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Analysing the machines working time utilization for improvement purposes

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Abstract

The article is a case study of the use of snapshot observation to analyse the factors causing time losses at selected laser burner stations, and to propose changes that will increase the effective utilization of working time. The purpose of this paper is to determine the best and worst utilization of working time at the examined workplaces, analyse the amount of time lost and identify the causes of losses, and propose solutions that will improve the utilization of working time. According to the snapshot observation, procedure 2 main - work and non-work - time fractions and 10 detailed time fractions in the working day were distinguished, and their percentage share for the analysed workstations was calculated. Analyses of the working day time utilization depending on the type of machines, days of observation, single shifts were done and selected results were averaged. The paper indicates that organizational and technical aspects, as well as the employees' faults, were the main reasons for time losses. Research has shown that the generally examined group of workstations was characterized by a high utilization level of working time. An unfavourable phenomenon was the ratio of the main time to the auxiliary time, the high share of the maintenance time fraction of the workstations, and incorrect organization of the interoperation transport, low workers motivation, rush, and routine. It was found that further improvement of work efficiency and reduce time losses requires paying attention to the optimization of employees' working conditions, training, motivation systems, and implementation of lean concept tools and MES/CMMS solutions into production.

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1. Introduction

In technological processes, there is a need to study various data on the working time of people, machines, or work tools and to establish working time standards (Lockyer et al., 1992; Czerwinska and Pacana, 2020). Working time research is a process that requires mental and physical effort, and is associated with the selection of an appropriate research method, which depends on many quantitative and qualitative criteria, such as, for example, the area of application, specificity of the process, plant conditions, conditions resulting from the process and their variability and design (Baraniak, 2009; Kanawaty, 1992; Pisuchpen and Chansangar, 2014). Working time standardization is the process of determining the times of planned performance of activities, tasks, and operations performed at particular workstations by a person, machine or work tool (Bartnicka et al., 2020; Bieda and Bieniok, 2011; Subramanian, 2008). One of the elementary issues in the standardization of working time is the study and analysis of the working time utilization (Niebel and Freivalds, 2003). Working time research aimed at determining the level of its utilization and increasing work productivity is one of the priorities and standard organizational research (Duran et al., 2015; Akansel et al., 2017). It is a basic tool for detecting, reducing, and eliminating wasteful time, i.e. time losses (Anvari et al., 2010) by an employee for both objective (no-fault) and subjective (culpable) reasons (Golden, 2012). Correctly established work standards result in the optimal utilization of machines and devices, increasing productivity, work discipline and efficiency, saving materials, raw materials, and energy (Al-Saleh, 2011; Akansel et al., 2017; Fin et al., 2017). Besides, work standards are used as measures of individual work productivity and as tools for determining wages (Kulkarni et al., 2014).

Working time research must be supported by a uniform classification and systematics of phenomena - types of work and breaks in work, occurring during a shift at the workplace (Baraniak, 2009; Niebel and Freivalds, 2003). The purpose of the analysis of the working day is to present the amount of individual working and non-working hours, to establish their mutual relationship and proportions between them, as well as to determine the causes and factors influencing the specific shaping of these values (Kanawaty, 1992). The financial outcomes of each plant result from not only the use of modern machinery (Ingaldi and Dziuba, 2015) and high qualifications of employees, but, above all, from the rational utilization of working time (Chase et al., 2001; Forsyth, 2004). Optimizing the functionality and time of uninterrupted operation of machine and devices is an important issue related to increasing the efficiency of the company and its competitiveness on the market in any industry (Kardas et al., 2017; Knop, 2018; Krynke et al., 2014).

It is possible to evaluate and improve the utilization of working time at workstations in an industrial plant. The article covers the study of the level of utilization of working day at selected workstations made up of machines and operators in a plant producing semi-trailers.

