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Analysis of the Possibility of Introducing the Reduction of Changeover Time of Selected CNC Machines Using the SMED Method

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Abstract
The paper presents the results of improving the production process using the SMED method. The process improvement was carried out in a company in the construction industry, using a machine park consisting of CNC machines. The study evaluated the current state of changeover times for selected CNC machines and proposed a reduction in changeover times for the machine park analysed. By introducing changes to the changeover process on selected CNC machines, it was possible to minimise the changeover time by more than 20% on all the machines analysed. The proposed reorganisation of the CNC operators' workstations resulted in a time reduction of approximately 61% for machine 1, 52% for machine 2 and 12% for machine 3. The installation of barcode readers on the profiles, on the other hand, made it possible to load the machining programmes into the CNC machines more quickly and resulted in a reduction in loading time of approximately 88% on average for each of the machines analysed.

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1. Introduction

In an era of increasing competitiveness, companies must constantly seek and implement the most beneficial solutions for different areas of their business. A dynamic environment forces creativity, and increasing competition, in turn, forces an endless cycle of adaptation to market requirements, which in most cases means the continuous development of key competences and optimisation of own resources, especially in production and logistics in the broadest sense (Barker, 1994; Gershenson, 2003; Sliva, 2020).

There are many tools with which it is possible for any company to function optimally. An example of such tools are Lean Management tools popular nowadays. Lean Management uses many practical tools to optimise costs and streamline work in a company. The choice of the right tool depends primarily on where the lean philosophy is implemented, i.e. in which industry or department of the company (Liker, 2011; Ohno, 2008; Rewers, 2015; Wisniewski, 2010; Ulewicz, 2021; Bouazza, 2021; Gazi, 2023).

This study investigated the improvement of a production process in a company distributing aluminium systems for the construction industry. Three CNC machines are used in the company's production process, which include Satellite Xt, Phantomatic M3 and Comet T6 manufactured by Emmegi. The aforementioned machines are used for the milling of profiles for door and window fittings and elemental façades. The aim of the study was to carry out a reduction in changeover times for selected CNC machines using the SMED method. The study evaluated the current state of changeover times for selected CNC machines and proposed a reduction in changeover times for the aforementioned machine park analysed in the selected company.

2. Literature review

Responding flexibly to ever-changing customer requirements (demand change dynamics) means that modifications to the manufactured product or changes to the formed components at individual production stations are implemented at

short intervals. In turn, the speed of the production process is implemented through, among others, (Marchwiński, 2010):

- standardisation of the work process,
- replacing accessories needed in the production process,
- reducing changeover times,
- shortening the course of technological procedures.

Of the issues presented above, machine or production line changeovers have a pejorative undertone. This state of affairs is caused by the fact that during the changeover period, machines and tools are not involved in production activities, and therefore their overall strategic availability time and value accumulation efficiency are minimised (Masadyński, 2007; Sabatka, 2017).

Changeover is defined as the total time elapsing from the production of the last complete item of value in the standard machine setting to the production of the first item in the newly programmed equipment setting, from which mass production can be initiated. Immediate changeover is very important for production, as it is primarily the time that most often determines the quantity of goods produced (Palucha, 2012).

A collection of techniques and tools for reducing changeover times on machines, equipment and production processes is the SMED methodology. The term "SMED" is an abbreviation of the phrase "Single Minute Exchange of Die" which translates as "one-minute circulation of a production instrument or mould" (Nowakowska-Grunt, 2010). The main objective of this method, which was developed by Japanese engineer Shigeo Shingo, is to carry out each changeover in less than 10 minutes by dividing and simplifying the entire process in such a way that the changeovers are carried out with as few tools as possible.

Shingeo Shingo detailed four basic phases of the machine changeover mechanism (Szwedzka, 2014; Chabowski, 2016):

- 0 – analysis of the changeover process
- I – separation of internal changeover activities from external activities,
- II – transformation of changeovers
- III – improvement of all changeover characteristics.

The zero stage of the machine changeover process only involves an in-depth analysis of the process flow, including the content of the individual steps of the changeover process and an analysis of the required resources associated with the machine changeover. No physical improvements to the process are made at this stage yet (Predoń, 2010; Bonamigo, 2022; Martines, 2018).

Whereas, stages I and II are based on the division of all the activities and operations carried out during changeover into two groups: internal, which include all those that must be carried out when the machine or equipment is switched off, and external, i.e. those that are carried out during the operation of the machine. This division has far-reaching consequences, since it is internal changeovers that cause losses in machine efficiency and downtime, resulting in longer production runs. The analyses and the process of shortening changeovers begins with internal changeovers (Smuśniewicz, 2013; Afonsoa, 2022).

The final stage of the SMED methodology consists of taking action to reduce as much as possible the duration of internal operations that could not be eliminated in stage I, nor converted to external operations in stage II. The third stage of the SMED methodology enables a reduction of up to 10% in changeover time. The posts have been reorganised, in accordance with the rules, as detailed in changeover time (Antosz, 2011; Monteiroa , 2019; Vieira, 2020).

