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THE PROCESS OF IMPROVING THE SET-UP TIME IN THE MANUFACTURING PROCESS

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Abstract: The article concerns the analysis of the efficiency of the process of retooling the production line. The analyzes of preparation and implementation of production changes (serial production) are presented. The main issues of technical preparation were included in the analyzes. In addition, the investment indicators and the return of the funds involved were estimated. The work presents justification for undertaking a topic for the analyzed production system. Analyzes of the prosecutions were carried out earlier and a plan for implementing new procedures was created. The analysis of the improvement project takes into account investment opportunities as well as the time of engagement of the working group.

Keywords: Lean Management, SMED technic, production preparation, time saving

1. INTRODUCTION

Today, if a company wants to achieve and maintain their competitive position on the market, must take into account the increasingly stringent quality criteria set by the customer. The quality of services perceived as a source of customer satisfaction. This factor, along with efficiency and costs, is now becoming an important element in the sustainability and development of each enterprise. Every company that wants to strengthen or maintain its position on the market in the future must try to make its offer attractive and diversified with new products and meet high quality standards. The key element of competitiveness is to adapt the offer to customer requirements. A special determinant of this point is the production on behalf of the client, fully personalized products (Brajer-Marczak, R., 2015.). This causes a significant increase in the number of products offered, which are part of the assortment, but often they are single-order products. In the customer service process, the company engages enormous resources, time and knowledge of its own employees, which must be supported by advanced production logistics and preparation of serial production.
The flexibility of manufacturing systems allows manufacturers to easily adapt to the harsh conditions of today's environment. The difficulty of these conditions is caused by the necessity to change the parameters of products manufactured in short or medium series, or to change the characteristics of production materials, etc. The assortment may be changed and regulate the size of the series of manufactured products, which

are the basis for adjusting the offer to changing conditions. Most often, such procedures require retooling of machines in the production line. These issues are particularly important in the conditions of a market economy, which forces producers to be able to quickly respond to the needs of customers. Flexibility is obtained thanks to the advanced automation of production processes and changeover systems combined with computerization of production planning and control. The level of flexibility of the production system is determined by the scope of tasks performed in this system per unit of time (Kowalczyk, J., 2010; Mazur M., Momeni H., 2018; Ulewicz R., Novy F., 2019). A flexible production control system that works well should ensure these results:

- diversifying the range of manufactured products,
- reduction of changeover times and time needed to activate new products,
- shortening the production cycle time and reducing the work-in-progress stock,
- the ability to better adapt to customer requirements (e.g. shorter delivery times, shorter series, more frequent changes of assortments).

Flexible manufacturing systems are in particular dedicated to the full automation of small and medium-series production in the field of technologically similar items. The implementation of FMS requires the use of modern production equipment (Łasiński G. 2007). But for technological processes in which such solutions are not offered or require far-reaching investment changes, a certain level of flexibility of manufacturing processes can be achieved through organizational changes. Without the need to purchase new devices or entire technological lines, the company also achieves flexibility by improving organizational processes. Such activities result in gaining benefits mainly in the time dimension. In the long run, such activities will result in the development of measurable financial benefits for the organization (Łunarski, J., 2008; Pacana A., Czerwińska K., 2019.). The financial benefits will result mainly from the shortening of the order fulfillment time and extending the effective time of the employee's work.

The development of each enterprise is based on the consolidation and improvement of the existing standards by formulating new and higher goals. Development can be based on two approaches: innovation and Kaizen (Ingaldi, M., et all 2018; Jagusiak-Kocik, M., 2014). Innovation is fast, great and spectacular, and can produce significant results in a minimum amount of time, but requires the application of significant changes and financial resources. In the case of the Kaizen philosophy, it requires the action of the management towards continuous development using small, effective steps, based on the knowledge and experience of all employees of the company. This approach, in the first place, allows the development of the company's potential by desiring, changing and improving the processes that operate in the system (Jagusiak-Kocik, M., 2016; Knop K., et all 2018; Knop, K., Olejarz, E., Ulewicz, R., 2019). However, the most important element of this type of approach, is the human factor of the company. It is referred to as the most important factor of all changes in the company and only the appropriate motivation for planned activities is a determinant of success. By engaging employees as part of implementing the Kaizen philosophy, they are given the opportunity to create new or better standards. Such action also allows employees to develop a sense of ownership towards the organization, and thus - the discipline necessary to adapt to them (Nowicka-Skowron M., Ulewicz R., 2015). The approach to implementing changes is one piece of the puzzle, and the other is the selection of appropriate tools for identifying, prioritizing and implementing projects that improve processes (technological and organizational). In this way, employees are involved in activities from the very beginning and create their own new working conditions. The Japanese approach to management and improvement, based on the Kaizen philosophy, includes a number of thematically diverse tools, such as: Poka-Yoke, SMED, Just InTime, Kanban cards, Heijunka, Jidoka, Andon, 5S practices, etc.

