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PRODUCTIVITY INCREASE THROUGH REDUCED CHANGEOVER TIME

The authors of this paper present the stages of SMED method implementation and standardization of jobs on the example of a company in the metal industry. Particular emphasis is placed on the analysis of the lathe socket, focusing on its standardization and the manner and times of changeover. The work described here is an example of introducing new solutions and improving the changeover process. The summary describes the key results of the improvements, resulting in improved availability of equipment, which in turn translates into increased productivity.

1. INTRODUCTION

Cost-effective, sustainable resource management consists not only in rational management of raw materials and consumables, but also in economical and reasonable time management. Elimination of waste by the reduction or total exclusion of overproduction, stock, inventory shortages, unnecessary movement of materials, and excessive movement are the basic problems currently faced by manufacturing companies [7],[13],[14].

Short life cycle of products on the market and the constant tendency to shorten the cycle makes companies produce more new products in ever shorter time. It also forces manufacturers to introduce products to the market faster than in the past [10],[11],[14].

Hence a question: how, already during production, can we eliminate actions which do not bring any added value, yet must be performed due to other processes? How to produce more products in a shorter time and at less cost? Lean Manufacturing methods offer solutions to resolve these problems.

Lean Manufacturing may lead to cost reductions due to the elimination of such waste as unnecessary conveyance, overproduction, inventory, useless motion and wait time. This method of efficient production management allows for the improvement of production time by shortening the time of manufacturing, which in turn may allow the entrepreneur to gain competitive advantage [4],[9].

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Key tools of Lean Manufacturing include: VSM – Value Stream Mapping, 5S – workplace organization method, Poka-Yoke – mistake-proofing method, TPM – Total Productivity Maintenance, JiT – Just in Time, QRM – Quick Response Manufacturing, Kaizen – the practice of continuous improvement, and SMED – the concept of Single Minute Exchange of Die, allowing for better machine availability. By using the above mentioned methods it is possible to eliminate or at least partially reduce waste (japanese: Muda). In his work on productive manufacturing Taiichi Ohno indicated seven wastes: overproduction, correction, waiting, unnecessary or incorrect processing, inventory, unnecessary motion. Currently one more waste is added to those seven identified by Ohno: untapped employee potential [5],[10],[13],[14].

One of Lean Manufacturing methods is SMED (Single Minute Exchange of Die), the term used interchangeably with "rapid changeover". The main idea of the method is to transfer as many operations as possible "outside", i.e. to perform external setup actions while the machine is still running. The SMED method allows to simplify and more efficiently perform each step of the changeover [1],[2],[11],[12].

2. REDUCTION OF CHANGEOVER TIME IN TERMS OF PRODUCTIVITY

The several-minute changeover method (SMED) was developed by Shingeo Shingo, who promoted the idea of rapid changeover since 1950. Shingeo Shingo listed four components leading to improved changeover time:

- analysis of current conditions of a given workstation,
- division of changeover tasks into internal (I) and external (E),
- transformation of internal setup actions into external actions,
- improvement of all aspects of the changeover [3],[6],[13].

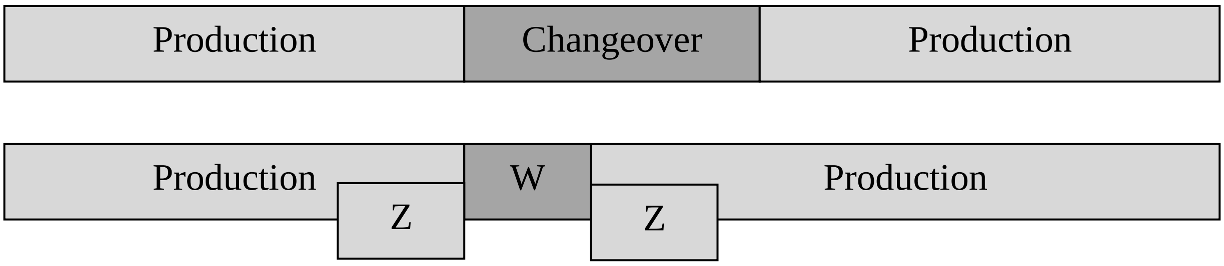

Fig. 1. SMED concept, (where: W - internal actions, Z - external actions)