3. Experimental part

Proper execution of the reduction of changeover times for selected CNC machines using the SMED method required the acquisition of accurate data on the process under analysis. Information such as the structure of the activities occurring during changeovers (how the different activities are performed) and their times was obtained by interviewing operators, observing the operators' work and measuring the operators' working times.

In order to make accurate registration of the duration of individual activities on selected CNC machines, all-day long observations of the changeover process took place, which were performed during one shift four times on the Satellite Xt machine, six times on the Comet T6 machine and eleven times on the Phantomatic M3 machine, which allowed for registering all the activities performed during changeovers. The timing of the activities was measured with a digital stopwatch, while any information observed was recorded in the form of notes. A process flow chart was created from these notes, which formed the basis for further optimisation studies.

The machine changeover process is the time between the completion of a machining programme on one component and the start of a new machining programme on the next component. It is worth pointing out that in the case of series production, elements are repeated, in which case some operations in the machine changeover were omitted.

The first stage of research into improving the changeover process on selected CNC machines was to divide the recorded activities on the machines into two basic groups, i.e. external activities and internal activities. The division of the recorded activities was suggested by the time when the activities could be performed, i.e. whether during the operation of the machine or only when the machine was stationary. For this purpose, activity sheets were made for selected CNC machines and the time measurements of individual activities were made, which are presented in Tables 1 – 3 in Appendix A.

It is also worth noting that currently all activities performed on the CNC machines analysed are considered internal activities (100%), despite the fact that the nature of many of them indicates that they are external activities. Analysing the data in Tables 1 – 3 it can also be stated that each subsequent process of changeover of CNC machines is unnecessarily prolonged, at least by the time of performing activities that could be done while the machines are working. Naturally, the possibility of reducing the time by the indicated value is only the first possible stage in the reduction of changeover times of the CNC machines analysed.

The next stage of the study was to develop a spaghetti diagram, i.e. a diagram of operator movements during the changeover process of selected CNC machines. The operator movement diagrams for individual CNC machines are presented in Figures 1 – 3.

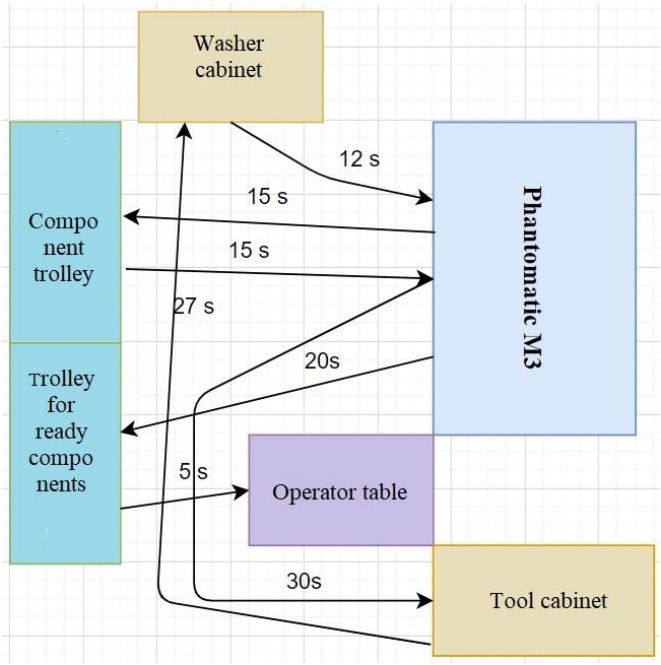

Fig. 1. Spaghetti diagram for the Phantomatic M3

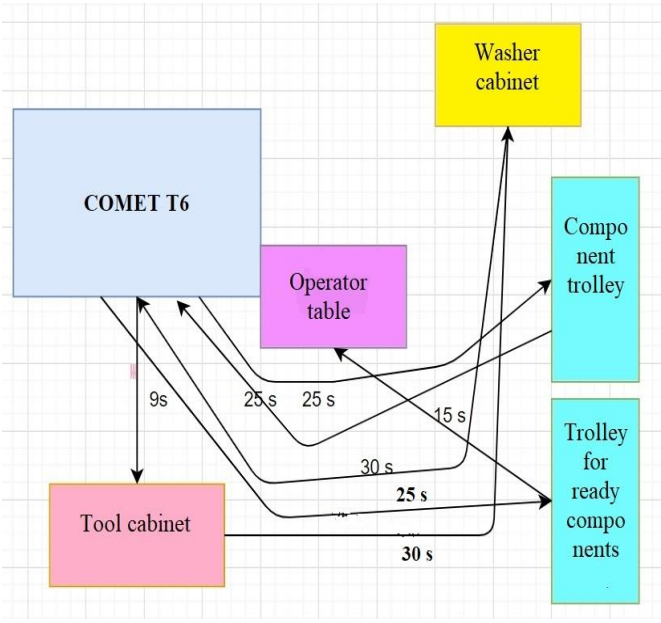

Fig. 2. Spaghetti diagram for the Comet 6

As illustrated in Figures 1 - 3, the operator, during the changeover process of CNC machines, travels considerable distances as well as moves in a pendulum manner which indicated that the elements in the operator's socket are misplaced. During the changeover of CNC machines, deviations from standard changeover procedures were also noted (too long distances between objects in the socket and the use of too many tools). It was found possible to reorganize the operator's workstation in order to perform changeover activities faster.