2. SMED – reduction of machine setup time

Case study is a form of research method that has been applied here. The analysis was made based on the description of the functioning of the workplace in the foundry. There, the working conditions were analyzed and a proposal for improving its organization was presented. The research used primarily the technique of observation, but also direct interviews and collecting and then analyzing documentation. The observations were focused on the guidelines of organizational changes related to the process of changing the casting mold at the workplace. These activities were carried out in accordance with the guidelines of the SMED method (Knop K., Ulewicz R., 2018; Liker J. K., Meier D., 2006; Wolniak R. 2020).
In the literature, the definition of the term "changeover" is the time that is counted from the moment of stopping the machine after producing the last good item from the previous batch, to starting the machine while producing the first good item of the next batch. " or simply definition: „the process of changing the production on the machine”. From this, the inference concerning the retooling process indicates that: this is the total number of activities that an operator or a maintenance worker should perform in order to start processing the next batch of the product (Pacana, A., et. all, 2016). This definition shows that a changeover is necessary but not part of the main process that indirectly adds value to the product. Due to the diversification of the changeover process in production, the organization of this process requires detailed preparation and organization (Marksberry P., Bustle J., Clevinger J. 2011). The measure of effectiveness for this approach is the time needed to change the production series at the workplace, supplemented with the correctness and completeness of individual activities.

2.1. Theoretical foundations and assumptions

The abbreviation SMED refers to the name Single Minute Exchange of Die, which clearly indicates the main purpose. The main goal is to perform all necessary tooling changes at the workplace in less than 10 minutes. In order to achieve this goal, detailed analyzes of activities during the changeover process and their proper organization are necessary, as well as the use of organizational techniques supporting the preparation for stopping the process and replacement of parts. The main developer of this method is S. Shingo, who has achieved a 40% reduction in setup times. The practical application of the guidelines of this method show the possibility of achieving the ratio of 50-60%.
The starting point for organizational work is the use of traditional solutions such as timing, string chart, and a verification board. Then appropriate organization each of the four stages of the retooling process, ie: Stage Zero – the stage of preparation and collection of information, i.e. registration of the retooling process which is carried out according to the old rules and analysis of the obtained results. The first stage consists in separating the activities into external and internal activities, as well as listing unnecessary activities. The second stage is the transformation of internal activities into

external, to the extent that is possible in a given production technology. Stage three, which is a preparation for the improvement of all activities, with particular emphasis on internal activities.

According to the assumptions of the SMED method, the work began with the registration of the setup process, which was carried out at the casting station. The casting processes are carried out on a stand equipped with a CNC machine tool, i.e. a partially automated process of tooling replacement (casting mold). The registered process of changing the form of the position was analyzed. The film was watched by a team of employees, including both managers and direct production workers. During the analysis of the film, the movements of all participants in the process were observed and the moments that required refinement were indicated. The main element of employees' activities were unnecessary movements that were performed by people handling the process. The work on the film, which was done by a group of employees, was also used to convince employees of the possibilities and the need to introduce organizational changes. And their own ideas for change are the basis for employee involvement in the entire change process.

2.2. Workplace Observation Results

A spaghetti chart has been developed, which shows all the paths that the worker has taken throughout the changeover process. The chart covered the paths between four CNC machine tool stations, a tool table, a storage area and stop warehouses. The entire process took 57 minutes, and the distance traveled many times by the employee was estimated at 1,200 meters. The main reason for the movement of employees was the search for tools and assembly elements for foundry molds. Machines and tools were not organized in any clear pattern. The places where the tools were put away are completely random places. Therefore, the first basic element of the changes was the introduction of an organized way of storing tools. At each of the processing stations, there is a cabinet with space for basic tools.