The key action which minimizes the changeover time to a minute is the transformation of internal setup actions (performed during machine standstill) into external actions (which may be performed when the machine is running, before completing one job and after starting another). The more actions are realized before the completion of the current job, the shorter the standstill of the machine. That results in increased availability of the technical resources, which translates into improved productivity (Fig. 1).

3. ANALYSIS OF CHANGEOVERS IN A MANUFACTURING COMPANY

The manufacturing plant where the studies were conducted specializes in the production of elements made of non-ferrous metals and steel. The production processes in the company involve chemical and mechanical treatment. The type of organization may be defined as serial repetitive production. The shop floor is organized in a non-pipeline manner. There is also no close link between workstations and the production process, and the direction of products is variable. Production cells were grouped according to technological specialization, e.g. turning group, milling machines group.

The analysis of changeovers was focused on the turning group, which - due to long changeover time - was a bottleneck in the process of production of steel rings for gearbox synchromesh. The preparations for the analysis involved:

- a review of documentation related to the scope of tasks and duties of employees,
- review of laws on the standardization of work and OHS regulations,
- observation of work at lathe workstations during changeover (spaghetti charts were prepared, together with a video recording),
- consultations with employees and their superiors, related mainly to work tasks, working conditions, and the current status of changeovers.

Figure 2 shows a spaghetti chart drawn based on the observations of activities related to the changeover (1 – the retooled CNC lathe, 2 – pallet rack with finished products, 3 – tool cabinet, 4 – cabinet with lathe chucks, 5 – the lathe operator performing the changeover, 6 – pallet with semi-finished goods, 7 – finished goods pallet for neighboring station, 8 – adjacent CNC lathe, 9 - lathe operator, 10 – pallet for semi-finished goods).

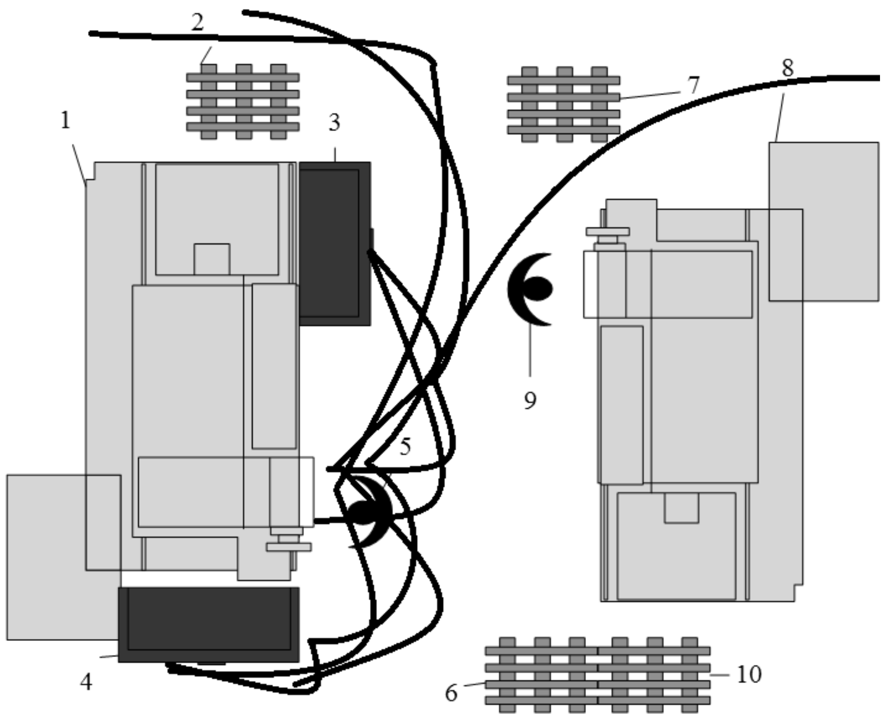

Fig. 2. Spaghetti chart

To describe the actions related to the changeover, a table was drawn, which details all the jobs of the operator together with their duration and classification into external/internal setup actions.