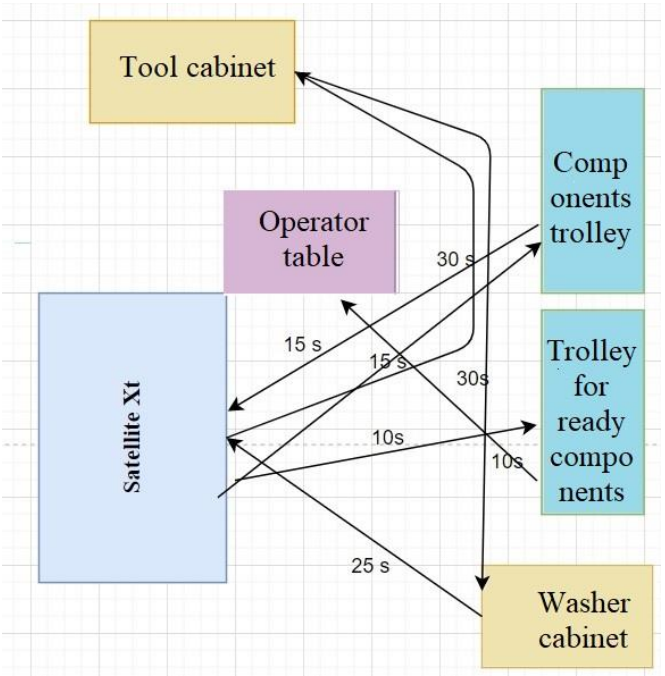

Fig. 3. Spaghetti diagram for the Satellite XT

Understanding the structure of the changeover process and the problems causing long times for individual operations on selected CNC machines, it was possible to propose changes to reduce changeover times.

The first step in reducing the changeover time of the CNC machines analysed was to change some of the activities carried out during machine standstill (internal activities) into so-called external activities, which can be carried out while the machine is running. The proposed changes from internal to external activities are shown in Table 4-6.

The main change, on which other improvement (reduction) proposals depended, was the design of a new CNC machine operator workstation, in the form of a socket. The socket would replace spatially scattered objects such as tool cabinets, washer cabinets or component trolleys that operators currently have to reach and thus waste time. The positioning of all objects in the operator socket should guarantee smooth transitions during the subsequent activities. Placing the washer cabinet and the tool cabinet next to each other and as close to the machine as possible, so that the operator can reach for the tools easily if necessary, without unnecessary movement, should also significantly reduce the duration of individual operations.

The new arrangement of items together with the spaghetti diagram in the operator socket for selected CNC machines is shown in Figure 4 - 6.

Table 4. Proposals for changes from internal to external activities for the Phantomatic M3

No.	Description of activities	Type of activity
1	The machine is waiting for the operator	external
2	Switching on the machine	external
3	General visual inspection of the machine	external
4	Arrangement of the stand with profiles to be CNC machined	external
5	Picking of the necessary tools	internal
6	Selecting the correct washers for the component fastening	internal
7	Loading of the CNC program	internal
8	Setting up the brackets according to the specifications	internal
9	Positioning the workpiece in the machine	internal
10	Blowing off the workpiece at the end of the programme	external
11	Turning of the component by 180º and reassembly in the machine	internal
12	Blowing off the workpiece at the end of the programme	external
13	Deburring from the sharp edge of the milling spot	external
14	Filling in the control sheet	external
15	Marking the performed component on the plan	external
16	Putting the completed workpiece on the trolley	external

Table 5. Proposals for changes from internal to external activities for the Comet T6

No.	Description of activities	Type of activity
1	The machine is waiting for the operator	external
2	Switching on the machine	external
3	General visual inspection of the machine	external
4	Arrangement of the stand with profiles to be CNC machined	external
5	Picking of the necessary tools	internal
6	Selecting the correct washers for the component fastening	internal
7	Loading of the CNC program	internal
8	Setting up the brackets according to the specifications	internal
9	Positioning the workpiece in the machine	internal
10	Blowing off the workpiece at the end of the programme	external
11	Turning of the component by 180º and reassembly in the machine	internal
12	Blowing off the workpiece at the end of the programme	external
13	Deburring from the sharp edge of the milling spot	external
14	Filling in the control sheet	external
15	Marking the performed component on the plan	external
16	Putting the completed workpiece on the trolley	external