The steps taken by the operator are presented in Table 1. The activities have been described taking into account the times necessary to complete them. All final observations and measurements were made while watching the film. During the projection, the times of individual movements made by the operator in the subsequent minutes of the retooling process were measured, which is presented in Table 1.

Table 1.
Activities performed while setting up the machine, including unit time

No.	Actions	Time [min]	Distance [m]
1	Delivery of semi-finished products	2:10	18
2	Delivery of a pallet truck	1:31	60
3	Organization, preparation of the workplace	4:13	-
4	Pallet delivery	0:18	10
5	Delivery of a pallet collector	0:35	20
6	Technical drawing location	2: 23	80
7	Cleaning the machine with compressed air	0:41	-
8	Delivery of the template from the rack	1:55	8
9	Setting the template on the machine	10:53	0

10	Delivering a ruler to the workplace	2:43	26
11	Delivery of the gasket from the tool cabinet	0:48	8
12	Delivery of tools	1:16	26
13	Supply of pins to secure the machine	0:42	26
14	Setting of machine parameters, such as program setting, speed and reference points	5:46	-
15	Approval of the program on the computer	0:08	6
16	Changing the cutting inserts	5:42	-
17	Delivering the appropriate tools from a tool cabinet	0:20	8
18	Bringing tools from another machine	1:02	26
19	Replacing the cutter and setting the correct height	4:26	-
20	Switch on the vacuum pump	0:40	-
21	Adjusting the pressure of the gasket to the semi-finished product	2:24	-
22	Turning on the machine	2:14	-
23	Attach the cover	0:51	-
24	Surface milling test and cutter depth adjustment	1:26	-
25	Correction of machine settings	1:35	-
	Sum	**56:42**	**322**

Installing the template on the machine takes the most time in the process of setting up the machine. It is interesting that it is not related to the distance traveled, but precisely to the precise setting on the machine. Based on a long discussion, during a team meeting, the reasons for the time lapse in the changeover process were identified and a number of conclusions were made.

It has been established that the large losses of time are the result of the lack of permanent places for tools. A lot of chaos is created when an employee has to look for them almost constantly. If the tools have a specific place, there is no need to waste time looking for them around the workshop. Another problem also related to tools is the lack of appropriate rack markings and the possibility of identifying the place by all employees. A very important problem is the habits of employees who do not put away their tools constantly in the same places. Another problem is the lack of transmission of technical drawings together with semi-finished products. There is also no appropriate, designated area for devices such as pallets, a pallet truck or stands needed for retooling.

3. ASSUMPTIONS OF ORGANIZATIONAL CHANGES AT THE WORK STATION

After diagnosing the current condition, an analysis of the causes was performed. Then a plan was developed for the implementation of activities that will improve the retooling process. In this regard, teamwork and brainstorming activities were used, based on successive film screenings and discussions. First, the focus was on the appropriate marking of tools, they were divided into two groups (more and less used). The list of tools has been developed and supplemented with information on where they will be stored. It was also decided that it was necessary to eliminate all tools that are not used at all or are damaged or worn. The usefulness and efficiency of individual tools were analyzed - with the use of a red card plan. The storage organization was also supplemented with the implementation of storage place labels for all tools and a shadow board was used. The necessity to clean the workplace was also indicated, this obligation was included in the workplace instructions.

However, the changes introduced were not limited to the organization of the tool park. As a consequence, it allowed for large changes in the movement of employees in search of the required tools. Further changes included CNC machining stations. The number of processing stations in the production hall has been divided into two operators who perform changeovers. Each employee had to carry out retooling for two positions and each employee received his own set of tools necessary for their implementation. The place where the tools are stored has been equipped with wheels, which makes the station with tools fully mobile and each time they are transported to a dedicated workplace. This solution eliminates the need to travel to the tool cabinet, overall reducing time, even in the case of incorrect or incomplete tooling. There was also thought about such a solution helping in the organization of work, which is the work standardization card, as well as another document, which is the standard compliance control card. These documents require employees to fully engage in changes and provide detailed guidelines on how to implement the process according to the new order. Preparation of the operator until the stoppage of the device and the replacement of tooling (internal retooling) included the implementation of a checklist of elements necessary to make changes. The chek list, which is used each time, allows for reliable preparation of tools and verification of their completeness. While the machine is working, the operator can easily prepare all the necessary elements to carry out the mold change next to the station where the change will be. Then, when the machine stops working, the worker prepared in this way can make the necessary movements related to the new setting. This element of improvement requires full motivation on the part of employees, due to their habits and length of service.

