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Implementation of the SMED method in a production enterprise

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INTRODUCTION

The aim of the article is to show the impact of the SMED method on improving the production process in an industrial enterprise. Based on the process map (the analysis covered studies from January to September 2018). Based on the data provided by the company, an analysis of the implementation of SMED was carried out, which allowed to propose changes for the production enterprise. As a research method, a case study was chosen because of the usefulness of solving problems in the field of company's management as well as the methods and tools used, in order to make rational and effective decisions (Piekkari and Welch, 2011). The source of data was information provided by the analysed company and own observations. Rapidly changing business environment, development of new technologies, the increasing intensity of competition and increasing globalization pose businesses against increasingly difficult requirements – in particular, that the complexity of the environment and its instability increase the uncertainty in decisionmaking. (Grabowska and Furman, 2015)

LEAN MANUFACTURING CONCEPT VS PRODUCTION MANAGEMENT

Production management covers all issues related to the design of production systems, organization of production processes, planning and control of production processes. In manufacturing management, two decision levels are distinguished: a strategic level that undertakes activities related to the design of the production system and defines strategies for future operations and an operational level that defines activities related to the functioning of the production system and specifies the structure and flow of processes in the designed system (Durlik, 2004).

The main process of each production management system is operational and tactical planning. The planning process consists of several phases and the goal is to get the right plan and to spread it over time.

Tactical plans include marketing, research, development and preparation of production, distribution, service, sales and finances. Tactical planning includes primarily a plan of material and production resources, product quality control and maintenance plans, failure-free machines and devices, networks and production installations. Operational plans include a plan for sales, production, supply,

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employment, investments and repairs.
Detailed operational planning is based on:
- assignment of production orders, equipment and supply of tools, materials, work instructions and provision of service at workstations,
- determining the order of performed tasks,
- determining the beginning and end of a particular task,
- updating the work status,
- program correction,
- determining and adjustment of production inventory,
- checking the quality of performance and correcting with reference to patterns and standards,
- examining the levels of the implementation cost and correcting deviations in relation to the standard.

In production systems, production planning requires precise and current preparation of production plans that result from the decision-making processes in the environment. The most commonly used modern methods of planning and production control include: MRP planning system, production optimization technology - OPT, Japanese systems - JiT and KANBAN.

Increasing competition of a global nature as well as increasing customer requirements mean that production costs and the possibility of timely execution of production orders become one of the elements determining the position of the company on the market. Therefore, production companies are forced to look for production reserves, increase efficiency and production efficiency, ie reduce production costs. They notice the need to monitor the effectiveness of using the owned machinery park, which gives options for identification of existing production reserves and wastage in the used technological processes.

Each enterprise should strive to use 100% of the machinery park and the production of zero-waste carried out with efficiency corresponding to the nominal capacity of owned machines and technological devices (Parmenter, 2010).

The parameter that facilitates the assessment of the efficiency of the machinery park available is the overall equipment efficiency indicator OEE (Overall Equipment Efectivness). The OEE indicator is calculated from three components of availability, quality and efficiency. The OEE indicator is the product of availability, quality of manufactured products and efficiency expressed in percent and presented in the Figure 1.

The OEE indicator allows to monitor the degree of use of machines as well as to determine whether the actions that the company considers a loss are such in reality. Examples of losses and their impact on the OEE result are presented in Table 1.

Lean Manufacturing is a concept of the so-called "Lean Manufacuring" (Hamrol, 2016) The Lean Manufacuring concept has developed based on the principles and tools of the Toyota Production System (Pawłowski, 2010). The Lean Manufacturing was initiated by the Japanese Toyota car concern. The essence of the Lean Manufacturing concept is in particular the reduction of manufacturing costs and the slimming down (simplification) of the entire process. This means limiting or decreasing the amount of resources used for production, especially those owned by the enterprise, such as: employees, space used in production halls, time, and investment outlays (Ziemniewicz, 2003).

$$\text{OEE} = \text{dostępność x jakość x wydajność}$$

Where:

Availability is the percentage share of time in which a given machine is used in the production process, i.e. it is the quotient of the real time of using the machine for the planned time of its use in the production process. machines at a specific production time. All failures, lack of materials, can contribute to stopping or reducing the availability of the machine in the process. Availability is calculated from the formula:

$$Dostępność = \frac{czas\ \ eksploatacji\ \ - nieplanowane\ \ \ przestoje}{czas\ \ eksploatacji}$$