Table 6. Proposals for changes from internal to external activities for the Satellite XT

No.	Description of activities	Type of activity
1	The machine is waiting for the operator	external
2	Switching on the machine	external
3	General visual inspection of the machine	external
4	Arrangement of the stand with profiles to be CNC machined	external
5	Picking of the necessary tools	internal
6	Selecting the correct washers for the component fastening	internal
7	Loading of the CNC program	internal
8	Setting up the brackets according to the specifications	internal
9	Positioning the workpiece in the machine	internal
10	Blowing off the workpiece at the end of the programme	external
11	Turning of the component by 180º and reassembly in the machine	internal
12	Blowing off the workpiece at the end of the programme	external
13	Deburring from the sharp edge of the milling spot	external
14	Filling in the control sheet	external
15	Marking the performed component on the plan	external
16	Putting the completed workpiece on the trolley	external

The main change, on which other improvement (reduction) proposals depended, was the design of a new CNC machine operator workstation, in the form of a socket. The socket would replace spatially scattered objects such as tool cabinets, washer cabinets or component trolleys that operators currently have to reach and thus waste time. The positioning of all objects in the operator socket should guarantee smooth transitions during the subsequent activities. Placing the washer cabinet and the tool cabinet next to each other and as close to the machine as possible, so that the operator can reach for the tools easily if necessary, without unnecessary movement, should also significantly reduce the duration of individual operations.

The new arrangement of items together with the spaghetti diagram in the operator socket for selected CNC machines is shown in Figure 4 - 6.

The use of barcode readers compatible with CNC machines was also proposed at all CNC machine operators' workstations Readers would make it possible to scan the code directly from the profile labels of the profiles to be machined, which would enable the programme to be loaded automatically into the machine. With this improvement, the operator will not waste time searching for the code on the machine screen.

Another possibility for speeding up the changeover process on CNC machines could be faster tool picking. It would be advisable to suggest that programmers write their programs in such a way (as far as possible) that they use a basic package of cutters, i.e. cutters 3, 5, 6, 8 and 10.

