EFFECT OF THE CHANGES IN THE FORMING METAL PARAMETERS ON PRODUCTION FLOW AND THE OVERALL EQUIPMENT EFFECTIVENESS COEFFICIENT

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Abstract

The paper presents the analysis of the machines efficiency use on the basis of an OEE coefficient for various periods of production for the company engaged in the manufacture of complex metal products. The Overall Equipment Effectiveness was assessed before and after changes improving the position of forming and after the implementation of the new shape of the forming matrix. With regard to the internal logistics companies it found that changes in addition to increase of the OEE (the result exceeds the value of the coefficient in relation to World Class) also affected on the production flow. It has been observed that proposed changes significantly improve the values of the TPM - availability, performance, and the quality indicators had more beneficial values.

Keywords: OEE, production engineering, process flow, metal forming

1. INTRODUCTION

To provide high-quality of metal products is particularly difficult because of the interdependent operation of the plastic deformation processes, thermal transformation and the impact of external factors (air, external forces, mechanical failure, employees' mistakes, inadequate fit machine tools fitting) [1-7]. In the other hand in the case of precise orders (industry with higher quality requirements) it is extremely difficult to provide adequate dimensional tolerances of details composed of many different metals. Many parts commonly used in the automotive industry in their structure contain more than one kind of metal (it is the target of its functional properties). For example, the hitch to in automotive active safety systems are used element made of aluminum alloy, steel cable and the entire part is covered with anticorrosive cataphoretic coating. The essence of proper preparation of multi-metal element is both the selection of materials, their preparation (heat treatment, cutting, surface treatment) and the use of the production process [1, 3, 6]. In the case of metal hot forming (various types of steel) [1, 2] and cold forming (aluminum alloys) [3], very important is the flow of materials and information which may be monitored by value stream mapping (VSM), the same design of the subsequent steps of the process, but it is also use properly fitting machines facilities (matrix, stamps, e.t.c) [8, 9].

In companies that deal with metal processing, there is a tendency to act in accordance with the principles of TQM (Total Quality Improvement) and TPM (Total Productive Maintenance). The interrelationship between these two enables continuous process control, its supervision, and thus gives great opportunity to improve at every stage. Management of the company in the metal industry imposes the usage of lean management methods, to ensure the maximum efficiency of machines and equipment. This efficiency is defined as the maximum utilization of the available time machine for the production of good quality in this case very helpful is monitoring of changes in OEE indicator [9, 10].

The OEE indicator (*Overall Equipment Effectiveness*), equipment utilization indicator, is an international standard for measuring the efficiency of machines. The OEE analysis starts with the determination of the total production time in which manufacturer is able to produce. The total production time is subtracted with planned downtime, which include all events that should be excluded from the analysis of efficiency, because at that time there was no intention to production carry out (eg. breaks, interruption, training, planned maintenance, lack of orders from customers) [11]. The remaining time is called the scheduled time of production. OEE analysis starts from scheduled time production time and analyze the efficiency losses that occur. There are three general categories of losses for consideration: downtime, loss of performance and quality. The OEE is the result of the other three measurable sub-indicators: Availability, Performance, and Quality. The OEE indicator is calculated according to the formula:

$$OEE = A \cdot P \cdot Q \qquad (1)$$

Where:

A - availability,
P - performance,
Q - quality.

Availability (A) indicator takes into account all outages, which include all events that will stop the production for a certain period of time (usually a few minutes), examples are: failure, lack of materials, retooling, maintenance of machinery, etc. The retooling time is taken for the analysis of OEE as in some sense downtime. The retooling time cannot be fully eliminated, but it can in most cases be reduced. Remaining available time is sometimes called operating time.

Performance (P) indicator takes into account the loss of production speed, all the factors that cause that the production goes with less than the maximum speed (e.g. micro-downtime, work at a reduced speed). The remaining time is sometimes called net operating time.

Quality (Q) indicator as a part of OEE indicator represents the amount of good units produced as a percentage of the total amount of units. The Quality indicator is a pure measurement of Process Yield that is designed to exclude the effects of Availability and Performance. The losses due to defects and rework are called quality losses [9, 11].

2. EXPERIMENTAL

2.1. Object characteristic

Research was carried out in a medium-sized company, which main field of activity is the manufacturing of components for the automotive industry. The object of the research was the process of metal hitch forming, the construction of which requires the creation of a mechanical connection: steel cable with ferrule, which is made of aluminum alloy containing Si, Mg. The whole production process is multi-stage, start with cables and bushings cutting (for a given size), next in separate (parallel processes) steel cable is twisted and bent, so that the complex contain a right angle. In the same time, bushings by cutting and preforming are prepared. The ends of steel cable are placed in the bushings' holes, and then in the matrix the entire system (steel cable with ferrule) is formed with hydraulic press. After multi-metal component forming detail entirely is subjected to chemical processing immersion (cataphoretic coating).

