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CONTRIBUTION TO THE DEVELOPMENT OF QUALITY CONTROL BASED ON MONITORING OF INDEX OF OVERALL EQUIPMENT EFFICIENCY

Hazim Bašić, Muhamed Brkić, Almira Softić
University of Sarajevo, Mechanical Engineering Faculty
Vilsonovo šetalište 9, Sarajevo
Bosnia and Herzegovina

Erna Omerašević
International University of Sarajevo, Faculty of Engineering and Natural Sciences
Hrasnička cesta 15, Ilidža Sarajevo
Bosnia and Herzegovina

ABSTRACT
In this paper the results of research of OEE (Overall Equipment Efficiency) concept and its application in organizations with high volume production are presented. Since the quality and productivity of the plant affects a lot of random and inconspicuous factors, the goal of this study is to show impact of those factors to the availability, efficiency and quality of the plant. It is possible to reveal another „hidden machine" among the others by downtime monitoring, analysis, and taking of corrective actions. A case study analysis of the production has been done by applying the tools and methods of quality management. Results of the analysis showed that the improvement is achieved in terms of reducing waste and increasing productivity in the manufacturing process for the two analyzed periods.
Keywords: quality assurance, work analysis, overall equipment efficiency, OEE

1. INTRODUCTION
Production quality management represents a particular scientific area, which includes planning and performing activities in order to achieve the required product quality at minimum cost. The methodology and tool, which is used for analysis and exploitation of production equipment in quality management, was discovered by S. Nakajima in sixties of the last century and presented as Overall Equipment Efficiency (OEE) concept, [1]. OEE represents a measuring instrument used to detect losses of the entire production system or losses of only one production device (machine), in order that these losses could be eliminated by using one of the optimization strategies such as Lean Production or Six Sigma. By measuring of the OEE index, it can be recognized how well the process is managed and which part of production process can be improved.

2. DESCRIPTION OF THE OEE METHOD
Because of the occurrence of losses, due to different types of delays, existing production equipment is not fully exploited, [3]. Total Productive Management (TPM) optimization strategy represents the key for discovering 'hidden machine', i.e. the possibility to pull out additional 25−30% capacity from production equipment, [2]. One of the main objectives of TPM is to increase the productivity of plant and equipment with a modest investment in maintenance. OEE is the traditional and most frequently used instrument in TPM and it demonstrates the *equipment capability* when equipment is in use.

2.1 Losses of equipment

In order to obtain a clear overview of different types of losses, with all their characteristics, possibilities of eliminating losses and pointing out the losses, OEE distinguishes three main areas of losses, [5]: availability, efficiency and quality. Traditional TPM optimization strategy repels 'six big losses' (Figure.1), [1]. OEE method hierarchically distinguishes three levels of losses: at the *first level* main losses are represented, *second level* are the losses at the factory level, and *third level* are the losses at the machine level.

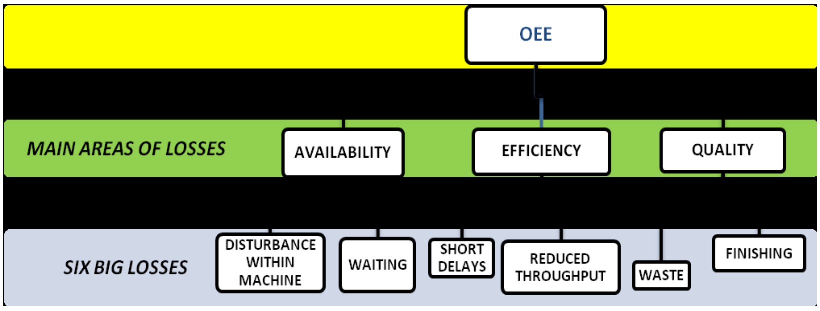

Figure 1. Basic areas of losses and six big (dominant) losses which define OEE

2.2 Merging of the three basic areas of losses in the OEE measure

Availability R is defined as the time period in which the equipment was available to produce but at same time there was no production of the product and it represents a percentage part of *real time* T_{st} of the equipment operating in the *planned time* T_{pl}, [5]. Efficiency losses E occur when machine is working, but not at maximum speed. These losses are determined from the ratio of the *real output* q_{st} and *maximum output* q_{te}, while machine is working *without interruption*. Quality losses Q occur when machine is producing parts which *at the first sight* do not satisfy required dimensions and tolerances. Losses are determined from the ratio between the *number of correct produced pieces* q and the number of *real produced pieces* q_{st},

Measured OEE factor represents product of availability, efficiency, and quality degree.

$$OEE = \frac{T_{st}}{T_{pl}} \frac{q_{st}}{q_{te}} \frac{q}{q_{st}} 100\% \tag{1}$$

$$OEE = \mathrm{R} \times E \times Q \times 100\% \tag{2}$$

3. EXPERIMENTAL STUDY BASED ON IMPLEMENTATION OF OEE METHOD

In order to take into account all critical points, OEE method has been implemented into company FAMOS Adi Sarajevo, based on plan that contains eight critical steps.