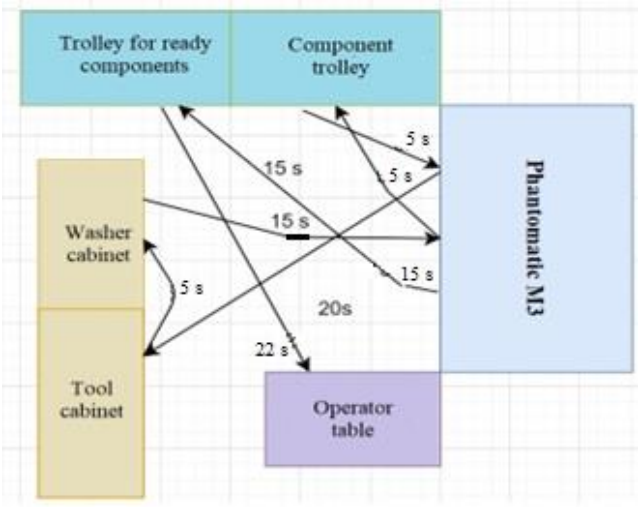

Fig. 4. New positioning and socket spaghetti diagram for the Phantomatic M3

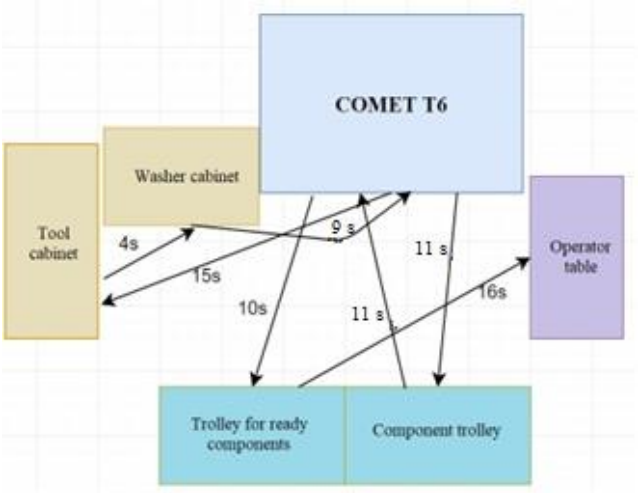

Fig. 5. New positioning and socket spaghetti diagram for the Comet T6

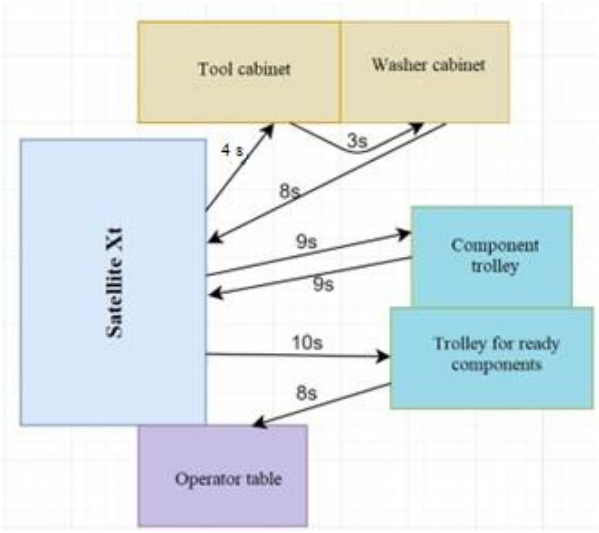

Fig. 6. New positioning and socket spaghetti diagram for the Satellite XT

In summary, the current arrangement of the elements comprising the operator's socket which the operator was forced to use meant that the operator had to travel much greater distances. It is worth noting that the improvement proposals involve the use of both methods of an organisational nature (arrangement of objects in the socket, organisation of tools) and methods of a technical nature (profile barcode reader).

5. Summary and conclusion

The changes proposed at the stations of operators of selected CNC machines have been implemented in the Production Company. In order to verify the changes made, process flow sheets were again drawn up for selected CNC machines, which are shown in Tables 7–9 of Appendix A. As the data in Tables 7-9 illustrate, at present, most of the activities carried out on CNC machines are performed as external activities. The share of external and internal activities in the total changeover time for individual CNC machines is shown in Figures 7 – 9.

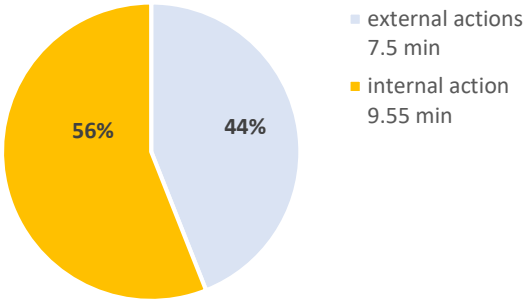

Fig. 7. Percentage share of activities in the changeover process of the Phantomatic M3 machine

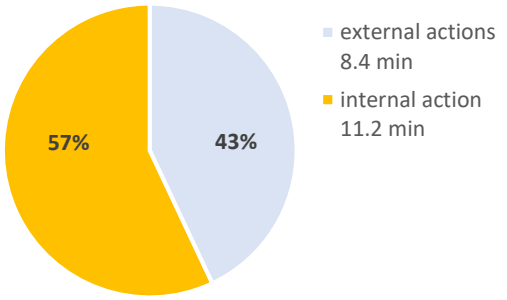

Fig 8. Percentage share of activities in the changeover process of the Comet T6 machine

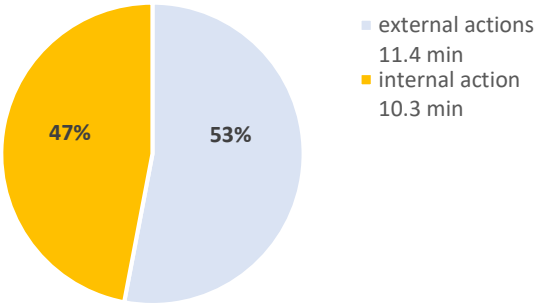

Fig. 9. Percentage share of activities in the changeover process of the Satellite Xt machine

By changing from external to internal operations, the changeover time for selected CNC machines was reduced in the first stage of improvement (Fig. 10 – 12).

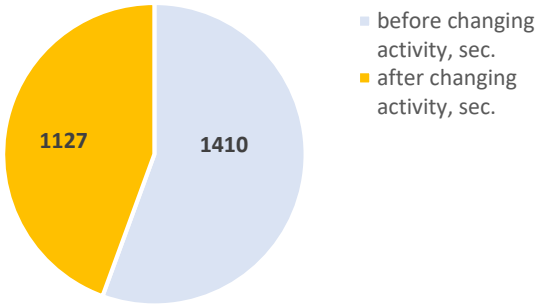

Fig. 10. Average changeover times for Phantomatic M3 machine, before and after the change of activities

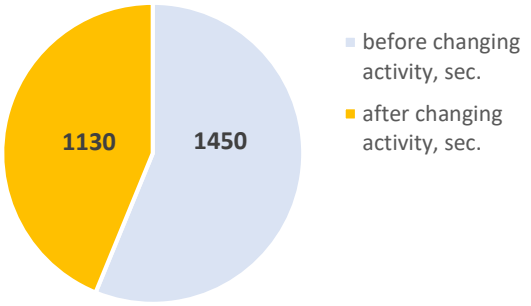

Fig. 11. Average changeover times for Comet T6 machine, before and after the change of activities