2.2. Research characteristic

As stemmed from observation and analysis of the statistical control of the process, the most problems occur in the step of metal forming. This paper presents results of analysis of the efficiency of the process (the forming step) with respect to the OEE coefficient. The research period included one month of work in the daily cycle (in three shifts of eight hours). According to the research team such period will allow for wider recognition of the problem of efficiency. The first research period refers to the step of production (traditional) - Period 1, and the second step to the introduction of changes to the design, use and matching elements in the matrix - Period 2. In order to accurately determine the three components of OEE factor, for the whole month were monitored: starting time of machine, retooling time, failures, planned stops, the number of completed units, the number of wrong in terms of quality, etc. All the obtained results were also compared with the values of world class coefficients.

3. RESULTS

The analysis of the machine efficiency (OEE) was determined based on the data collected during the 20 days of work in 8-hour system. On the basis of the data set the structure of loss in the availability of the machine is conducted on **Table 1** and **Figure 1.**

Table 1 The level of implementation of the production plan [%] on the machine in the analyzed periods of research

Category	Period 1		Period 2	
	Time, min	Percentage share, %	Time, min	Percentage share, %
Ordered Time	44640		44640	
Planned Breaks	4545		4525	
Planned Production Time	40095		40115	
Failures	1906	4.8	1424	3.5
Retooling	1005	2.5	985	2.5
Starting	1020	2.5	980	2.4
Others	410	1.0	500	1.2
Losses on Availability (LA)	**4341.0**	**10.8**	**3889.0**	**9.8**
Losses on Quality (LQ)	**2472.0**	**7.8**	**1180.5**	**3.4**
Losses on Performance (LP)	**4143.0**	**11.6**	**1481.5**	**4.1**
Efficient Production (EP)	**29139.0**	**72.7**	**33564.0**	**83.7**

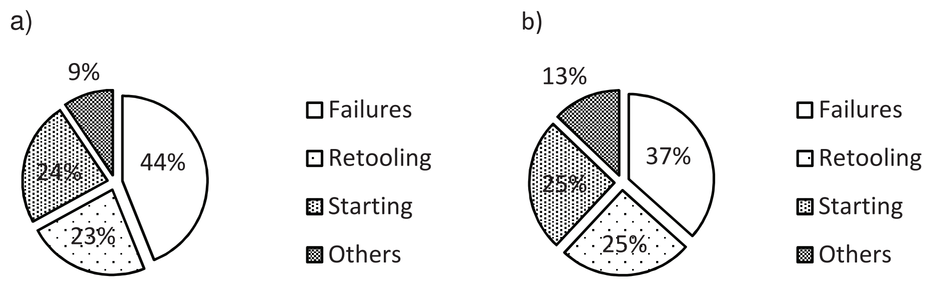


Figure 1 The structure of the machine availability losses: a) period 1; b) period 2

As is clear from the data presented in **Table 1** and **Figure 1** the greatest losses in the machines availability generate failures, in first period it is about 44%, whereas in period 2 only 37%. As it is visible on data there is reduced the time losses generated by others reasons (e.g. bad introduction of metal, feeder jammed, mismatched profile, poorly assembled tip, matrix loosening, lack of training of replacement worker). These changes are due to the improvement of machine design that prevented the improper introduction of metal parts before tightening during the formation. Despite no-considerable difference in the percentage structure it should be noted that the exchange of the matrix and improvements of the hydraulic press greatly reduced availability losses (**Figure 2**).

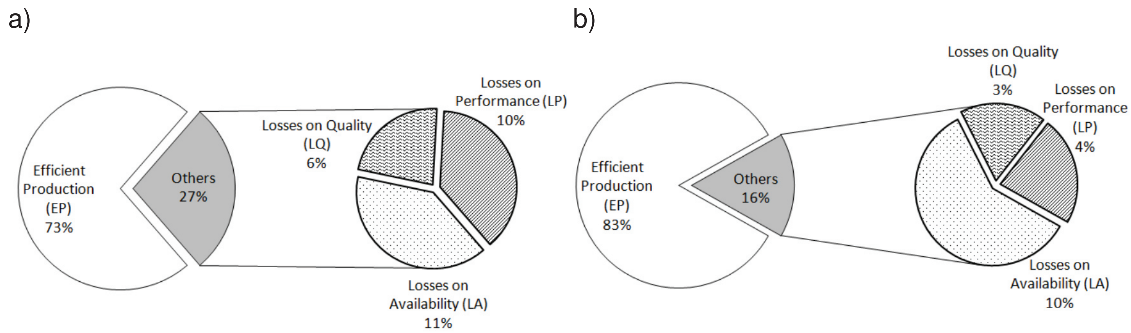


Figure 2 Structure of time losses on the background of efficient production: a) period 1; b) period 2

In **Figure 3** presented charts depicting percentage of variable availability of machines, machine performance and quality of production in the 20-day study period. The graph also noted the trend line, each of these factors.