Table 1. Activities related to the changeover

Item no.	Description of the action	Time [min]	Classification [W-Internal/Z-External]
1	Completion of the job preceding the changeover	1	W
2	Calling the forklift to collect products	10	Z
3	Cleaning the insides of the turning chamber from chips and coolant	12	W
4	Disassembly of the chuck	5	W
5	Disassembly of tools from the tool caddy	17	W
6	Going to the foreman for the technological documentation	15	Z
7	Bringing new tools to the workstation	5	Z
8	Installation of new tools in the tool caddy	20	W
9	The search for self-centering chuck	15	Z
10	Installation of self-centering chuck	5	W
11	Uploading the new turning program	5	W
12	Test of the new program	1	W
13	Correction of the uploaded program	10	W
14	Program tests after adjustments	10	W
15	Clearing the workstation of the tools used for the changeover	10	Z
16	Performing test products, their verification and start of production	7	Z
	TOTAL:	148	

The total changeover time was 148 minutes (2 hours and 28 minutes). The analysis revealed poor organization of the work of the operator, who performed the retooling in the wrong order, or performed activities which need not have been performed at that time. An additional difficulty lied in the lack of standardized location of tools in tool caddies, and in the lack of marking of tool sockets (Fig. 3).

Table 1 shows that installation of tools in the tool caddy was the longest operation; this was due to the lack of numbering on tool sockets (the operator installed the turning tools in the wrong order). The unnecessary activities included corrections to the introduced turning programme and the need to call a trolley and bring the technological documentation. Discussions with the management and analysis of documents revealed that certain standards had been developed for delivering documents by the foreman and collecting ready products directly after the completion of the job, but the standards are not respected.

Fig. 3. Lack of marking on tool sockets

Fig. 4. Clutter on the tool table

Long assembly and disassembly time was also caused by the lack of standardization on the workplace. Tools on tool tables were not properly organized and arranged, and as a result the operator had to check the drawers min search for the tools that were needed. Additionally, during the changeover the operator did not put back the bolts and wrenches in an orderly manner, allowing for their re-use without having to search for them. Figure 4 illustrates the situation observed during the analysed changeovers. On the tool table there were some lathe tool mounts, wrenches, bolts, and control devices. The worker, in spite of his significant experience, performed his work inefficiently.

4. IMPROVEMENT ACTIONS

In order to improve the changeover time, an implementation schedule was drafted for the SMED and 5S concept (see Table 2). The changeover improvement programme was participated in by the authors and by the employees of the company, both from the management and production departments.

Table 2. Implementation Schedule

IMPLEMENTATION SCHEDULE		
Item no.	Jobs	Person in charge
1	Introduction of KANBAN signage to eliminate unnecessary tooling	area manager
2	Purchase of foams for shadow boards	area manager
3	Organization of 5S methodology training for operators and assistants	Karwasz
4	Organization of SMED methodology training for operators	Chabowski
5	Development of changeover scenario. Drafting a list of activities performed during changeover	Chabowski
6	Regular CNC lathe changeover trainings	SMED coordinators
7	Preparing room in drawers with shadow boards for tool storage	area manager
8	Development of changeover standards: - operator assistance during changeover, - schedule of workstation cleaning, - schedule of machine maintenance and inspection.	area manager, production foreman
9	Providing necessary changeover tools	production foreman
10	Modification of distribution of tables and pallets	area manager
11	Preparation of platforms for operators performing the changeovers	mechanic of the composites production department

In order to reduce internal activities, standards were developed for activities performed during changeovers (see Table 3).