Step No. 1. The choice of pilot machine whose work will be accompanied by the OEE team

The production process is defined so that the machines are placed in line, according to the product operation process. Selected machine represents the bottleneck on the production line and requires the largest time for one cycle of processing the piece T_c. Value of the OEE line corresponds to value of OEE of the machine which has the longest operating time per piece, [4]. Chosen team members were: team leader-technologist who was in charge for the production process, the manager, and all the operators who served selected machine, one employee from maintenance and one from purchasing.

Step No. 2. Defining the parameters to be monitored

Monitoring of selected machine will be at the beginning of OEE index measurements for a period of 30 days from the start, first period. Six months after the end of the first period, new control, with duration of 30 days, will be applied. Refining on the selected machine is not possible, so it will be recognized two types of waste: material waste and processing waste. Processing cycle time T_c is determined and set up into the software and used for calculation of the OEE index value.

Step No. 3. Making the OEE form and codebook for delay monitoring
Delay codebook was made by analyzing the characteristic delays. Codebook contains numerical codes of delays and name of the delay. During the delay identification, it is considered that identifications are clear and precise, in order to avoid possible uncertainties during the data analysis. The form contains:

– identification of monitored machine,
– the operator on working machine,
– time for filling the form,
– type and amount of waste,
– the number of processed pieces,
– codes of delay/event, and time and duration of delay.

Step No. 4. Team training
The training is conducted by experienced trainer for OEE method. The duration of the training was three days (theoretical part, practical presentation on the machine and collecting data, and on the third day collected data were analyzed under the supervision of trainer.

Step No. 5. Data collecting
Operators submit the completed forms to the manager after every shift and manager inputs data into base software for OEE index calculation.

Step No. 6. Data processing
At the end of shift, manager must enter collected data into database. In order to get a report, it is needed to specify the date/period for which you want to find value of OEE and choose machine. After activation, detailed report will be obtained, (Figure 3).

Step No. 7. Presentation of results, data analysis and initiating corrective measures
The principle of Deming's cycle PDCA (P – plan, D – do, C – check, and A – act) was used during the analysis of collected data, [6]. The most influential losses at the machine level are: no work in progress, planned substitution of cutting tool and waiting for half product. The losses *'No half product'* and *'Waiting for a half product'* grows into *'No half product'* on factory level. On the other hand, the loss *'No half product'* on factory level grows into main loss *'Imposed delays'*. In this case, it was analyzed "half product" loss and corrective measures on factory level. By determining the most influential loss, corrective measures are defined same as the goal to be achieved.

After six-month period a new detailed analysis has been applied for thirty-day period in order to make an insight into the effectiveness of applied corrective measures. Analysis of collected data, in the second period, on factory level shows that the *'No half product'* loss has been lost 2130 minutes. Achieved result was better then settled goal, to reduce lost time under 2580 minutes.

Step No. 8. Informing administration
After second period of analyzing, the results are presented to the management. Figure 2 shows that the value of the index in the first period was 88,3 %, but in the second period it was 68,4 %. The increasing of the OEE index for 19,9% results in increasing availability for 15 % and increasing the efficiency for 6,6 %, and the quality factor was increased only for 0,1 %.