2. Theoretical background

There are three basic groups of factors involved in the production process: people, work objects, and work items (Lockyer et al., 1992; Ulewicz and Ulewicz, 2020). The condition for the efficiency and high effectiveness of the production process is the fullest possible harmonization of all their factors, in particular the mutual adjustment of workers and material factors (Brzeziśnki and Klimecka-Tatar, 2016; Jagusiak-Kocik and Krynke, 2016; Kardas, 2012; Stasiak-Betlejewska, 2018; Stasiak-Betlejewska and Ulewicz, 2018). The optimization of the human-machine system (Krynke and Mielczarek, 2018) requires adjusting not only the material elements of this system to the biological properties of man, but also the physical working environment and work organization (Lan et al., 2009). The close relationship and mutual conditions of the above-mentioned elements (equipment, environment, organization) indicate the need for a comprehensive solution of ergonomic issues, the need to simultaneously shape all the material elements of work, taking into account their mutual dependencies and conditions (Shikdara and Sawaqedb, 2004).

Working time is one of the most complex as well as socially and economically important issues in labour law (Kanawaty, 1992). Its legal regulation is an important determinant of work organization, and, at the same time, it determines the sphere of protected employee interests. It is also one of the factors determining the employment policy implemented in each country (Waciskowska, 2011).

As the organic composition of capital changes, while the importance of machine labour increases and the share of human labour decreases, it becomes more and more difficult to isolate the direct impact of shortened working time on employee productivity from the indirect impact on the organization and technology of the enterprise (Ingaldi and Dziuba, 2015; Korkmaz et al., 2020; Knop and Ulewicz, 2019). The consequence of the reduction in working time may be a reduction in losses during the working day due to the transition from the extensive organization of the working day to an intensive one (Kanawaty, 1992). When working time is shorter, the last hours during which the accident rate is usually higher than the average are dropped from the working day or week. With a shorter working day and week, the quality of work also improves (Lawlor, 1970). When the working time is shortened below the optimum of production, the hourly productivity does increase, but the increase is not so great as to completely compensate for the reduction in the production volume (Ulewicz and Mazur, 2019; Niebel and Freivalds, 2003).

Among the working time research methods used to analyse the working time and, as a result, shorten it, the following should be distinguished as the most popular: *timing, photography of the working day, analysis of elementary movements - MTM, comparison and estimation, Work-Factor method, survey methods, photo-film method, snapshot observations* (Baraniak, 2009).

Timing is a method of measuring repetitive operations or their elements (treatment, activity, work movement) in order to determine, on the basis of a certain number of measurements, the appropriate duration and rational execution at a normal pace of work. Timing observations can be made either continuously or at random (Baraniak, 2009; Mundel, 1973).

Photography of the working day is based on continuous observation and measurement of time used at the position, taking into account working times and breaks. The period needed to take one photo usually coincides with the period of one shift or a part of it. The working day photography aims to determine the degree of use of working time and the amount of its actual consumption for the development of the standard. Besides, the results of the working day photography are used to improve the organization of production (organization of work and workstations), to improve the material, technical and organizational security of production, and are the starting point for the development of time standards and service standards (Baraniak, 2009; Mundel, 1973).

Elementary motion analysis, otherwise known as the MTM method (*Methods-Time Measurement*), is one of the most popular methods of normalizing the operation time. MTM was created mainly from the combination of methodological basics of studying movements and studying time. It is used to improve the workflow, determining the times of work completion and qualifying (determining the degree of difficulty) of work. MTM states that any human action can be broken down into simple elementary movements performed by the body and limbs and that the action time is the sum of the times of the movements that make up this action. There are three main groups of movements in this method: nine hand movements, two eye movements, fifteen body, and leg movements (Almeida and Ferreira, 2009; Cimino et al., 2008; Morlock et al., 2017).

Another method of working time research is *comparison and estimation*. It is often difficult or impossible to use time measurements for the piece and small-lot production, craftsmanship, maintenance, and the introduction of new products. Therefore, in such cases, times are often determined by comparison or estimation. A "comparison" is generally understood as the juxtaposition of objects or activities to establish differences or correspondence. The purpose of the comparison is to determine the course that is the closest to the one under consideration. Estimation approximates quantitative data. It is typical that estimates data can always be measured later. When estimating, the normative time for a run section is determined either from historical records or from experience (comparative estimation) (Baraniak, 2009; Mundel, 1973).