Efficiency is a quantity that determines the machine's production capacity at the speed of the production process. The efficiency depends on the operator's ability, the quality of the batch materials, machine wear, periodic inspections and adjustments. Efficiency can be calculated from the formula:

$$Wydajność = \frac{liczba\ wykonanych - czas\ cyklu}{czas\ eksploatacji - nieplanowane\ przestoje}$$

Quality is the ratio of good production, ie products that meet the quality assumptions of the actual production in which that is a machine that produces. Quality losses are all products; which do not meet the established quality standards, requiring repeated processing on a given machine, batch materials not machined by the machine, as well as all finished products. For measurement, it is necessary to register the amount of non-compliant components produced. Quality is calculated from the formula:

$$Jakość = \frac{liczba\ \ wykonanyc\ \ h - ilość\ wadliwa}{liczba\ \ wykonanyc\ \ h}$$

Fig. 1 Characteristics of OEE indicator

Table 1
Examples of losses and their impact on the result OEE

The reason for the loss of time	Comments	Impact on the OEE result
Planned break	Breakfast break, no orders, staff training	Planned stops should not be losses, because they are planned, and thus included in accessibility
Failures	All unplanned machine stops for a longer time due to technical reasons	Negative impact on the availability indicator
Minor stops	All unplanned machine stops for a shorter period of time that do not require UR intervention	Micro-stops affect performance negatively
Unplanned stops	E.g. logistic reason - delivery delay	Depends on the duration of the downtime, affects the availability (long downtime) or performance (short downtime)
Retooling, adjusting, setting up, starting the machine	Preparing the machine to start production, retooling as changing the machine equipment, minor adjustments (e.g. setting the temperature)	It can have an impact on availability if the retooling time is exceeded, otherwise it will reduce the service life
Product defect	Producing a defective product takes time, and additional time is needed to produce a good product	Decreases quality
Loss of efficiency (speed)	Deliberate deceleration of the machine and caused by external factors n. Oil temperature in the engine	Decreases efficiency

The precursor in the development of Lean Manufacturing was the Toyota Production System (TPS). All components of the above mentioned system are aimed at achieving profits for the company, which is possible due to the focus on development and the value of employees. Encouraging employees to constantly improve their work and duties and proper motivating techniques is one of the elements of Lean Manufacturing.

TPS (called Toyota Production System) consists in planning and designing production so that it is beneficial and attractive from the customer's point of view. This system is the starting point in the analysis of the production process, and the value precisely defined by the customer should be the most important for the company. When examining and defining the needs of customers, the production areas should be separated, adding value to the areas that do not increase this added value. Added value is what customers want and are ready to pay.

Areas and activities that do not contribute to the added value are considered waste, but it must be remembered that in the production process they can not be completely excluded.

Eliminating waste as an element of Lean Manufacturing, is based on the development of the so-called an activity map that shows all activities in the production process. Activities that increase the added value of the product remain unchanged, while those that do not increase the added value, and at the same time are eliminable, are removed from the process or modified (Szatkowski, 2014).

We distinguish seven basic types of waste:

- Overproduction - production of such a number of products that currently exceeds the requirements of customers (internal or external),
- Production shortages - shortages and errors of employees, problems with the quality of products,
- Stocks - More raw materials, work in progress and finished goods than needed to maintain the continuity of the process,
- Incorrect methods of production - use of inappropriate tools, technologies, unnecessary or complicated processes,
- Downtime - inactivity of the operator or machine during the cycle, which may be caused by failures, improper work organization,
- Excessive transport - unnecessary transport or moving of material or products or inefficient use of transport equipment,
- Unnecessary traffic at the workplace - all kinds of unnecessary operator activities, improperly planned workplace.

The key elements can be distinguished in the Lean Manufacturing concept (Antosz, 2015):

- Value stream optimization.
- Identification of values for the customer
- Transition from the suction system and synchronization of the demand and supply chain.
- Improving flows for all products.
- Introduction of undisturbed value flow, which will be supported by control and synchronization.

As part of this concept, the goal is to create a simple and transparent organizational

structure of the company, continuous improvement of work organization and elimination of errors. Lean Manufacturing puts a lot of emphasis on shaping long-term and direct contacts with suppliers as well as with recipients.
The basic tools of Lean Management include: TPM, VMS, SIX SIGMA, SMED, 5S, Kaizen, Kanban, POKA YOKE.