Table 3. Changeover scenario

Item no.	Action	Person in charge	How implemented
1	Delivery of technological documentation and turning programme	foreman	collect from the cabinet
2	Collection of necessary tools and chucks	operator	tool cabinets
3	Complete production	operator	manually

4	Collect finished products after signalling that production is complete and deliver input material for the next job	forklift operator	forklift
5	Clean the machine from chips and cooling agent	operator	manually, compressed air
6	Remove tools	assistant	manually (torque wrench)
7	Remove the lathe chuck	assistant	manually (torque wrench)
8	Replace tools	operator	manually (torque wrench)
9	Replace the lathe chuck	operator	manually (torque wrench)
10	Download new programme to the controller	operator	pendrive
11	Tests and possible programme corrections	operator	manually
12	Production start	operator	measure, crank, manually
13	Cleaning the floor from chips and dust	assistant	broom, dustpan
14	Putting back tools and chucks	assistant	tool cabinets

The layout of cabinets and pallet racks was also modified in order to improve the organization of work (see Fig. 5). Currently every turning machine has its own tool cabinet, containing only the necessary tools, wrenches, and chucks. As a result the organization of work of lathe operators improved, too. Currently their paths do not cross, and the flow of material through the workstations is smooth and uni-directional (Fig. 5).

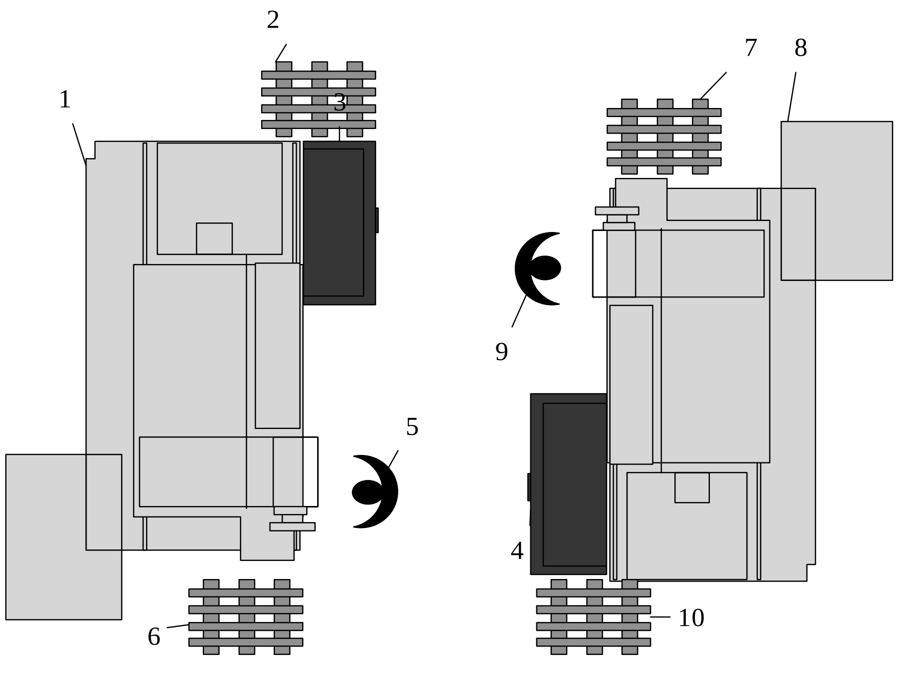

Fig. 5. Pallet rack layout after improvement

The schedule of trainings introduced in the implementation cycle was based on regular meetings of employees with the training staff. The trainings consisted in presenting the workers with theoretical backgrounds of the 5S and SMED methods, followed by practical workshops related to the standardization of workstations and machine changeovers. As a result, the trained people were made aware of the need to improve work organization and changeover processes. Building such awareness resulted in the KAIZEN programme, where the employees proposed their own solutions related to the improvement of production workstations. Such initiative triggered the launch of the 5S programme in the entire production hall and elimination of waste related to the lack of standards. SMED and 5S training are carried out regularly every two weeks in order to maintain and further improve the developed standards.