The Work-Factor method classifies movements depending on four factors: the part of the body performing the movement, the path of the movement, resistance or weight accompanying the movement, the level of development of the movement by the performer (Baraniak, 2009; Mundel, 1973).

Survey methods are mainly used in office work and to research, organize or improve workplaces. In the first case, the questionnaire is filled in with data on the type and nature of activities performed by the employees concerned. Surveys as means of organizational work of positions can be divided as into the ones serving for obtaining general information about workplaces, characterizing the environmental conditions, operating and equipping workstations, compiling activities performed at a given position (Baraniak, 2009; Mundel, 1973).

The photo-film method is a variation of the observation method, used mainly in the study of very fast-paced processes, processes inaccessible to the human eye, carried out by large teams of people and machines, etc. Filming can be performed in normal, slow or accelerated motion (Baraniak, 2009; Mundel, 1973).

Snapshot observations are an integral part of work research methods and are replacing the traditional method of working day photography. They are connected with determining the frequency of predetermined types of courses of one or more types of operating systems using randomized short-term observations. People and means of work can be observed. When using the snapshot method, no chronometer is used at all, nor is the constant vigilance of an observer at the workplace. This method is based on the use of the probability theory for both the made and recorded observations, every certain time (Aalto and Goncalves, 2019; Baraniak, 2009; Grudzewski, 1966; Mundel, 1973).

Choosing the optimal method for the set conditions and the goals it is to serve is not easy. The most widespread and recognized methods of determining time data, including assembly time, are *time measurement (timing), snapshot observation, time calculation based on process parameters, comparison and estimation, surveying and interview technique* (Ghongadi et al., 2015). In production processes, mathematical methods and self-recording devices installed at technological devices (numerically controlled machine tools, etc.) are most often used (Panasiuk and Kaczmarek, 2019). Fig. 1 shows the percentage usage of methods in production areas supporting production, storage, maintenance and logistics. Tests and measurements are used to determine the actual course and method of work performance reveal time losses resulting from the applied method of work (determination of production reserves), determine rational work methods and the necessary time of their realisation (Baraniak, 2009).

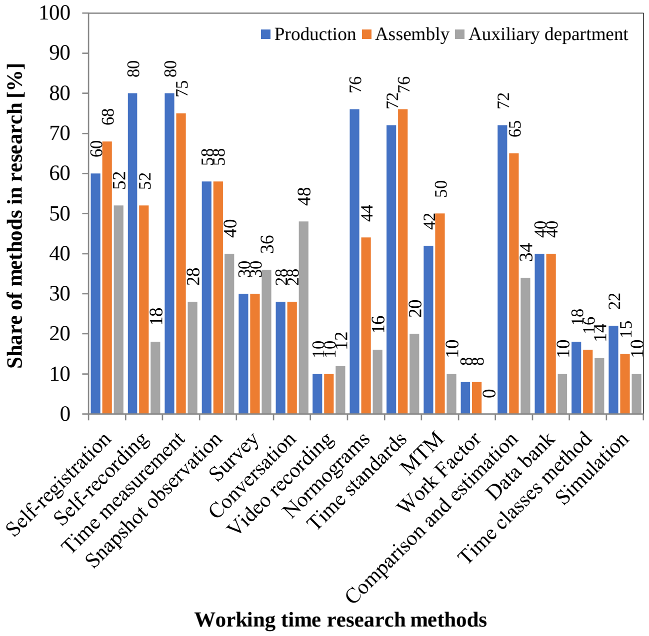

Fig. 1. Share of individual working time research methods by department in a production company (Baraniak, 2009)

3. Research methodology

The aim of the study was to make an organizational diagnosis of the level of time utilization at selected laser burner stations at the pre-treatment department in the selected plant. More specific aims was to determine the structure of the working days' time utilization, to indicate the level of time losses and their causes, and to propose improvement actions.

