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REDUCTION OF CHANGEOVER TIME IN A CNC MILLING MACHINE USING EROWA ZEROING SYSTEM BASED ON THE EXAMPLE OF SAMASZ COMPANY, BIAŁYSTOK

Abstract. The paper presents a practical way to shorten changeover of HAAS VF3 milling machine during the production of parts for mowers performed at a manufacturing company SaMASZ, Bialystok. A typical SMED approach was applied, i.e. times of individual actions were measured upon a priorly recorded film. Then, the operations were grouped into external and internal ones. For the purpose of analysis the Gantt diagram was used. In order to increase the share of external actions, the EROWA zero-point system chuck was used. As a result, most of the internal actions could be converted into external ones, that do not take up valuable working time of the machine. Calculated resulting economic effect significantly reduces production costs and the EROWA system applied in the process further improves machining precision of manufactured parts, and thus the quality of the manufactured agricultural machinery.

Keywords: SMED, pneumatic base plate, Gantt diagram

REDUKCJA CZASÓW PRZEZBROJEŃ FREZARKI CNC Z WYKORZYSTANIEM SYSTEMU ZEROWANIA EROWA NA PRZYKŁADZIE FIRMY SAMASZ W BIAŁYMSTOKU

Streszczenie. Artykuł prezentuje praktyczny sposób skrócenia czasów przezbrojeń frezarki HAAS VF3 podczas produkcji części dla kosiarek wykonywanych przez przedsiębiorstwo produkcyjne SaMASZ, w Białymstoku. W publikacji wykorzystano typowe podejście SMEA to znaczy czasy poszczególnych operacji mierzono na podstawie nagranego uprzednio filmu. Następnie operacje zostały pogrupowane na zewnętrzne i wewnętrzne. W analizie wykorzystano również wykres Gantta. W celu udziału zewnętrznych operacji wykorzystano system zerowania EROWA. W rezultacie część wewnętrznych operacji została zamieniona na zewnętrzne, które nie zajmują cennego czasu maszyny. Skalkulowane efekty ekonomiczne pozwoliły na znaczącą redukcję poziomu kosztów. Dodatkowo wykorzystanie systemu EROWA pozwoliło na poprawę precyzji wykonywanych części i jakości wyprodukowanego sprzętu rolniczego.

Słowa kluczowe: SMED, pneumatyczna płyta podstawy, diagram Gantta

1. SMED method applied to reduction of changeover time in milling machines used in manufacturing plants

SMED is a set of methods and techniques which allows to change the devices, components and settings of the production line within even a few minutes [1]. The creator of the concept – S. Shingo had developed and improved it for about 19 years. Nowadays the SMED techniques can be applied in all manufacturing companies and used in any machine [2]. In order to streamline the entire production system, the implementation of SMED is best to start from the "bottleneck" machine [3]. SMED also allows to increase the competitiveness of the company – which is a flexible range of products and short lead times. The process of changeover varies depending on the type of equipment and tools for which these operations are carried out. However, there are some similar stages which include [4]:

1. preliminary preparation of dismantling, checking condition of materials and devices;
2. disassembly and assembly of tools;
3. centering and setting the necessary parameters;
4. producing a test version of the blanks.

Quick changeovers involve [5]:

- performing as many external actions outside the machine as possible while it is running;
- using, where possible, one-move clamping.

The main causes of machine downtime include [6]:

- changeovers – they take up 35% of the downtime;
- no tools;
- supplementing the material;
- start-up;
- failure;
- employee breaks;
- cleaning;
- preparation for work;
- control measurement;
- maintenance;
- defective material.

Stages of SMED method:

Analysis of the existing state – observing the manufacturing process and the current method of changeover. Operation time is measured and employees are interviewed. This information is then used to analyse the operations that occur during the changeover.

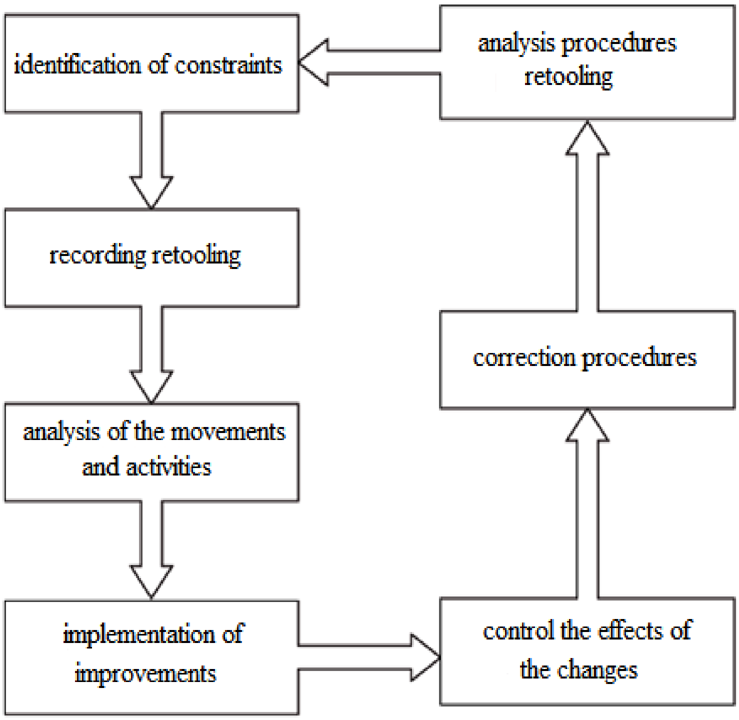


Fig. 1. Analysis of current conditions of changeover and implementation of improvements
Source: Nowacki M.: Redukcja czasu przezbrojeń – sprawdzone metody. Zarządzanie produkcją w praktyce. Wiedza i Praktyka, Warszawa 2010, s. 6.