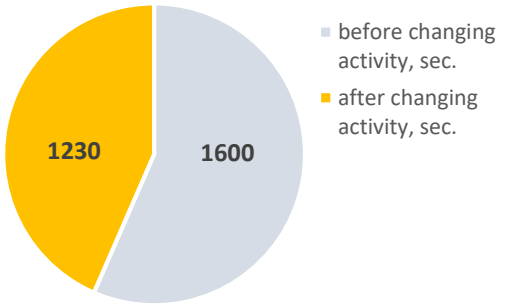

Fig. 12. Average changeover times for Satellite Xt machine, before and after the change of activities

The next step in streamlining the changeover process for selected CNC machines was to reorganise the operators' sockets, as the operators were travelling too long distances, which is perfectly illustrated in Figures 1-3. As part of the reorganisation of the aforementioned workstations, tool cabinets, washer cabinets and a profile trolley were rearranged so that the operator could reach for tools without unnecessary movements and could make smooth transitions during the following activities. After the reorganisation of the workstation, the operator travels much shorter distances, as shown in Figures 4-6, and the time taken to carry out the various activities is therefore reduced. A comparison of the total times of all activities performed at the operators' workstations of selected CNC machines, before and after the reorganisation of the workstations, is shown in Figures 13-15.

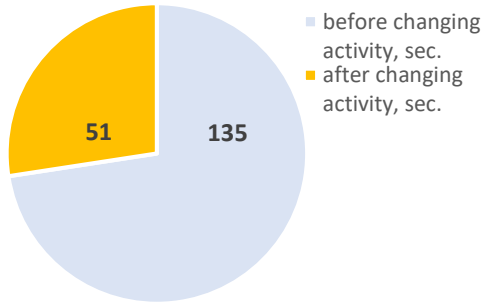

Fig. 13. Summary times of activities performed at the CNC Satellite Xt machine operators workstation before and after reorganisation

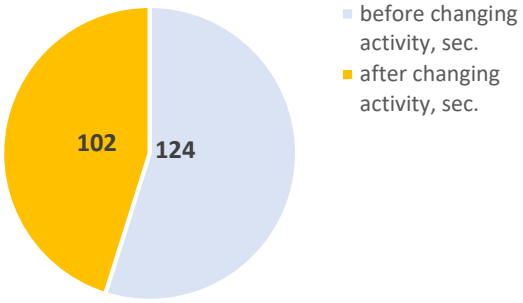

Fig. 14. Summary times of activities performed at the CNC Phantomatic M3 machine operators workstation before and after reorganisation

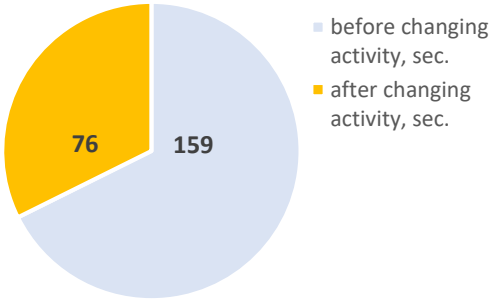

Fig. 15. Summary times of activities performed at the CNC Comet T6 machine operators workstation before and after reorganisation

In addition, operators of selected CNC machines have been equipped with readers for loading programmes on the machine from codes placed on the label of the machined workpieces, which has also significantly reduced the time taken to process workpieces on the machine. It should be mentioned that before the reorganisation, operators manually found the programme on the machine, which had to match the barcode on the profile label.

As a final step in streamlining the changeover process, CNC machine programmers were advised to use a basic cutter package (where possible), allowing faster tooling picking for a particular job.

The organisational and technical changes made to the workstations of operators of the CNC Satellite Xt, Phantomatic M3 and Comet T6 machines, the change from internal to external operations during the changeover process, the use of code

readers on the profile labels and the suggestion to the CNC programmers of the use of basic milling cutter packages have significantly improved the changeover process of the CNC machines in the company under analysis.

To sum up:

- The proposed changes in activities during the changeover process from internal to external resulted in a reduction in changeover time of approximately 25% for the Phantomatic M3, 23% for the Comet T6 and 21% for the Satellite Xt.
- The proposed reorganisation of the CNC operators' workstations resulted in a time reduction of about 61% for the Satellite Xt machine, 52% for the Comet T6 machine and 12% for the Phantomatic M3 machine.
- The installation of barcode readers on the profiles, made it possible to load the machining programmes into the CNC machines more quickly and resulted in a reduction in loading time of approximately 88% on average for each of the machines analysed.