The object of the study was the manufacturer of trailers and bodies located in Poland. The plant produces, among others, semi-trailers, tippers, bodies, agricultural trailers, septic vehicles, spreaders. The subject of the study was the production process of semi-trailers. The observations were made at the pre-treatment department in the examined plant at selected laser burner stations. The working conditions in the plant should be considered good, the production halls are bright and spacious, and the plant has a modern machine park.

The snapshot observation method was chosen as the research method of the workstations working time because the method can be used in relation to both people and machine (the machine-manual workstations). Additionally, the analysis was subjected to a large number of workstations. The method was also chosen because of the lower costs and shorter time of data collection and analysis of results, as compared to other working time research methods (Baraniak, 2009; Mundel, 1973).

While conducting a working time study using the snapshot observation method, one should start with the division of the technique into a fraction system (two or multi-fraction) (Nesterak and Siudy, 2020). Fractions are time elements according to the classification of working time; they are the activities and their duration is clearly identifiable from the total work time fund. The two basic factions divide the working time into the "work" and "non-work" factions (Bieda and

Bieniok, 2011; Nesterak and Siudy, 2020). In the research, a multi-fraction system was used in which 10 fractions were separated (Fig 2). Their selection was determined by the characteristics of the analysed enterprise, working day organisation and types of the realised production processes. Description of the 10-fraction system (Bieda and Bieniok, 2011), which was used for a comprehensive analysis of the working time usage, is presented in Table 1.