1. Dividing operations into internal and external which is possible through the use of several tools. These can include [7]:
   - checklists which should contain, among others a list of tools, materials and operating performance of machines;
   - control of devices and parts - any faults or defects should be identified prior to changeover;
   - improvement of transport operations and changes in the position of tools and parts;
   - preliminary transport should be accomplished before starting the changeover, and tools and parts should be transported to the warehouse after starting a production.
2. Conversion of internal operations into external – ensuring that all internal operations are assigned to an appropriate group and looking for ways to convert them into external operations [8]. According to many authors transformation of internal activities into external is a very effective method to shorten setup time of a milling machine [9].

3. The improvement of all aspects of the changeover – improving external actions (e.g.: transport of parts) and streamlining internal actions (e.g.: performing several tasks simultaneously) [10].

The management should appoint a suitable project team to perform individual stages of the SMED methodology. Such team should include [11]:

- coordinator – responsible for training and support;
- line manager – creates a team;
- foreman – responsible for drawing up an instruction and introduction of innovations;
- operator – head of the team, puts forward and implements innovations.

It is possible to use auxilliary techniques at every stage of implementation of SMED. These include e.g.: filming, surveys, verification board, test start-up [12].

Implementation of the SMED method does not only mean a shorter changeover time, but also a number of other advantages [13]:

- increase of the production system flexibility;
- increase of safety during changeover;
- increase of the chances for the implementation of new methods of production organisation;
- increase of product quality;
- a smaller number of tools required at a work station;
- more efficient usage of equipment at a company;
- the number of errors during changeover is reduced to a minimum;
- the products are produced in a shorter time.

It can be concluded then that a smaller number of products manufactured during one changeover reduces inventory levels. This results in the reduction of throughput time and increase of quality, and thus cost reduction [14].

Detection of problems in the company is carried out with the use of graphs. The most widely used is the Gantt diagram for easy control of the implementation of scheduled tasks.

A Gantt diagram is a horizontal bar graph. The horizontal axis shows the task, the machines or work station, and the vertical axis indicates the time of the task or work time of the machine or of the employee [15]. The bars are used to provide data on the start, duration, and the end of a given action. One of the features of this graph is its clarity [16]. It is also an effective tool for planning and tracking progress of tasks and work advancement [17], provides technical details about production scheduling [18]. A regular bar graph cannot provide presentation of the relationship between actions and their order of occurrence [19].

2. Application of EROWA tooling in changeover of CNC mills in SaMASZ company

EROWA is a Swiss company operating globally. The company is mainly engaged in the development, production and distribution of state-of-the-art technology. Consulting in the field of precision engineering and development of technical culture are services offered by the company. EROWA's products range from tooling systems for automation of devices and software to process control for the whole metal industry. Range of products can be divided into four categories [20]:

- Data Transfer Systems – machine control software; production;
- Measuring Systems – devices for quality check and data acquisition;
- Tooling Systems – workpiece – machine interface;
- Loading Systems – robots and automation.

EROWA's products comply with the quality requirements which is confirmed by the certificate of quality management held by EROWA. It includes the aspects such as marketing, distribution and service of tooling systems and solutions in the field of automation, development, production and consulting [21].

The company has a plate MTS (Modular Tooling System) in its range. Application of this plate makes it possible to machine workpieces of different sizes. The only limit to the size of the workpiece can result from the machine, in which the plate is mounted. In the case of application of MTS it is possible to join the plates, so that even long pieces can be machined [22]. MTS or MTS + plates can be operated automatically or manually. Spacing of mounting trunnions is 200 or 250 cm. One of the important advantages of these plates is the fact that the base point is specified and it is not necessary to define it. Application of the plate guarantees changeover time reduced to a minimum thanks to standardized interface. Once the workpiece is mounted it is possible to machine it from 5 sides. MTS plates can be divided into two categories taking into account the customer's needs – hydraulic or pneumatic.

