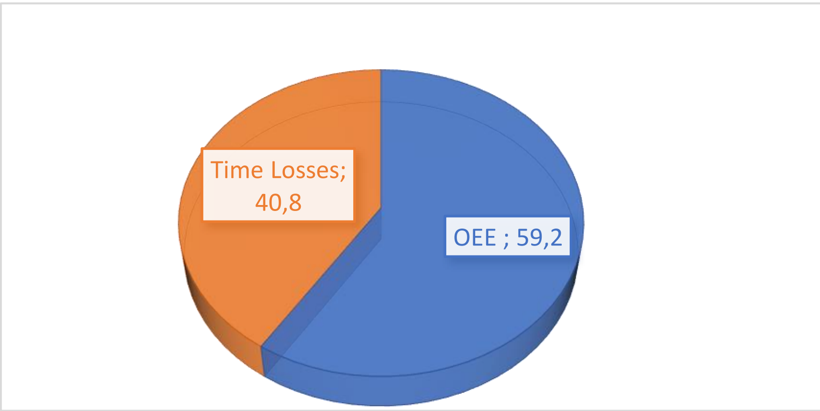

Fig. 3 Total OEE for 2022 on the production line

Time losses (Table 1 and Table 2) are the time losses of planned and unplanned stops on production lines.

Table 1 Planned stops during 2022

Planned stops	**Line [h]**
Planned stops in total	642.41
Planned maintenance	0.33
Organisation of processes	23.46
Training and meetings	123.54
Industrialization	495.09

Table 2 Unplanned stops during 2022

Unscheduled stops	**Line [h]**
Unscheduled stops in total	487.02
Machine malfunctions	63.75
Instrument malfunctions	150.89
Robot malfunctions	16.57
Errors in the production process	81
Errors in process control	56.35
Quality defects	93.65
Unjustified stops	0.75
Short stops	24.07

Suggestions for improving OEE

One option is to change tool supplier and look for a supplier with tools that guarantee higher quality, as most stoppages are due to this loss. This unnecessarily reduces the value of the OEE.

When removing aluminium sheet metal parts, there is a problem that the robotic arm is sometimes not able to separate the sheet metal parts from each other using grippers, as these sheet metal parts are oil-preserved and stacked on top of each other. As a result, they are sometimes quite tightly joined (glued together). The solution would be to apply pneumatic high pressure nozzles that would blow air at high pressure between the sheet metal parts along the sides of the sheet metal parts, blowing the sheet metal parts together, causing them to come apart more easily and then allowing the robotic arm to remove the sheet metal part more easily.

Other stoppages caused by the grippers on the robotic arms are due to their suction cups. Because of these suction cups, frequent short stops sometimes occur, these stops are internally referred to as vacuum faults. The solution would be to inspect these suction cups more often, maintain them more frequently, or replace them with more durable suction cups.

On the production line, the bases for the robotic arms are directly connected to the presses, which causes vibrations to be transferred from the presses to the robotic arms and then to the grippers. One possible solution would be to apply anti-vibration pads between the robotic arms and the bases. These anti-vibration pads would ensure that there would not be as much vibration transfer to the sheet metal parts and would result in the elimination of sheet metal part crashes.

CONCLUSION

The aim of the work was to quantify the OEE on the production line and to analyse the OEE based on time losses. Based on the collected tasks, we found that the achieved OEE on the line is 59.2%, which is a very low level.

We analyzed the time loss by focusing on planned and unplanned stops. The time losses are clearly shown in the individual tables. In these tables there are categories and individual times that show us how long each stop took.

Therefore, we have proposed solutions to increase OEE. In the first proposal to improve the resulting OEE, we have listed how to reduce the stops due to the tools. Another suggestion was the application of pneumatic nozzles in the removal of blanks. Another option for improving the resulting OEE was for example more frequent maintenance of the grippers. To eliminate vibrations on the production line, we suggested the application of an anti-vibration pad. All these sub-suggestions would affect the final OEE outcome of the organization.

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REFERENCES

[1] Bujna, M, Prístavka, M., Čičo, P., (2020). Reliability of technical systems. Nitra: Slovak University of Agriculture, 2020. ISBN 978-80-552-2285-1.

[2] Carlo, F., Arleo, A., Tucci, M., (2014). OEE Evaluation of a Paced Assembly Line through Different Calculation and Simulation Methods: A Case Study in the Pharmaceutical Environment', International Journal of Engineering Business Management. doi: 10.5772/59158. [online] [cited 2022-3-22] Available at: <https://journals.sagepub.com/doi/10.5772/59158 >

[3] Cheah, C.; Prakash, J., Ong, K., (2020) Overall equipment effectiveness: a review and development of an integrated improvement framework. International Journal of Productivity and Quality Management, 2020, [online] [cited 2022-3-22]. Available at: <https://www.researchgate.net/profile/Ong-Kok-Seng/publication/332692888_Overall_equipment_effectiveness_OEE_a_review_and_development_of_an_integrated_improvement_framework/links/5e0993d6a6fdcc28374865ee/Overall-equipment-effectiveness-OEE-a-review-and-development-of-an-integrated-improvement-framework.pdf>

[4] Clarke, P., (2020). OEE and Why It's Important [online] [cited 2022-3-22]. Available at: < https://slcontrols.com/oee-and-why-its-important/>

[5] Jeong, K., Phillips, D., (2001). 'Operational efficiency and effectiveness measurement', Int. J. Oper. Prod. Manag., vol. 21, no. 11, pp. 1404-1416, 2001 [online] [cited 2022-3-22] Available at: <https://spmconsultant.co.in/sites/default/files/downloads/Operational%20efficiency%20and%20effectiveness%20measurement.pdf >

[6] Luptak, P., (2021). What is Overall Equipment Effectevines [online] [cit.2022-3-22]. Available at: <https://www.resco.net/blog/oee-in-manufacturing-definition-and-calculation/>

[7] Stamatis, D., (2010). The OEE primer: understanding overall equipment effectiveness, reliability, and maintainability. CRC Press, 2010. ISBN 978-1-4398-1406-2

[8] Trout, J., (2022). What Is Overall Equipment Effectiveness (OEE)? [online] [cited 2022-3-22] Available at: <https://www.reliableplant.com/Read/11785/overall-equipment-effectiveness>

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