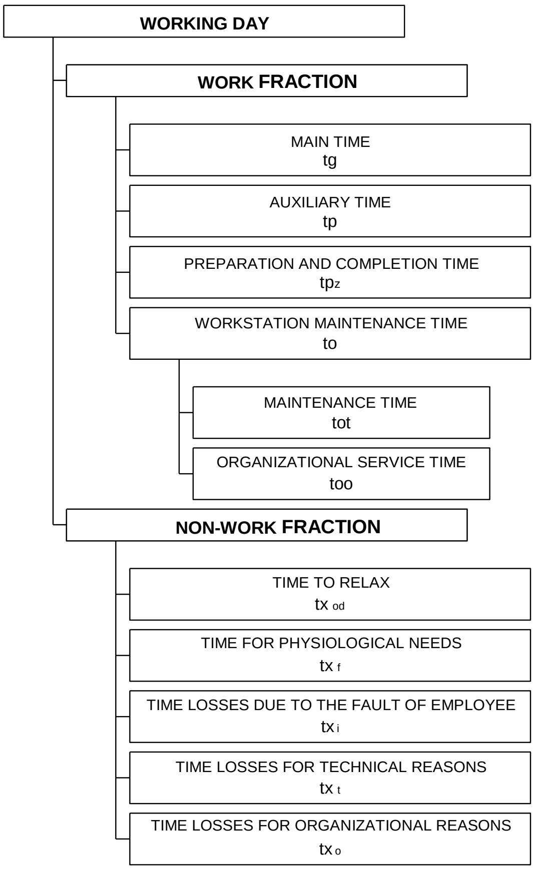

Fig. 2. Classification of working time for the snapshot observations aim

Table 1. Set of the 10 analysed standard time fractions

No.	Fraction symbol	Fraction name	Designation	Factors influencing the fraction duration
Work Fraction:				
1.	t_g	Main time	The time during which the worker performs the main technological activity, i.e. performs a technological operation on the workpiece being processed	- type of work performed, its complexity, - organization of the workstation.
2.	t_p	Auxiliary time	Time devoted to performing auxiliary technological activities that are necessary to perform the technological operation, e.g. sheet loading, program upload.	- employee experience, - employee motivation to work, - organization of the workstation.
3.	t_{pz}	Preparation and completion time	Time spent by the worker to prepare the workplace before it starts, learn how to perform the assigned work, instructions on starting a new type of production, picking up tools, tidying up the workplace afterwards, putting back tools.	- type of tools used, - place of their storage, - size and type of workstation.
4.	t_{oo}	Organizational service time	Time spent on business calls, saving work done. Training related to the launch of production of a new type.	- number of types produced, - stock at the spare parts station, - type of documentation.
5.	t_{ot}	Maintenance time	Time necessary to maintain the workstation in full technical condition, e.g. cleaning the radiator.	- complexity of the machine, - the degree of wear of the machine.
Non-Work Fraction:				
6.	t_{xod}	Time to relax	Breakfast break, leave.	- working conditions, - lighting.
7.	t_{xf}	Time for physiological needs	Employee exits	- distance from toilets and their number
8.	t_{xi}	Time losses due to the fault of the employee	Stoppages caused by an employee's poor working relationship, e.g. private interviews and breaks not provided for in the work regulations	- bad attitude of the employee to work
9.	t_{xt}	Time losses for technical reasons	Breaks caused by machine failure, lack of electricity, repairs by a mechanic	- no replaceable parts
10.	t_{xo}	Time losses for organizational reasons	Breaks caused by bad work organization, e.g. lack of raw material, errors in the program	- no synchronization of individual departments

The working time is counted from the beginning to its end and is divided into standard time and non-standard time. Standard working time is when the employee works or rests following the standards and regulations. Non-working time is unplanned breaks, disruptions in work that may be dependent or independent on the worker (Nesterak and Siudy, 2020). The division of the working day into fractionswas determined by such factors as the purpose of the research, the way of presenting the results and their accuracy, the type of work at the workstations, organizational and technical conditions of work, and the opportunities of the team conducting research and registering the research results (time, cost).

A detailed list of activities occurring in individual time fractions for the workstation of the laser cutter operator, which was the basis for analyzes, is:

- preparation and completion time (t_{pz}):
  - tidying up the workstation,
  - hiding auxiliary devices,
  - cleaning machines after work.
- organizational service time (t_{oo}):
  - business conversation,
  - writing down the work performed in the auxiliary notebook,
  - training at the workplace.
- maintenance time (t_{ot}):
  - regulating beam parameters,
  - adjusting the focal length,
  - nozzle replacement,
  - washing the lens.
- time to relax (t_{xod}):
  - breakfast.
- time for physiological needs (t_{xf}):
  - a natural need.
- time lossess due to the fault of the employee (t_{xi}):
  - private conversation,
  - smoking,
  - going out for lunch,
  - dealing with personal matters - in the HR department, or reading a press,
  - delayed start of work,
  - premature termination of work,
  - breakfast and rest (outside the time specified by internal regulations and law),
  - absence from the workplace.
- time losses for technical reasons (t_{xt}):
  - lack of energy,
  - too low air supply pressure,
  - damage to the gas nozzle,
  - repair of the machine by a mechanic,
  - test of the machine after repair.
- time losses for organizational reasons (t_{xo}):
  - no consumables at the workplace,
  - no orders,
  - lack of documentation related to the workstation,
  - going out for a mechanic,
  - no spare parts.

A fragment of the used sheet for the snapshot observations is shown in Fig. 3.

Company: ………………………… Departament: ……………………...		SNAPSHOT OBERVATIONS SHEET						Obervation no.: ……………………… Data: ………………………………… Oberver's name: ……………...……..				
No.	Workstation No.	Observed time fractions										Overall observation
		t_g	t_p	t_{pz}	t_{oo}	t_{ot}	t_{xod}	t_{xf}	t_{xi}	t_{xt}	t_{xo}	
1												
2												
…												
Calculated working time structure in%												
1												
2												
…												
	Sum											

Fig. 3. A fragment of the used sheet for the snapshot observations

In order to calculate the necessary number of observations, the following data were established: confidence level in%, accuracy in%, fraction size in% (Baraniak, 2009; Mundel, 1973). The accuracy of the measurement was assumed, i.e. the size of the relative error that is allowed for the obtained results. Determining the size of the error depends on the aim of the study; for industry, 5% was assumed (Baraniak, 2009; Mundel, 1973). The size of the fraction was determined based on preliminary studies. The number of observations was calculated from the formula (1) for each fraction, but the study was based on the value calculated for the fraction with the smallest percentage share of the preparation and completion time - 14%.