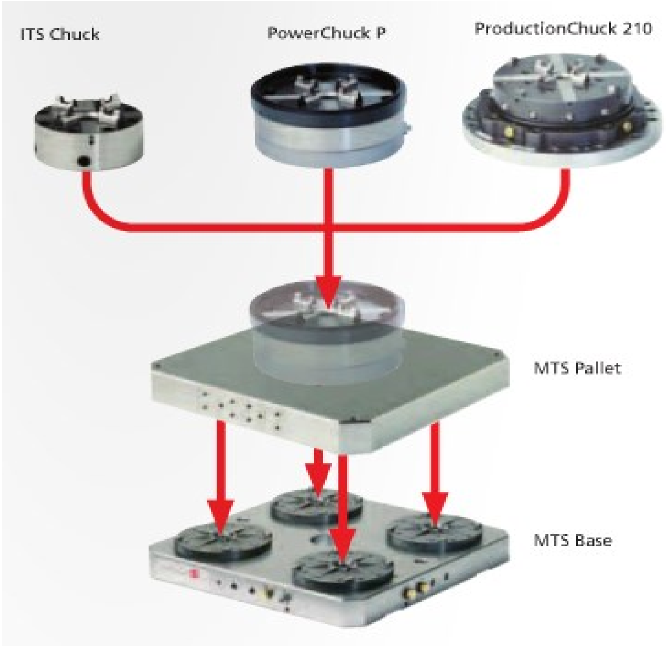


Fig. 2. Base plate, pallet and MTS chucks
Source: EROWA AG, MTS Zero Point Workholding System, The universal interface, www.issuu.com/erowa/docs/erowa_mts_e, 17.08.2016.

The photograph presents mounted chucks. Required compressed air pressure is at least 7 bar. Attaching the chuck on the table is performed using a pneumatic actuator. By using the MTS plate various chucks can be mounted. The efficiency of the application of the plates increases along with the decrease of gaps between chucks.

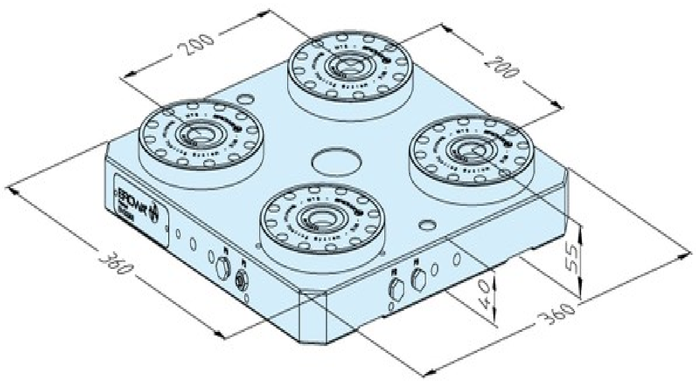


Fig. 3. EROWA pneumatic base plate
Source: EROWA AG, MTS Zero Point Workholding System, The universal interface, ww.issuu.com/erowa/docs/erowa_mts_e, 20.12.2015.

To facilitate the changeover of milling machine HAAS VF3 the pneumatic plate ER-0333000 was installed, with the dimensions of 360 x 360, manufactured from unhardened steel. Air pipes are connected at the side of the plate. The plate can be mounted directly on the machine table. Below is a picture of a pneumatic plate without mounting chucks for flanges.

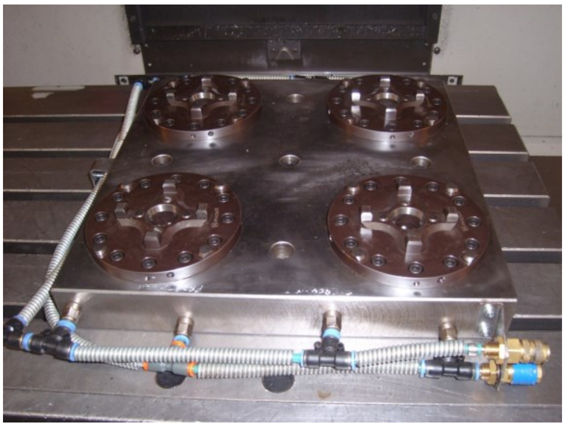


Fig. 4. A base plate corresponding to MTS Base in Fig. 2 and 3
Source: The authors.

If the flange is machined the plate is equipped with a single standard chuck shown below. Then the chuck for clamping a flange is mounted by means of compressed air in EROWA plate chuck.

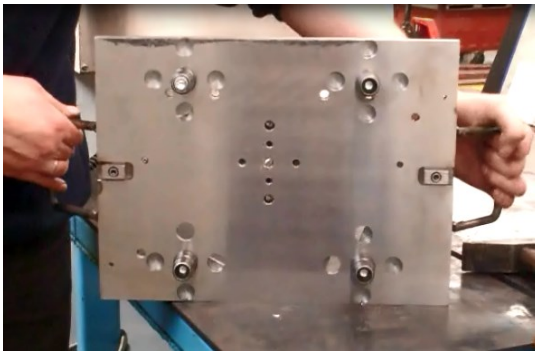


Fig. 5. Bottom view of the support plate, corresponding to MTS Pallet in Fig. 2
Source: The authors.

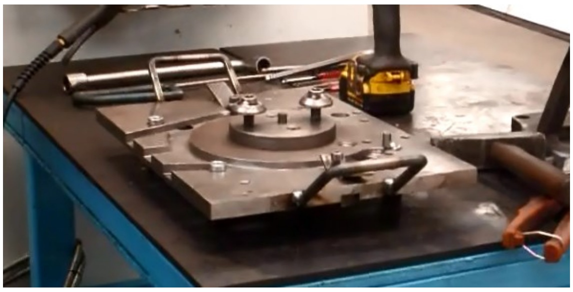


Fig. 6. Side view of a support plate (corresponding to MTS pallet in Fig. 3) with visible clamping chuck for machined flange
Source: The authors.