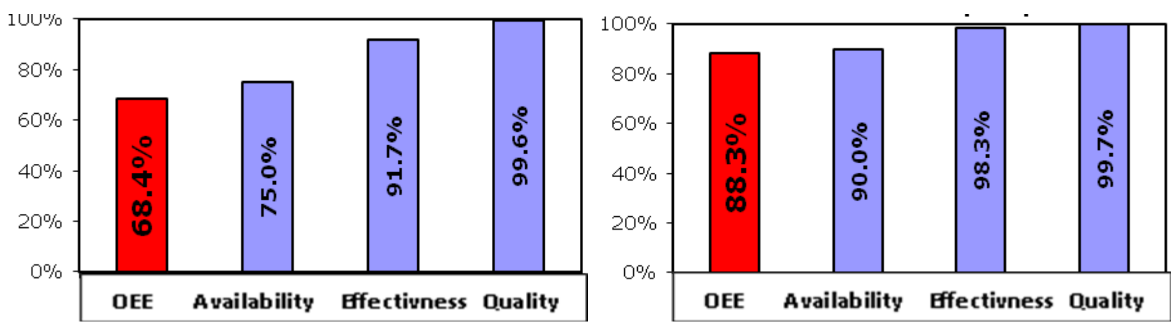

Figure 2. Basic losses areas and OEE index values

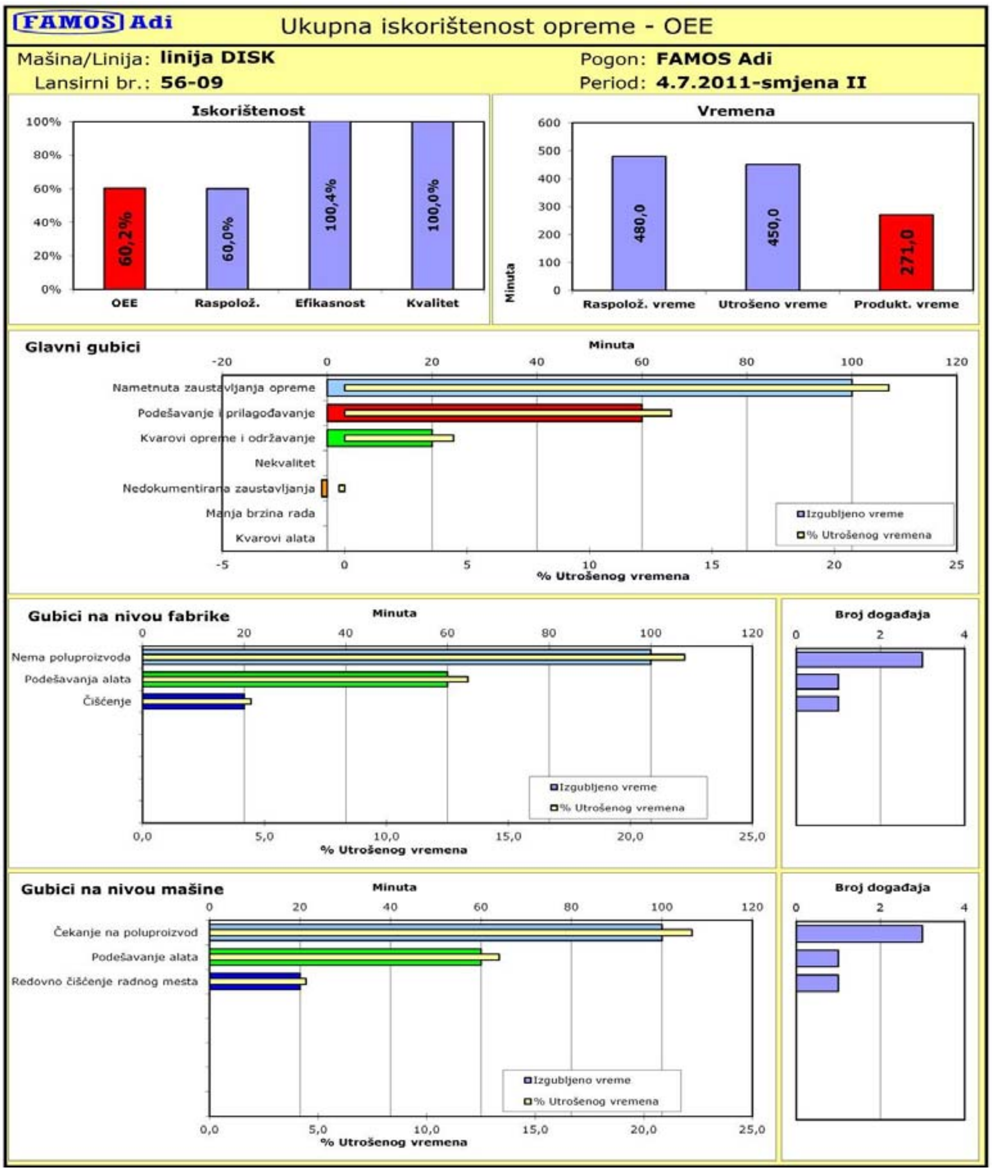

Figure 3.Detailed OEE report of overall equipment exploitation

4. CONCLUSION

By implementing OEE form, the systematic monitoring was enabled to company FAMOS Adi. In order to monitor the effects of OEE method, two periods were analyzed in this paper. First period was defined as phase of implementing OEE method, and second period was after six months of monitoring OEE index. Based on implemented corrective actions in second period OEE index value was increased by 19.9% compared to the first period. This increase is mainly the result of very simple and cost acceptable improvements.

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