The total number of observations (n) was calculated for the confidence level of 95% from Tippett's formula (Tippett, 1982):

$$n = \frac{4\,(100 - \bar{p}) \cdot 100^2}{\bar{p} \cdot y^2} \tag{1}$$

where:
p – share of the fraction with the lowest percentage share,
y – relative error of fraction share%.

The calculated number of necessary observations was:

$$n = \frac{4\,(100 - 14) \cdot 100^2}{14 \cdot 5^2} = 9829 \tag{2}$$

The number of daily rounds (m) was calculated from the formula (Baraniak, 2009; Mundel, 1973):

$$m = \frac{n}{s \cdot d} \tag{3}$$

where:
n – total number of observations,
s – number of analysed workstations,
d – number of days that snapshot observations will be made.

The calculated number of daily rounds was:

$$m = \frac{9829}{28 \cdot 10} = 40 \quad (4)$$

Determination of the moments of starting the observation can be made by two methods: by lot way or by means of auxiliary tables, i.e. an array of random numbers or an array of spatial numbers (Baraniak, 2009; Mundel, 1973). The moments of irregular observations were determined by drawing cards marked from zero to 479. Each sheet was equivalent to one minute of a working shift. After appropriate conversion, the hours of rounds were obtained. Forty rounds a day were established: working time from 6.00 to 14.00, the time needed for one round of workstations was estimated at 4 minutes. A separate minute plan was developed for the next 10 days of the research.

During each observation, the course of the process and the operator's behaviour were carefully observed. Well-organized and qualified operators were able to use the time during the machine's operation for additional work-related activities, as well as for drinking coffee or eating a meal outside the scheduled break. The observations were recorded on the prepared sheet in the form of minutes and entered into the table (Fig. 3) at the end of each observation day. All the observed machines were placed nearby, which allowed observing all the machines simultaneously.

Research carried out on the workstations of the pre-treatment department provided information on the structure and the utilization of the working day on the analysed workstations. The percentage research results have been presented the division of the work shift into particular time fractions. For a better visual presentation and insight into data, the results were presented in the form of drawings.

Based on the observation sheets, the percentage share of each time fraction was calculated for a given type of workstation. The percentage share of each time fraction (P) was calculated from the formula (Baraniak, 2009; Mundel, 1973):

$$P = \frac{\sum a_i}{n} \quad (5)$$

where:
Σa_i – number of observations for a given time fraction during research at a given workplace,
n – total number of observations.

The percentage share of non-working time (P_1) was calculated from the formula (Baraniak, 2009; Mundel, 1973):

$$P_1 = t_{xo} + t_{xt} + t_{xi} + t_{xf} + t_{xod} \ [\%] \quad (6)$$

where:
t_{xo} – time of losses for organizational reasons,
t_{xt} – time losses for technical reasons,
t_{xi} – time of loss due to the fault of the employee,
t_{xf} – time for physiological needs,
t_{xod} – time to relax.

The percentage share of working time (P_2) was calculated from the formula (Baraniak, 2009; Mundel, 1973):

$$P_2 = t_{ot} + t_{oo} + t_{pz} + t_p + t_g \ [\%] \quad (7)$$

where:
t_{ot} – maintenance time,
t_{oo} – organizational service time,
t_{pz} – preparation and completion time,
t_p – auxiliary time,
t_g – main time.

4. Results and discussion

4.1. Utilization of the working day by individual workstations

The share of working time individual fractions at individual workstations based on the formula (5) is presented in Fig. 4.