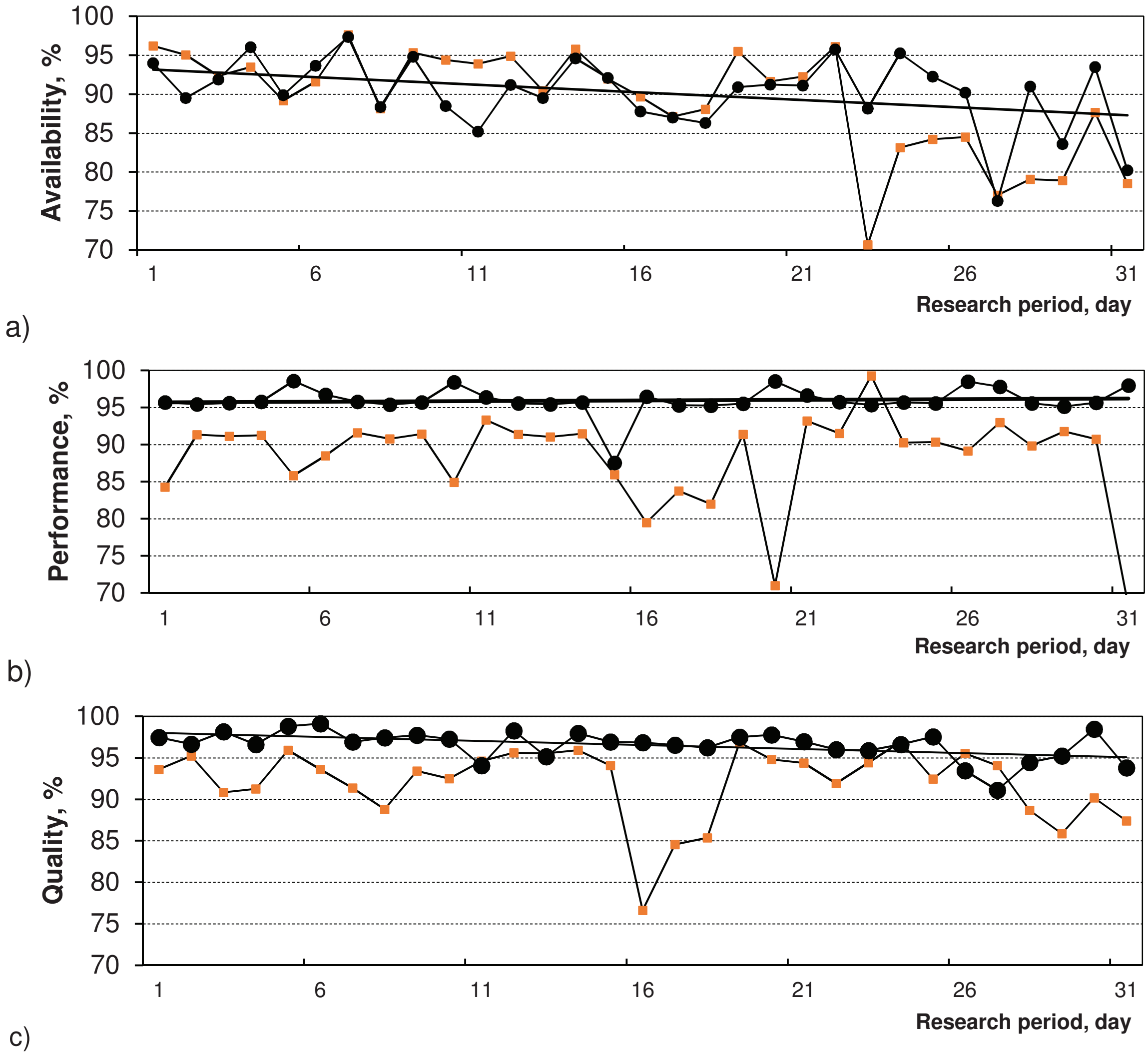
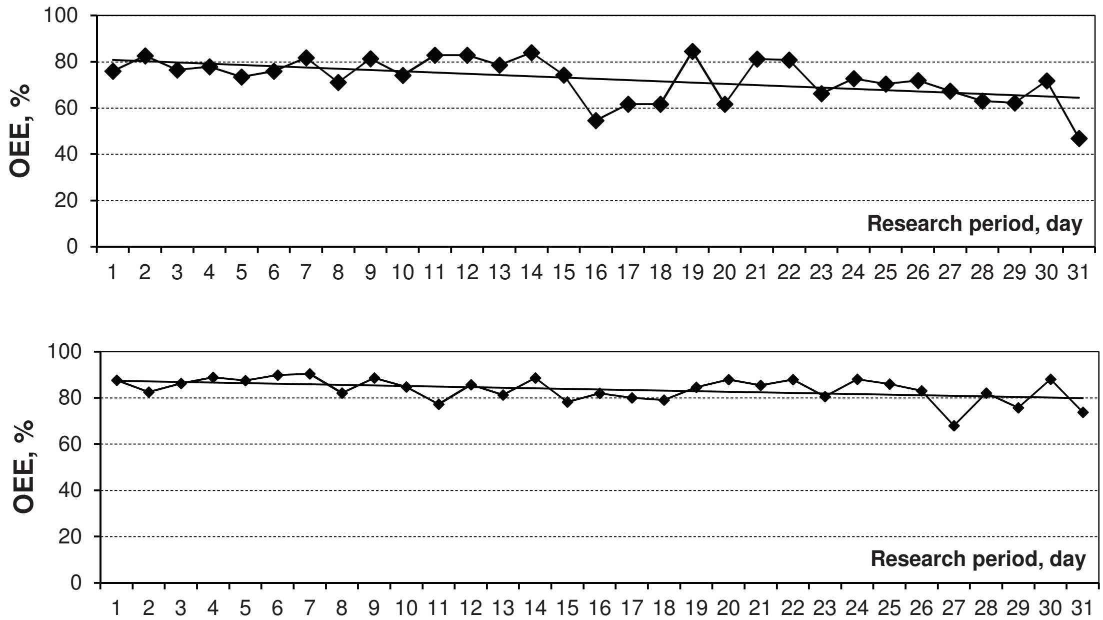