It was assumed that the changes in the work organization at the operator's position will be clear and will shorten his work by at least 10-12 minutes. In accordance with the assumption of the task, the period of the retooling process according to the new guidelines included a week of two-shift work. After this period, the duration of the stages of retooling at work stations was once again analyzed and the results are presented in Table 2.

Table 2.
Activities performed while setting up the machine, including unit time - after improvement.

No.	Actions	Time [min]	Distance [m]
1	Delivery of semi-finished products	2:10	18
2	Delivery of a pallet truck	1:31	60
3	Organization, preparation of the workplace	4:13	-
4	Pallet delivery	0:18	10
5	Delivery of a pallet collector	0:35	20
6	Technical drawing location	2: 23	80
7	Cleaning the machine with compressed air	0:41	-
8	Delivery of the template from the rack	1:55	8

9	Setting the template on the machine	5:24	0
10	Delivering a ruler to the workplace	0:00	-
11	Delivery of the gasket from the tool cabinet	0:00	-
12	Delivery of tools	0:00	-
13	Supply of pins to secure the machine	0:00	-
14	Setting of machine parameters, such as program setting, speed and reference points	5:46	-
15	Approval of the program on the computer	0:08	6
16	Changing the cutting inserts	4:40	-
17	Delivering the appropriate tools from a tool cabinet	0:20	8
18	Bringing tools from another machine	0:00	-
19	Replacing the cutter and setting the correct height	4:26	-
20	Switch on the vacuum pump	0:40	-
21	Adjusting the pressure of the gasket to the semi-finished product	2:24	-
22	Turning on the machine	2:14	-
23	Attach the cover	0:51	-
24	Surface milling test and cutter depth adjustment	1:26	-
25	Correction of machine settings	1:35	-
	Sum	**44:42**	**210**

The total setup time was reduced by 12 minutes. The distance that an employee has to cover during this process has also decreased significantly. The distance factor is an important determinant for the employees themselves and a motivator for further improvement. The operation duration factor is an absolute value for the management, showing the possibility of saving working time at work stations. This indicator directly reflects the possibility of increasing the amount of production

4. SUMMARY

The effectiveness of applying small organizational changes is clearly visible, which translates into time savings in the changeover process. The application of the SMED method mainly focuses on changing the internal to external conversion. These changes mainly concerned the completion of tools and equipment and their proper organization. Appropriate and well-thought-out organization of the tooling significantly shorten the time needed to identify them during changeover. Employees involved in organizational changes independently look for new solutions for subsequent changes. These assumptions are confirmed by reducing the duration to zero of all activities related to the preparation of tools. Such activities do not mean that they have been eliminated, but they are carried out while the machine is still producing, and therefore do not constitute a waste of effective production time.

The differences are clearly visible, after the first phase of applying the new solution. The time needed to change one machine, calculated as 56.42 minutes, which was recorded on the film, was shortened after some innovations were introduced to 44.42 minutes. This is a very good result, assuming that only attempts were made to use this method. The 12 minutes saved in the setup time of one machine must be multiplied by four machining stations in one shift only. Additionally, the average number of equipment changeovers during the weekly working time was 1.3 per one machine. The time savings per working day and working week were 62 minutes and 624 minutes per week. Production equipment works efficiently during one day by over an hour, which allows for an increase in the number of products produced during this period. In total, four machines produce from 12 to 41 items a day (depending on the size and complexity of the mold). In terms of the amount of products, the daily profit of the company in the saved time amounted to 412 to 902 PLN. Considering the issue in the long run increases the effective use of the machine park and results in real savings.

The developed effects of the work of CNC machine tools allow for further searching for organizational solutions at subsequent work stations in the enterprise. It is the basis for organizational changes, and in the long term, and for investment.

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