To streamline production by increasing productivity, it is advisable to use two plates – the base (Fig. 4) and the auxiliary one with a chuck (Fig. 5, 6). By implementing these changes the production will become more fluid.

3. Analysis of flange technological process and changeover operations

The subject of research is a flange that forms the basis of the body of bevel gear mounted on the cutting bar. The figure below shows the location of the flange.

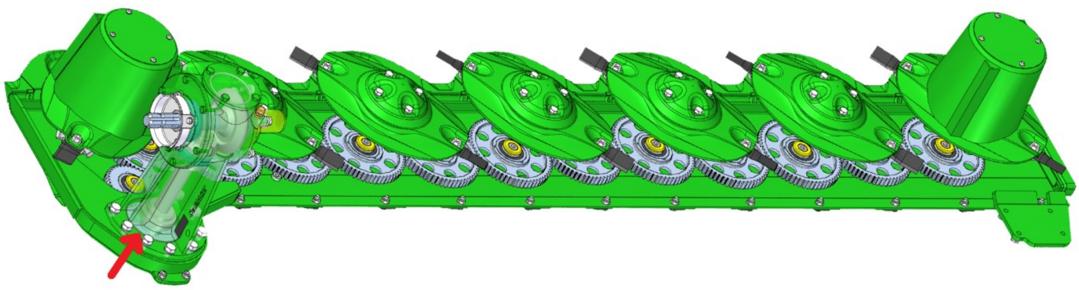


Fig. 7. Right-hand cutting unit of KDD 860 disc mower
Source: A. Stolarski, SaMASZ, Białystok.

Fig. 8. Flange after machining
Source: The authors.

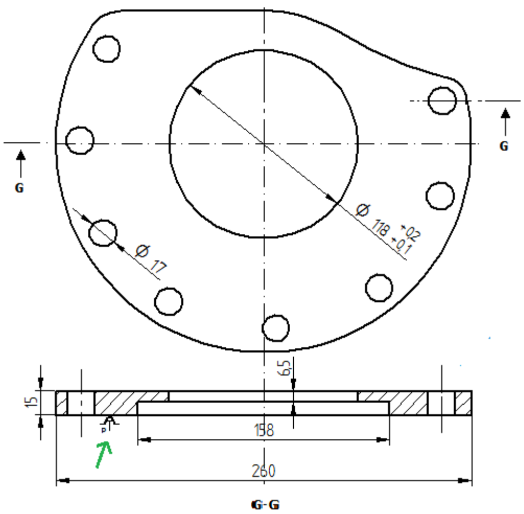


Fig. 9. Flange mounted on a pneumatic plate during the drilling of 8 holes
Source: Based on technical data supplied by SaMASZ.

SaMASZ company manufactures over 300 types of agricultural and municipal machines as well as snow ploughs.

KDD 860 is a type of a mower with an arm's length of 8.60 m and a swath width of 2 x 1.20-1.60. The mower is equipped with 14 discs and 28 knives [18]. As it can be seen in the flowchart of flange processing below, the operation performed on the CNC mill is one of four machining operations. A stage subjected to streamlining has been marked in red in Fig. 9.

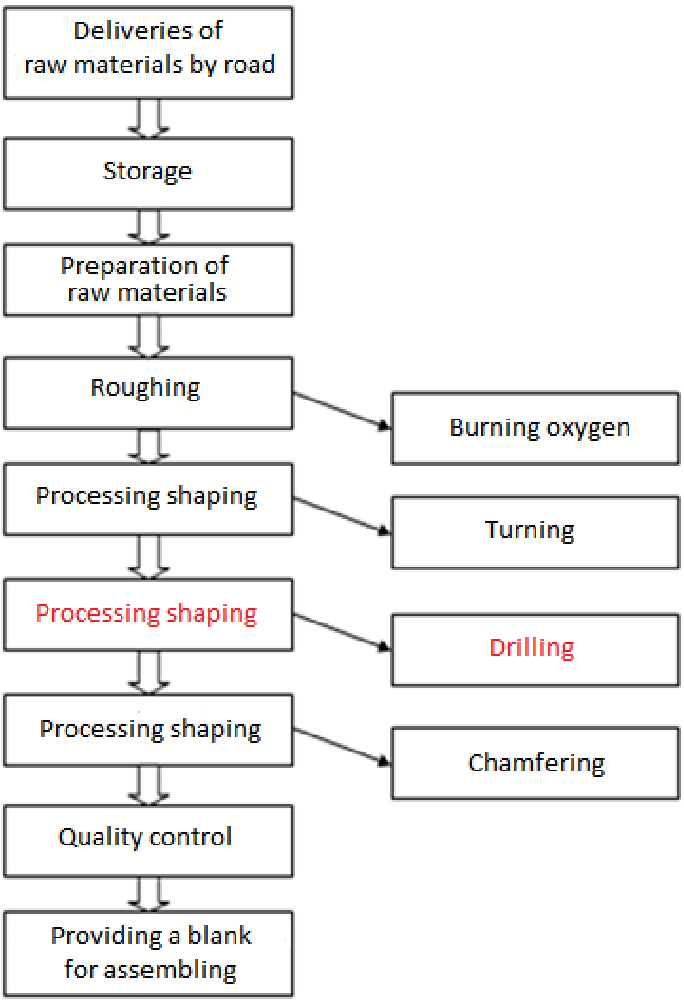


Fig. 10. Technological process of machined flange with indicated improved operation
Source: The authors.