5. ANALYSIS OF THE INTRODUCED IMPROVEMENTS

Comparing the changeovers carried out before and after the improvement processes, the changeover time was reduced by nearly 50% (Fig. 6 and Fig.7). The introduction of standards for the layout of tools, palette racks, and tool cabinets increased the comfort and efficiency of operators performing the changeovers.

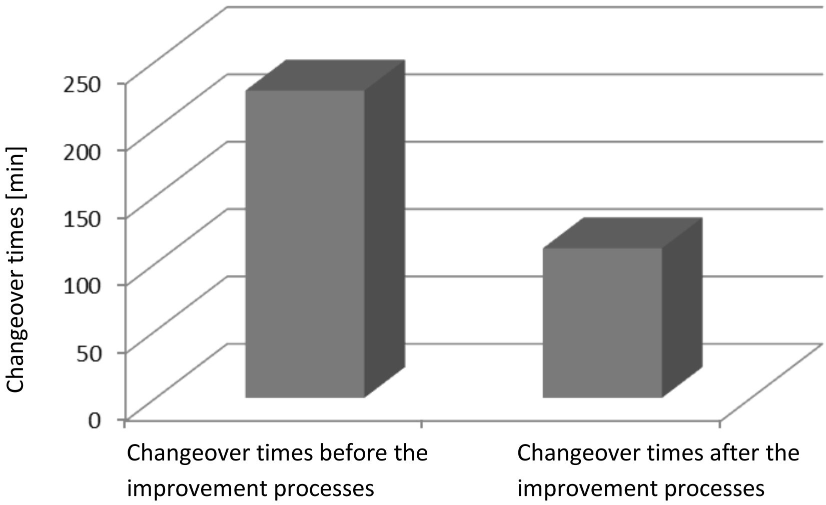

Fig. 6. Comparison of changeover times

The analysis of changeover times in subsequent periods shows that the number of changeovers is growing, while their duration – decreases. It results from continuous trainings and employee perfection in changeover processes. In the case of the analyzed company, the increase in the number of changeovers and the reduction of changeover time results in the reduction of time needed to complete a job on a given lathe in the analyzed months by 20% (Table 4). It could be achieved due to the possibility to start the next job sooner, as a result of shorter changeover.

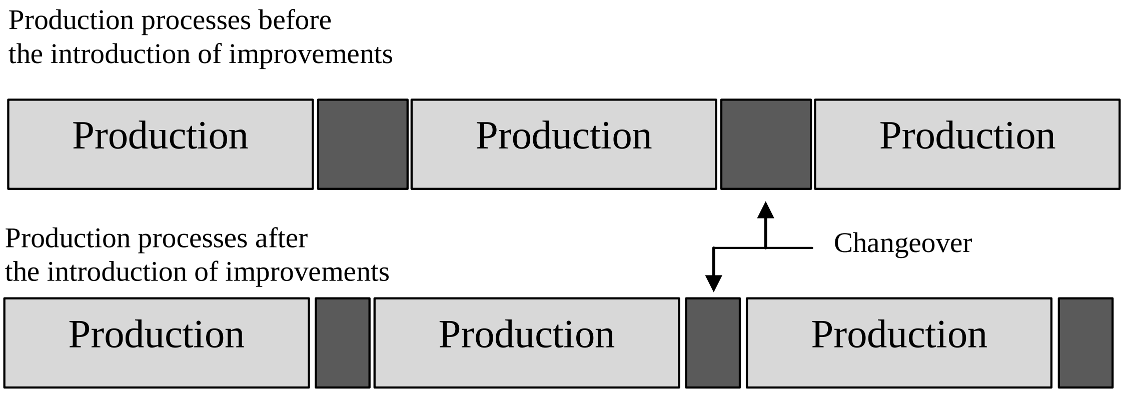

Fig. 7. Comparison of production processes, before and after the introduction of improvements