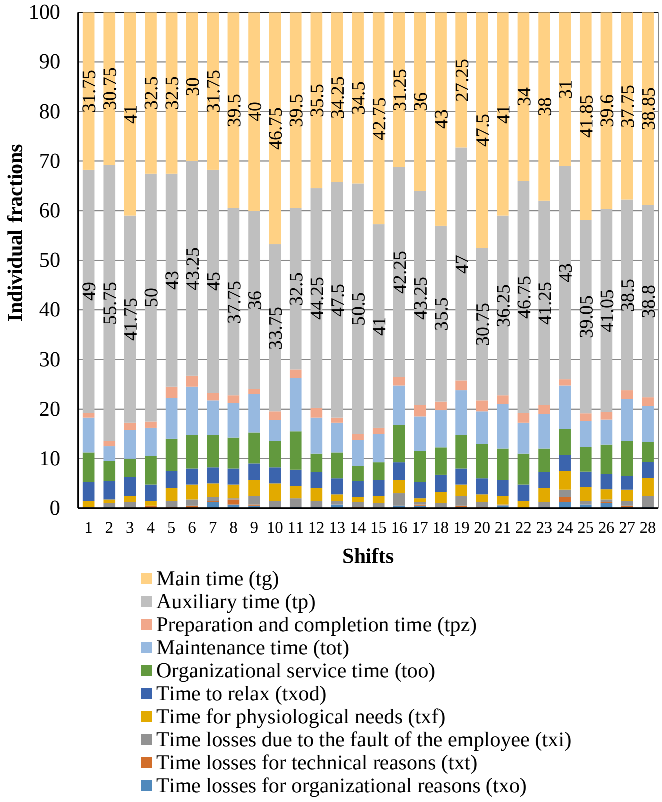

Fig. 4. Percentage share of individual time fractions on the analysed workstations

Workstations no. 4 and 22 have the highest share of the working time. The share of the working time and non-working time for these workstations was as follows:

- shift no. 4: the working time - 95.25%, the non-working time - 4.75%, the main time - 32.50%, the auxiliary time - 50.00% (Fig. 5)
- shift no. 22: the working time - 95.25%; the non-working time - 4.75%; the main time - 34.00%; the auxiliary time - 46.75% (Fig. 6).

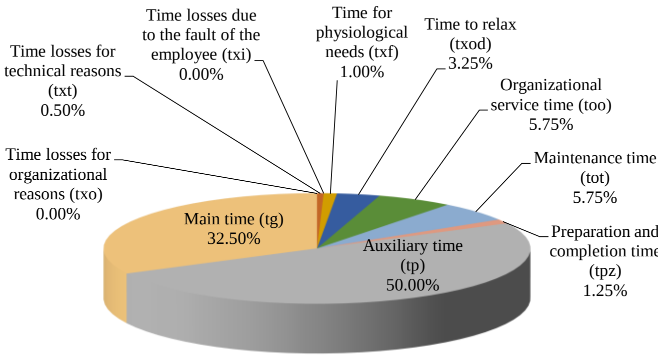

Fig. 5. Percentages of individual time fractions in shift no. 4

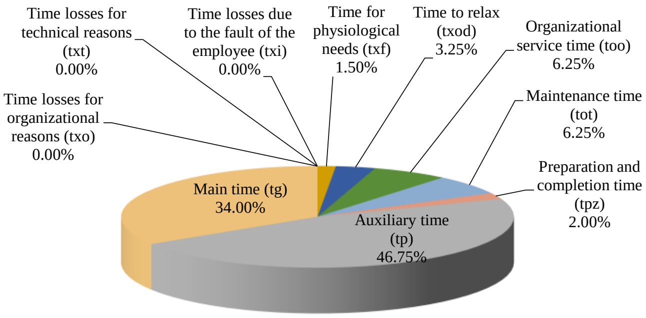

Fig. 6. Percentages of individual time fractions in shift no 22

The high share of the working time on the analysed shifts resulted from high efficiency in performing operations and the discipline of employees.

The share of the time losses for organizational reasons (t_{xo}) was mainly due to making reworks and searching for a mechanic. These losses in the preparation department ranged from 0.25% to 1.25%. The largest share of the time losses was recorded at:

- shift no. 7 and 24, where t_{xo} = 1.25%.
- shift no. 26, where t_{xo} = 1.00%,
- shifts no. 8, 13 and 25, where t_{xo} = 0.75%,
- shifts no. 9,16, 17, 21, where t_{xo} = 0.50%,
- shifts no. 2, 11, 12, 19, 23, 27, 28, where t_{xo} = 0,25%.