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Appendix

Appendix A

Table 1. Measurement of the changeover time of the Phantomatic M3

No.	Description of activities	Measurement, [s].											Average time, [s]
		1	2	3	4	5	6	7	8	9	10	11	
1	The machine is waiting for the operator	5	-	-	-	-	-	-	-	-	-	-	5
2	Switching on the machine	20	-	-	-	-	-	-	-	-	-	-	20
3	General visual inspection of the machine	30	-	-	-	-	-	-	-	-	-	-	30
4	Arrangement of the stand with profiles to be CNC machined	220	215	217	223	225	227	213	221	219	218	222	220
5	Picking of the necessary tools	300	310	290	287	313	302	305	293	301	299	300	300
6	Selecting the correct washers for the component fastening	149	147	144	155	155	148	142	158	152	148	152	150
7	Loading of the CNC program	179	175	178	188	180	179	174	179	187	180	181	180
8	Setting up the brackets according to the specifications	242	244	234	236	236	244	243	241	240	239	241	240
9	Positioning the workpiece in the machine	15	15	15	15	15	15	15	15	15	15	15	15
10	Blowing off the workpiece at the end of the programme	18	20	18	20	21	18	18	21	21	21	19	20
11	Turning of the component by 180º and reassembly in the machine	14	14	15	16	14	16	16	16	16	14	16	15
12	Blowing off the workpiece at the end of the programme	21	21	18	19	20	21	18	21	20	22	20	20
13	Deburring from the sharp edge of the milling spot	118	115	117	117	118	124	124	125	122	121	122	120
14	Filling in the control sheet	28	32	30	31	32	32	30	31	30	30	28	30
15	Marking the performed component on the plan	29	30	30	31	28	32	33	28	27	29	32	30
16	Putting the completed workpiece on the trolley	16	17	17	15	15	14	15	14	13	16	16	15

Table 2. Measurement of the changeover activity time of the Comet T6 machine

No.	Description of activities	Measurement, [s]						Average time, [s]
		1	2	3	4	5	6	
1	The machine is waiting for the operator	5	-	-	-	-	-	5
2	Switching on the machine	20	-	-	-	-	-	20
3	General visual inspection of the machine	30	-	-	-	-	-	30
4	Arrangement of the stand with profiles to be CNC machined	220	215	217	223	225	227	220
5	Picking of the necessary tools	350	340	360	355	345	350	340
6	Selecting the correct washers for the component fastening	149	147	144	155	155	148	150
7	Loading of the CNC program	179	175	178	188	180	179	180
8	Setting up the brackets according to the specifications	242	244	234	236	236	244	240
9	Positioning the workpiece in the machine	15	15	15	15	15	15	15
10	Blowing off the workpiece at the end of the programme	19	20	20	18	20	21	20
11	Turning of the component by 180º and reassembly in the machine	15	14	14	15	15	15	15
12	Blowing off the workpiece at the end of the programme	21	21	21	22	19	20	20
13	Deburring from the sharp edge of the milling spot	117	116	121	115	118	124	120
14	Filling in the control sheet	33	27	30	28	32	32	30
15	Marking the performed component on the plan	27	32	33	32	31	33	30
16	Putting the completed workpiece on the trolley	17	16	15	16	16	16	15

Table 3. Measurement of the changeover activity time of the Satellite Xt machine

No.	Description of activities	Measurement, [s]				Average time, [s]
		1	2	3	4	
1	The machine is waiting for the operator	5	-	-	-	5
2	Switching on the machine	20	-	-	-	20
3	General visual inspection of the machine	30	-	-	-	60
4	Arrangement of the stand with profiles to be CNC machined	220	215	217	223	230
5	Picking of the necessary tools	350	370	360	370	360
6	Selecting the correct washers for the component fastening	149	147	144	155	150
7	Loading of the CNC program	179	175	178	188	180
8	Setting up the brackets according to the specifications	242	244	234	236	250
9	Positioning the workpiece in the machine	15	15	15	15	15
10	Blowing off the workpiece at the end of the programme	21	20	21	20	25
11	Turning of the component by 180º and reassembly in the machine	14	14	16	15	15
12	Blowing off the workpiece at the end of the programme	19	20	21	20	25
13	Deburring from the sharp edge of the milling spot	124	118	120	118	180
14	Filling in the control sheet	32	28	32	28	30
15	Marking the performed component on the plan	29	30	31	29	30
16	Putting the completed workpiece on the trolley	13	15	16	15	25

Table 7. Measurements of the time taken to perform changeover operations on a Phantomatic M3 machine after changes

No.	Description of activities	Measurement, [s]											Average time, [s]	Type of activity
		1	2	3	4	5	6	7	8	9	10	11		
1	The machine is waiting for the operator	5	-	-	-	-	-	-	-	-	-	-	5	**external**
2	Switching on the machine	20	-	-	-	-	-	-	-	-	-	-	20	**external**
3	General visual inspection of the machine	30	-	-	-	-	-	-	-	-	-	-	30	**external**
4	Arrangement of the stand with profiles to be CNC machined	170	171	172	167	168	171	170	170	171	172	167	168	**external**
5	Picking of the necessary tools	220	221	225	215	216	224	220	220	221	225	215	216	**internal**
6	Selecting the correct washers for the component fastening	149	147	144	155	155	148	142	158	152	148	152	150	**internal**
7	Loading of the CNC program	30	29	28	32	33	28	30	30	29	28	32	33	**internal**
8	Setting up the brackets according to the specifications	242	244	234	236	236	244	243	241	240	239	241	240	**internal**
9	Positioning the workpiece in the machine	15	15	15	15	15	15	15	15	15	15	15	15	**internal**
10	Blowing off the workpiece at the end of the programme	18	20	18	20	21	18	18	21	21	21	19	20	**external**
11	Turning of the component by 180º and reassembly in the machine	14	14	15	16	14	16	16	16	16	14	16	15	**internal**
12	Blowing off the workpiece at the end of the programme	21	21	18	19	20	21	18	21	20	22	20	20	**external**
13	Deburring from the sharp edge of the milling spot	118	115	117	117	118	124	124	125	122	121	122	120	**external**
14	Filling in the control sheet	28	32	30	31	32	32	30	31	30	30	28	30	**external**
15	Marking the performed component on the plan	29	30	30	31	28	32	33	28	27	29	32	30	**external**
16	Putting the completed workpiece on the trolley	16	17	17	15	15	14	15	14	13	16	16	15	**external**