The first machining operation is oxygen lance burning, the second one is broaching a hole, followed by drilling of 8 holes and finished with the last process, which is chamfering of the hole. Total machining time for a single workpiece is 16 minutes and 44 seconds. The first operation is performed on Trawiasta Street, then a half-finished product is transported to the machining section on Kombatantów Street. In order to manufacture a product it is necessary to conduct a changeover in 3 machines such as a lathe, CNC milling machine and a drilling machine. Eight holes 17 mm in diametre are drilled on the HAAS VF3 milling machine.

The analysis of the changeover process on HAAS VF3 milling machine was carried out on the basis of a video film recorded in the manufacturing company SaMASZ, Bialystok on 13 November 2015. The recording shows the process of attaching and removing of the mounting chuck which is currently used in the company. The second part of the film shows the process of changeover at a work station with the use of EROWA system. The recording also contains a part of machining process of the metal flange which is a part of the KDD 860 mower. Operations performed on the machining station were grouped on the basis of the recording and other data obtained in the process. A diagram below presents time summary based on the division of operations into external and internal ones.

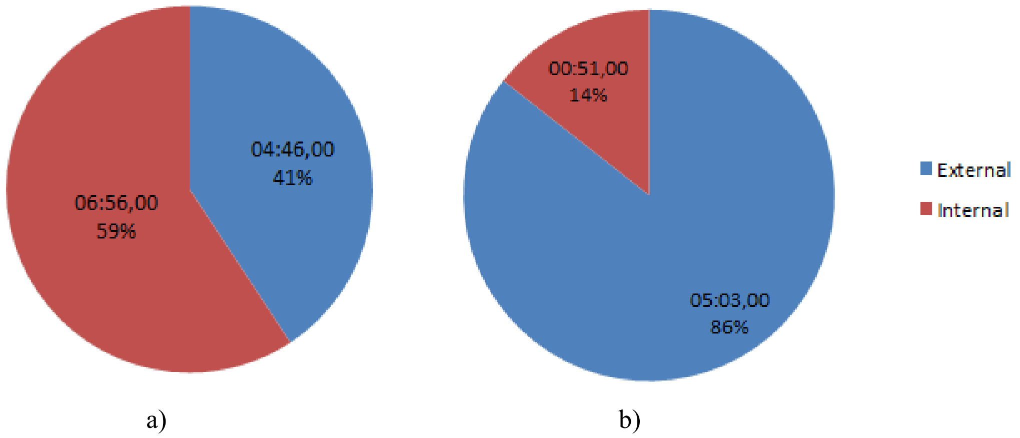
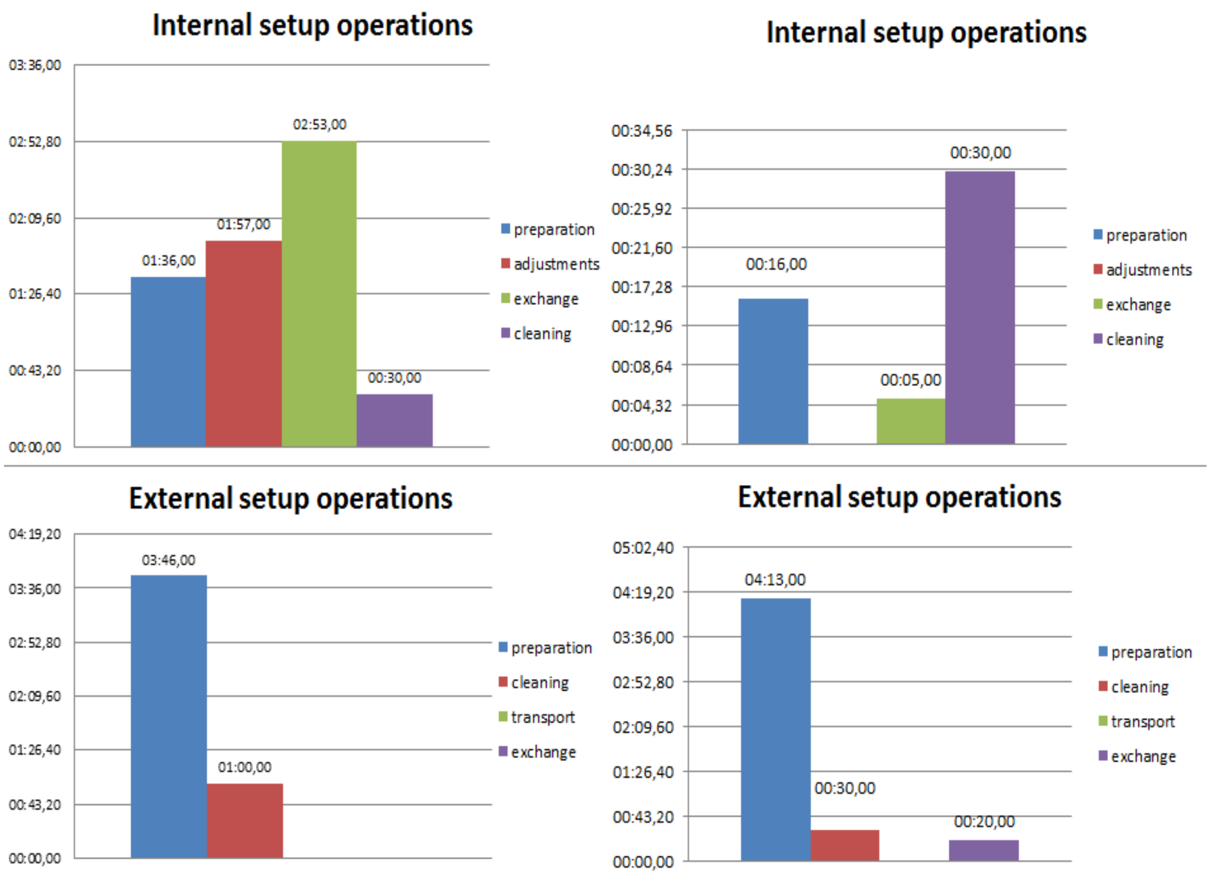