SMED – CASE STUDY

The analysed company belongs to the automotive industry. The manufacturing company is a global manufacturer and supplier of bearings, power transmission systems, alloy steels, lubricants, surface engineering, engines, chain transmissions, gearboxes.
Using the SMED method in the analysed enterprise, the following benefits can be distinguished from shortening the changeover times:

- reduction of production batches due to higher production flexibility,
- the ability to respond faster to changing customer's order - an increase in customer satisfaction,
- reduction in the level of stocks: materials, raw materials, finished products and work in progress
- ordering the process together with the equipment related to the retooling.
- better control of the retooling process,
- greater productivity of retooled machines and processes,
- reduction of production time of the product passage through the stream of company value,
- improvement of financial liquidity,
- higher workplace organization standards during retooling.

On each of the production streams, the company is working on reducing the SMED time. Each stream has individual goals to achieve. The changeover times range from several minutes to several hours depending on the process.
zThe team meets once a week and analyzes all the data regarding the changeover time. Before the team improves the changeover time, process mapping is organized. The whole retooling is mapped.
If the retooling takes several hours, it is mapped by several people for 1.5-3 h/person, then the results are analysed. The goal is to transfer as many internal retoolings as possible to the outside and this way since the machine stopped on one product until the production starts on the second product, less time passes. Finally, the company gains on the productivity of the area. Detailed analysis of the work has been subjected to the forge because of the large changeover time (Fig. 2). These forges are characterized by considerable accuracy and the ability to maintain this accuracy over a relatively long period of time.
Figure 3 shows a graph of the causes of prolonged retooling between January and September 2018. About 82 of 598 retoolings were performed above the time specified in the standard.

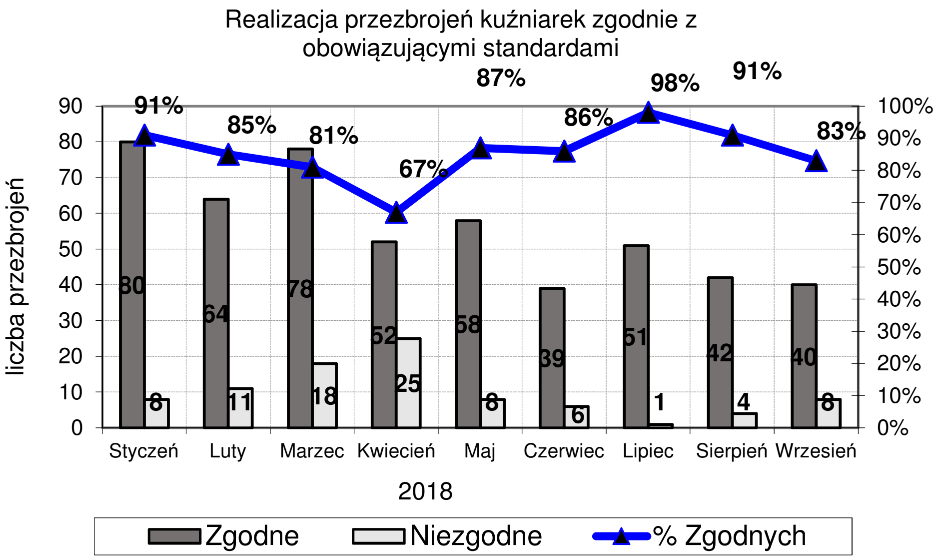

Fig. 2 Chart for the retooling of forging machines in accordance with the applicable standards

Source: (own elaboration on the basis data from company).