Table 8. Measurements of the time taken to perform changeover operations on a Comet T6 machine after changes.

No.	Description of activities	Measurement, [s]						Average time, [s]	Type of activity
		1	2	3	4	5	6		
1	The machine is waiting for the operator	5	-	-	-	-	-	5	**external**
2	Switching on the machine	20	-	-	-	-	-	20	**external**
3	General visual inspection of the machine	30	-	-	-	-	-	30	**external**
4	Arrangement of the stand with profiles to be CNC machined	170	171	172	167	168	171	170	**external**
5	Picking of the necessary tools	220	221	225	215	216	224	220	**internal**
6	Selecting the correct washers for the component fastening	149	147	144	155	155	148	150	**internal**
7	Loading of the CNC program	30	29	28	32	33	28	30	**internal**
8	Setting up the brackets according to the specifications	242	244	234	236	236	244	240	**internal**
9	Positioning the workpiece in the machine	15	15	15	15	15	15	15	**internal**
10	Blowing off the workpiece at the end of the programme	19	20	20	18	20	21	20	**external**
11	Turning of the component by 180º and reassembly in the machine	15	14	14	15	15	15	15	**internal**
12	Blowing off the workpiece at the end of the programme	21	21	21	22	19	20	20	**external**
13	Deburring from the sharp edge of the milling spot	117	116	121	115	118	124	120	**external**
14	Filling in the control sheet	33	27	30	28	32	32	30	**external**
15	Marking the performed component on the plan	27	32	33	32	31	33	30	**external**
16	Putting the completed workpiece on the trolley	17	16	15	16	16	16	15	**external**

Table 9. Measurements of the time taken to perform changeover operations on a Satellite Xt machine after changes.

No.	Description of activities	Measurement, [s]				Average time, [s]	Type of activity
		1	2	3	4		
1	The machine is waiting for the operator	5	-	-	-	5	**external**
2	Switching on the machine	20	-	-	-	20	**external**
3	General visual inspection of the machine	30	-	-	-	60	**external**
4	Arrangement of the stand with profiles to be CNC machined	220	215	217	223	220	**external**
5	Picking of the necessary tools	220	215	217	223	220	**internal**
6	Selecting the correct washers for the component fastening	149	147	144	155	150	**internal**
7	Loading of the CNC program	30	25	27	33	30	**internal**
8	Setting up the brackets according to the specifications	242	244	234	236	240	**internal**
9	Positioning the workpiece in the machine	15	15	15	15	15	**internal**
10	Blowing off the workpiece at the end of the programme	21	20	21	20	25	**external**
11	Turning of the component by 180º and reassembly in the machine	14	14	16	15	15	**internal**
12	Blowing off the workpiece at the end of the programme	19	20	21	20	25	**external**
13	Deburring from the sharp edge of the milling spot	124	118	120	118	120	**external**
14	Filling in the control sheet	32	28	32	28	30	**external**
15	Marking the performed component on the plan	29	30	31	29	30	**external**
16	Putting the completed workpiece on the trolley	13	15	16	15	25	**external**

使用 SMED 方法引入所选 CNC 机器转换时间减少的可能性分析

關鍵詞
精益制造工具
改进制造工艺
贴片机
机器改造

摘要
本文介绍了使用 SMED 方法改进生产过程的结果。 过程改进是在建筑行业的一家公司中进行的，使用由数控机床组成的加工园区。 该研究评估了所选 CNC 机器的转换时间的现状，并建议减少所分析的机器园区的转换时间。 通过对选定 CNC 机器的转换过程进行更改，可以将所有分析机器的转换时间减少 20% 以上。 拟议的 CNC 操作员工作站重组使机器 1 的时间减少了大约 61%，机器 2 的时间减少了 52%，机器 3 的时间减少了 12%。另一方面，在型材上安装条形码阅读器使其成为可能 可以更快地将加工程序加载到 CNC 机器中，并导致所分析的每台机器的加载时间平均减少约 88%。。