Fig. 11. Changeover operations divided into internal and external; a) before reduction of changeover time; b) after reduction of changeover time
Source: The authors.

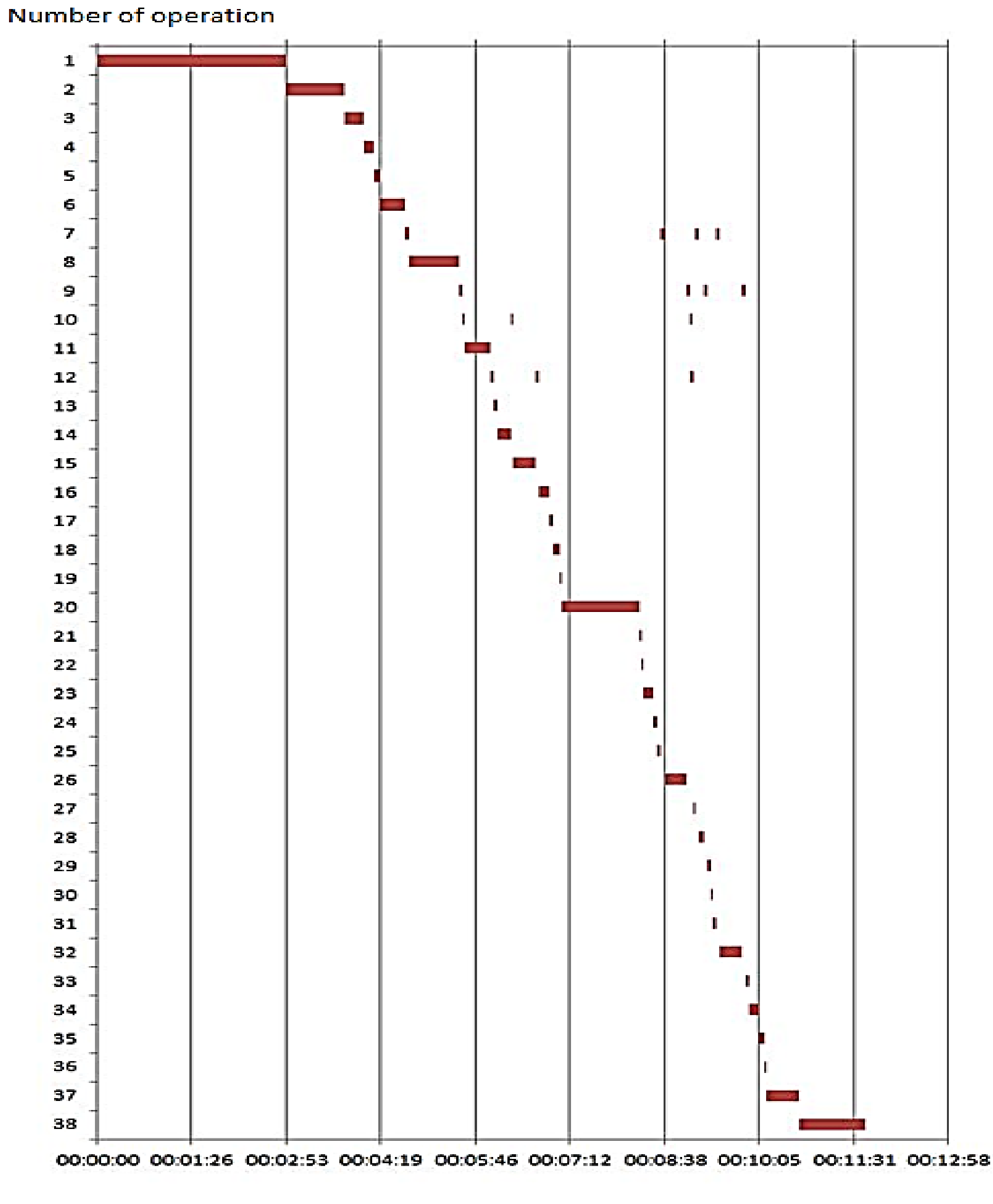
The diagram on the left shows the division of operations that was used before the implementation of improvements. Before the introduction of changes, 59% of actions could be classified as internal operations. In contrast, by introducing EROWA system into production process, internal operations were reduced to 45%. In fact, these actions have been converted into external operations or completely eliminated from the machining process. Distribution of actions depending on the category is shown below.