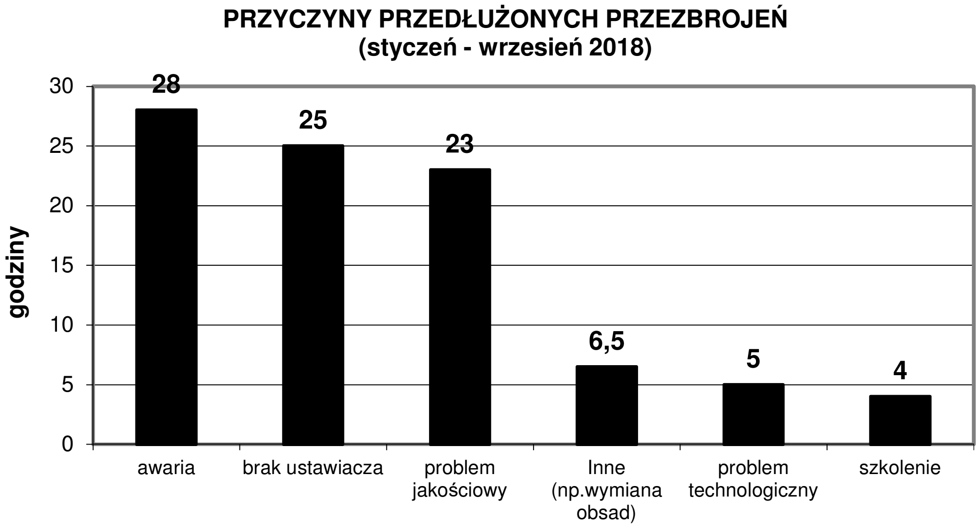

Fig. 3 A graph of the causes of prolonged changeovers

Source: Own elaboration on the basis data from company.

To sum up, in order to improve the changeover production, they were divided into:

1. Large - consisting in starting the production of the product requiring a change of tooling due to the diameter of the manufactured element.
2. Small - consisting in starting the production of the product requiring a change of the type of material, length, type of head, hole diameter, type of the printed pattern, but not requiring a change in the diameter of the produced item.

Large changeovers are time-consuming because they very often contain all kinds of changes made for small retoolings. Therefore, the analysis of the changeover process will be carried out on the example of large retooling.

The times of individual operations are summarized in Table 2.

Table 2
The initial times of individual operations for the large retooling of the forging section

No.	Performed operation	Time [min]
1.	New production order	13
2.	Completing the tooling	20
3.	Cleaning the tooling	85
4.	Setting the sensors on the receiver depending on the length of the arbour	9
5.	Loading a new program on the machine (in memory for both spindles)	23
6.	Make sure that the tools in the frames are suitable (tool quality and size)	19
7.	If necessary - load the bar with the appropriate diameter on the feeder	10
8.	Setting appropriate information in parameters and variables on both sides	23
9.	Adjustment of the retainer roll on the barfeeder depending on the diameter	8
10.	The process of warming the machine	14
11.	The sum of time to search for various things	19
		∑ 243 min

Source: Own elaboration on the basis data from company.

PROPOSAL FOR IMPROVING ACTIONS

To ensure high precision of forging as well as to ensure the extension of machine durability, the process of "warming up" of the machine is very important. If the forging process starts on the machine without sufficient heating of individual machine elements, the guides will not have adequate lubrication, which can lead to their faster destruction. The workpiece will not get the right dimensions due to the temperature of individual elements that have not yet reached the appropriate temperature.

Sufficient warming is very important for achieving proper lubrication of guides and preventing excessive wear as well as elimination of rubbing friction vibrations. It also allows for forging with very high accuracy and repeatability.

It is important that everyone in the company can see small problems before they develop into big complications. In order to quickly and effectively organize the position and shorten the changeover time, the following actions have been undertaken:

Determination of the area of conducting the ordinal action - the station of the forging machine and the storage of parts.

1. Taking photos of places that require ordering - parts warehouse.
2. A red label action was carried out - items that are redundant are marked with red cards to be removed from the lathe operator's station to the parts warehouse.
3. The station was carefully cleaned and the adjoined parts warehouse.
4. All things have been arranged according to such rules, so that the operator knows where everything is and could quickly find and put them away.
5. Rack and shelf markings in the parts warehouse have been introduced.
6. General cleaning of tools, machines and devices was carried out
7. Actions have been taken to eliminate contaminants at the place of their formation.
8. Make the division of cleaning tasks between the employees of the position.
9. Placement of utensils to keep cleanness in the parts warehouse.
10. Preparing a list of control questions that will enable full implementation of the established principles of maintaining order and cleanliness.
11. The enforcement by the supervisorsn the cleanliness and order obeying as a first step in the way of raising employees' morale and discipline.

After establishing the above issues, a further changeover was planned, which was carried out in accordance with the new division of duties.

After the next changeover, the following data was obtained, which are presented in the Table 3.