Table 4. Comparison of the number and timing of changeover in the analyzed months

Month	Changeovers	
	Number of changeovers	Average duration of a single changeover [min]
September	43	228
October	73	117
November	81	115
December	83	110

6. CONCLUSIONS

Reduction of changeover time translates into increased productivity. Shorter stops between production jobs result in more effective management of time available for the particular position. Properly organized changeovers allow for the elimination of waste and increase in job throughput in workstations which are production bottlenecks. Good organization of changeovers reduces also deficiencies related to product quality. Standards established for production workstations help to improve work ergonomics and employee comfort. For the concept of Single Minute Exchange of Die (SMED) and S5 workstation standards, it turned out that building employee awareness was crucial. The trainings proved that employees who were well informed about the purpose of the changes and motivated to action work more efficiently and accurately. Regular trainings planned for the employees guarantee that the organizational solutions introduced will be maintained and further improved.

REFERENCES

[1] ANG A.T.H., SIVAKUMAR A.I., Qi C., 2009, *Criteria selection and analysis for single machine dynamic on-line scheduling with multiple objectives and sequence-dependent setups*, Computers & Industrial Engineering, 56/4, 1223-1231.

[2] GOUBERGEN D., 2008, *Set-up reduction for lean cells and multi-machine situations*, International Federation for Information Processing, 257, 295-303.
[3] HASAN M.A., SARKIS J., SHANKAR R., 2012, *Agility and production flow layouts: An analytical decision analysis,* Computers & Industrial Engineering, 62/4, 898-907.
[4] MALHOTRA, V., RAJ T., ARORA A., 2003, *Reconfigurable manufacturing system: An overview,* International Journal of Machine Intelligence, 1/2, 38-46.
[5] MICHLOWICZ E., 2013, *Logistics in production processes*, Journal of Machine Engineering, 13/4, 5-17.
[6] MOREIRA A.C., Compos Silva Pais G., 2011, *Single Minute Exchange of Die: A Case Study Implementation,* Journal of Technology Management and Innovation, 29-46.
[7] OBORSKI P., 2015, *Integration of advanced monitoring in manufacturing systems*, Journal of Machine Engineering, 15/2, 55-68.
[8] OHNO T., 2008, *Toyota Production System. More than large-scale production*, Wrocław, Poland, ProdPress.com, 17, ISBN 978-83-926020-8-8. (in Polish).
[9] RAHATULAIN A., ONORI M., 2015, *Production system innovation through evolvability: existing challenges & requirements,* Journal of Machine Engineering, 15/3.
[10] SCGEDIN J, SVENSSON HARARI N., JACKSON M., DELERYD M., 2016, *Management of newness in an assembly system,* Journal of Machine Engineering, 16/1, 92-108.
[11] SHULL R.L., PLISKOFF S.S., 2013, *Changeover delay and concurrent schedules: some effects on relative performance measures*, Journal of the Experimental Analysis of Behavior, 10/6, 517-527.
[12] WOLNIAK R., 2013, *Lean Manufacturing methods and tools and how they shape innovation in industry*, IZIP Conference, Zakopane, Poland, (in Polish).
[13] WOMACK J.P., Jones D. T., 2001, *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*, Centrum Informacji Menadżera, Warszawa, Poland, (in Polish).
[14] ŻYWICKI K., 2010, *Improving manufacturing methods through Lean Manufacturing*, Zeszyty Naukowe Politechniki Poznańskiej, Budowa Maszyn i Zarządzanie Produkcją, 14, 103-121, (in Polish).