Figure 3 Distribution of indicators value with the trend line during the period of research: a) Availability, b) Performance, c) Quality (▪period 1, ●period 2)

As follows from the presented figure (**Figure 3**) in the case of Availability indicator, the largest share of which was recorded (during the study in period 1 before metal forming improvement) around 90% percent, and the trend line indicates a downward, due to the fact that under the premise of the matrix is changed once a month (in both cases, the investigation started immediately after the exchange) - the trend line indicates that the availability decreased with study time. In a number days, the availability level decreases to very low values, even 70 %. A review of the data used to the study indicate that the large decline during the machine's availability is due to a number of equipment failures. Major differences can be seen in the graphs representing the changes in the value of Performance and Quality. Characteristic steps in the chart reflect the machine performance of days in which they made the planned operational service (every fifth day). According to period 1 (traditional forming process, where the operator decide about arrangement of the metal elements in the matrix) the average value of performance is considerably lower than world class, whereas in period 2 (with matrix, which regulates the metal forming process and avoiding incorrect deformation of metal) oscillate around the value 95%.

In **Figure 4**. the distribution of OEE coefficient values with the function of the trend in the study periods have been presented. As the graphs show in both average value of OEE indicator for 31-day study was below world class (**Table 2**). Such a large discrepancy in the values of indicators: availability, quality and performance, mainly due to the type of manufactured components. Quality problems in many cases were caused absence of the employee, the operator replacement was not adequate trained - the human factor has been eliminated through the use of appropriate equipment (improved matrix).



a)

b)

Figure 4 Distribution of OEE coefficient value with the trend line during the period of research: a) period 1, b) period 2

Table 2 Comparison of the TPM indicators values for the tested process with the values of the world level (World Class OEE)

TPM Indicators	Process in period 1	Process in period 2	World Class
Availability	89.2	90.2	90.0
Performance	88.4	95.9	95.0
Quality	92.2	96.6	99.9
OEE	72.7	83.6	85.0

Such large variations on the plan may cause a reduction in productivity of finished metal products. Based on the measurements, it was found that the best way to improve the performance of the machine is to increase the skills of workers operating the press, and the implementation of SMED techniques in machine retooling.

4. CONCLUSION

- The average value of performance in case of traditional metal forming (manual) is considerably lower than world class, whereas with matrix equipped with the cavity regulating metal forming process and avoiding incorrect deformation of metal oscillate around the value 95%.
- The production had never showed 100% performance of the established manufacturing plan, most often the value fluctuated around 90% and lower, but in a few days there is marked a large decrease in production efficiency.
- Distribution of OEE coefficient values with the function of the trend in the study, in both periods, shows average value below world class
- Implementation of the new matrix eliminates human errors, further caused the improvement in the TPM indicators, but the lack of stability of the process indicates the need for further improvement of the step of forming an multi-metal element.

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