Table 3
The times of individual changeover operations received after implementing changes

No.	Performed operation	Time [min]
1.	New production order	0
2.	Completing the tooling	0
3.	Cleaning the tooling	0
4.	Setting the sensors on the receiver depending on the length of the arbour	9
5.	Loading a new program on the machine (in memory for both spindles)	23
6.	Making sure that the tools in the frames are suitable (quality and size of the tool)	18
7.	If necessary - load the bar with the appropriate diameter on the feeder	10
8.	Setting appropriate information in parameters and variables on both sides	25
9.	Adjustment of the retainer roll on the barfeeder depending on the diameter	10
10.	The process of warming the machine	10
11.	The sum of time to search for various things	0
		∑ 105 min

Source: Own elaboration on the basis data from company.

The reduction of operation times (point 3, table 3) is related to the assignment of an additional person in the form of an assistant for the time of cleaning the tooling.
Analyzing the data obtained after the second retooling, significant time savings are visible and its shortening during the retooling of the machine. To a large extent, this is due to the fact that internal operations are shifted into external ones.
In addition, to a significant shortening of the changeover time, contributed the allocation of an additional person - helper to speed up the cleaning of the tooling.
Also, the arrangement of workplaces has visibly contributed to shortening the time of major retooling.
The results of the times of individual operations for the 1st and 2nd retoolings, together with their comparison with each other, were collected in the Table 4.

Table 4
List of times of individual operations performed for the I and II changeover

No.	Performed operation	Time for I changeover [min]	Time for II changeover [min]
1.	New production order	13	0
2.	Completing the tooling	20	0
3.	Cleaning the tooling	85	0
4.	Setting the sensors on the receiver depending on the length of the arbour	9	9
5.	Loading a new program on the machine (in memory for both spindles)	23	23
6.	Making sure that the tools in the frames are suitable (quality and size of the tool)	18	18
7.	If necessary - load the bar with the appropriate diameter on the feeder	10	10
8.	Setting appropriate information in parameters and variables on both sides	23	25
9.	Adjustment of the retainer roll on the barfeeder depending on the diameter	8	10
10.	The process of warming the machine	14	10
11.	The sum of time to search for various things	19	0
		∑ 243 min	**∑ 105 min**

Source: Own elaboration on the basis data from company.

Analyzing the time of individual operations, it was observed that: the changeover time was reduced from 243 min to 105 min, ie by 53%. After making the changes, the time for the retooling of the forges was reduced by 45%. The changes introduced were related only to the shift of some employees and, above all, to the transfer of a significant number of internal works into external ones.

CONCLUSION

The volatility of production factors and the dynamics of the production environment means that the plans quickly cease to be current, which forces the need to control production using the Lean Manufacturing methods and tools for this purpose. In a modern approach to business management, an important factor is the careful observation of changes that take place in the environment, which allows making the right strategic decisions and fosters improvement.

The essence of Lean Manufacturing is to obtain: a large number of new customers, adequate economic results, minimum inventory and reduction of production costs, excellent production and service quality, small production cycles, efficient organization and management. The Lean concept offers many tools that allow efficient and effective implementation of the "lean" management model in an enterprise, as well as for undertaking further improvement activities. An indicator of modern enterprise is number of clients as well as level of their satisfaction, that is why the key factor for every manufacturing company is quality (Kuczyńska-Chałada, Furman 2016, s. 1895).

It should be noted that the important element of process improvement is also the work safe aspect (Małysa et al., 2016; Małysa et al., 2017) - implemented improvements should include safe working conditions and reduce the number of potential accidents. Good organization of work increase of safety in enterprises but all works have to build the attitudes of safe work but there are a lot of internal sources of risk in the building such new work place (Gajdzik, Grzybowska, 2013).

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Abstract. The increase in competitiveness between production enterprises results from the contemporary conditions of the global economy. Technical progress, globalization and constantly increasing customer requirements contribute to the development of organizational and business management techniques. The improvement of production is currently accompanied by modern tools and methods of Lean Manufacturing concepts such as: SMED, 5S, Kaiznen, Kanban, Poka-Yoke etc. The SMED method plays an important role in improving production processes. It also affects the reduction of losses and wastage, increase of value for stakeholders (especially for customers), as well as better motivation for employees. Thanks to the SMED method, the production company is able to achieve greater efficiency and productivity, as well as the high quality of products and services provided.

Keywords: SMED, Lean Manufacturing, production management, production process