a) b)

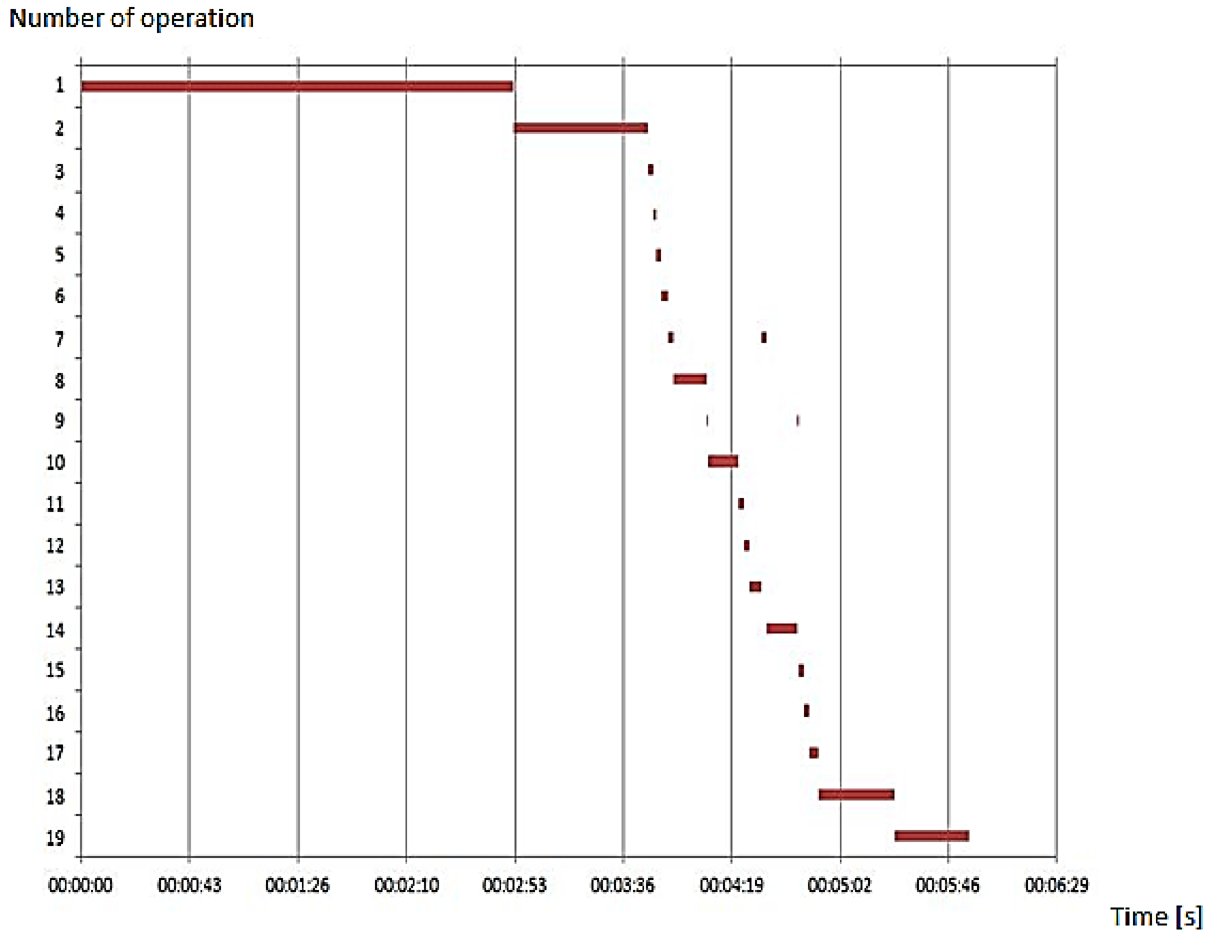
Fig. 12. Categories of operations; a) before reduction of changeover time; b) after reduction of changeover time
Source: The authors.

Gantt diagram which has been drawn is to demonstrate the location of the longest operations in the process.



1 – Preparation of operative to work (gathering information on the production process and gathering all necessary tools), 2 – Finding appropriate mounting tools (vise and chuck), 3 – Setting parts of vise on the table, 4 – Collecting a chuck and placing it on the table, 5 – Collecting remaining parts of vise, 6 – Further mounting of vises on the table, 7 – Collecting spanner-type tools, 8 – Fitting a devise in vises, 9 – Putting spanners aside, 10 – Closing the doors of the machine, 11 – Setting and tooling of basis point and a chuck, 12 – Opening the doors of the machine 13 – Collecting appropriate milling cutter, 14 – Fitting correct tool for machining, 15 – Further setting of basis point and data configuration for machining, 16 – Unscrewing a bolt, 17 – Collecting a measuring tool, 18 – Manual check up of basis point setting, 19 – Putting aside a measuring tool, 20 – Tool-table distance configuration, 21 – Collecting a workpiece for machining, 22 – Collecting a bolt to screw, 23 – Fitting bolts, 24 – Collecting a second part of mounting element, 25 – Fitting a mounting element, 26 – Screwing bolts, 27 – Removing drill bit, 28 – Unscrewing bolts, 29 – Removing and putting aside a part of mounting chuck, 30 – Removing machined workpiece, 31 – Placing machined workpiece on the table, 32 – Uncrewing mounting bolts, 33 – Removing vise after finished task, 34 – Removing and putting a chuck in a designed place, 35 – Dismantling of second part of vise, 36 – Putting a vise away 37 – Cleaning the table 38 – Tidying up workplace.

Fig. 13. Gantt diagram before reduction of changeover time
Source: The authors.



1 – Preparation of operative to work (gathering information on the production process and gathering all necessary tools), 2 – Finding appropriate mounting device for a chuck, 3 – Collecting half-product, 4 – Placing half-poduct on a chuck, 5 – Collecting a jaw for a chuck, 6 – Fitting a jaw in a chuck, 7 – Collecting a spanner, 8 – Screwing the bolts, 9 – Unscrewing the bolts, 10 – Mounting the chuck in EROWA plate, 11 – Closing the doors of the machine, 12 – Opening the doors of the machine, 13 – Removing the chuck from EROWA pneumatic plate, 14 – Unscrewing the bolts, 15 – Removing the plate holding a blank in the chuck, 16 – Removing the flange from the chuck, 17 – Putting the blank away, 18 – Cleaning the table, 19 – Tidying up the workplace.

Fig. 14. Gantt diagram after reduction of changeover time
Source: The authors.

4. Economic result of changeover time reduction

The work on HAAS VF3 mill is usually done in three shifts. Changeovers on the work station are frequent due to excessive range of products manufactured there. In 2014 a total number of orders for the right-side main frame of KDD 860 mower reached 29. The orders included a total of 410 items. The total cost of changeover, which included e.g. the cost of one manhour of HAAS VF3 and payments to employees, can be estimated at about PLN 85. Standard changeover time of the machine is approximately 11-12 minutes.

Fig. 15. EROWA plate mounted on HASS VF3 mill
Source: The authors.

The savings that could be obtained in 2014 using EROWA plate during the machining process of flange, which is a part of the KDD 860 mower:
29 changeovers * 11 min = 319 min = 5 h 19 min,
29 changeovers * 60 s = 1740 s = 29 min,
319 min – 29 min = 290 min ≈ 4 h 50 min,
4 h 50 min * 85 PLN/h ≈ 382.5 PLN.

In the process of 29 changeovers of the same workpiece, the company could save in 2014 382.5 zł. In the production of 410 flanges the saving was PLN 0.93 per each element. According to an interview with the employee, there are three changeovers conducted on HAAS VF3 milling machine each day. Changeover times recorded on the day of the interview were: 20, 10 and 5 minutes. In total then, on that day changeover time of the machine for different workpieces amounted to 35 minutes. Assuming that the machine works 250 days per year, and the changeover time for these workpieces with the use of plate would be a total of 3 minutes, we can make the following calculation:
35 min * 250 days = 8750 min = 145 h 50 min,
1 min * 250 days = 250 min = 4 h 10 min,
145 h 50 min – 4 h 10 min = 141 h 40 min,
141 h 40 min * PLN 93/h = PLN 13 175.

Estimates show that the company SaMasz Bialystok may save about PLN 13 175 on changeovers performed three times a day on HAAS VF3 mill, working 250 days per year. Shortening of changeover time would affect not only reduction of costs, but also increase the safety at the work station and bring down the downtime of machines to the minimum. By using modern solutions the company becomes more competitive and its products are more innovative. Pneumatic plate makes it possible to change workpieces more frequently during the production which is a very important aspect for a company such as SaMASZ because the company apart from mass production has also been involved in manufacturing custom made products.

5. Summary

Analysis of the proposed improvements consisting in reduced changeover time was carried out for one element. The results, however have little effect on the company as SaMASZ is engaged in mass production, and in order to achieve major results changeover streamlining should also be introduced for other machines. When analysing the results, it should be keep in mind that the company's activity has been converting from mass production to individual, custom made machines. Production of single parts increases the number and the time of changeovers. It must be pointed out then, that the implementation of improvements initially entails costs for the company and carries the risk of failure. One of the advantages of the proposed improvement is that the pneumatic plates are less expensive to operate than e.g. hydraulic plates.

The proposed solution can be further streamlined, for instance by standardisation of work procedures and continuous monitoring and analysis of the improvements. Outside the company EROWA workholding systems are also in the product range of companies such as Gerant or Schunk. The resulting times of operations achieved by applying the SMED method are presented in a graphic design by using Gantt diagram. This is to illustrate operations that take up the most time in the changeover process. Such summary is rare in the literature on SMED methodology.

Routine and habits of staff and their fear of losing employment are typical difficulties encountered during the implementation of improvements. To avoid resistance of workers from the introduction of improvements talks and training should be organised raising awareness among personnel about the benefits of new technologies. One major advantage of upgrading the machinery is increase of health and safety at work and simplification of the operation of machines.

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