No losses were recorded on shifts no. 1, 3, 4, 5, 6, 10, 14, 15, 18, 20, 22.

The share of time losses due to technical reasons (t_{xt}) was not high; minor repairs and machines adjustment caused it after their repair. These losses in the examined company ranged from 0.25% to 1.00%. The largest share of the time losses was recorded:

- for shift no. 8, where t_{xt} = 1.00%,
- for shift no. 4, 6, where t_{xt} = 0.50%,
- for shift no. 5, 7, 9, 14, 17, 19, 20, 26, 27, where t_{xt} = 0.25%.

There were no time losses in other workstations. In the research period, no major breakdown was noticed.

The share of time losses due to the employee's fault (t_{xi}) was caused by the employee's inappropriate relationship to work, i.e. time wasted on private conversations, extending a cigarette break, eating, brewing coffee, leaving work early. These losses ranged from 0.25% to 2.50%. The workstations are characterized by the highest share of the time losses on:

- shift no. 16, where t_{xi} =2.50%,
- shift no. 28, where t_{xi} = 2.25%,
- shift no. 19, where t_{xi} = 2.00%,
- shift no. 9, where t_{xi} = 1.75%,
- shift no. 11, where t_{xi} = 1.75%,
- shift no. 10 i 24, where t_{xi} = 1.50%.

For shifts no. 3, 5, 6, 12, 14, 15, 18, 20, 23, 27 the time losses were in the range from 1.00% to 1.25%. For shifts no. 1, 2, 7, 8, 13, 17, 21, 25, 26 the losses were below 1.00% (from 0.25% to 0.75%). The time losses due to the employee's fault were not noted in shifts no. 4 and 22.

4.2. Utilization of the working day due to the machines type

The differences in the percentage shares of working time and non-working time for particular types of machines were insignificant. For burner no. 6, the percentage share of working time was the highest and amounted to 93.65%, and for burner no. 5, it was the lowest and amounted to 92.25%. The highest percentage share of time losses due to organizational reasons occurred for burner no. 5 and amounted to 0.42%, and the lowest one was for burner no. 6 and amounted to 0.13%. Burner no. 5 was also characterized by the highest percentage value of time losses for technical reasons amounting to 0.42%. The time losses due to the employees' fault were the highest for those who were working on burner no. 5 and amounted to 1.25%. The smallest percentage share of time losses due to the employees' fault (1%) was recorded for employees operating burners no. 1-4. It was related to the high work discipline in these workstations. The smallest percentage share of main time occurred also for burners no. 1-4 and amounted to 36.22%, which was related to short stitching (short cutting programs). The utilization level of the working day depending on the analysed machines type was shown in Fig. 7.

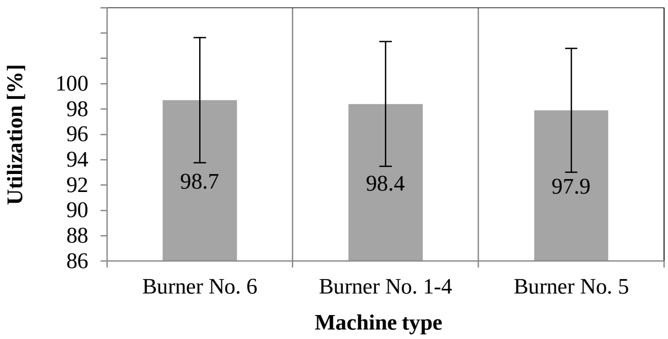

Fig. 7. The level of the working day utilization depending on the type of machines

The working day utilization rate for individual burners was as follows: no. 6 - 98.71%, no. 1-4 - 98.43%, no. 5 - 97.92%. The percentage share analysis of the working time and non-working time showed that the type of machines had no major impact on the working day utilization level.

4.3. Utilization of the working day due to days of observation

The utilization of the working day in the following days of observation was presented in Fig. 8.

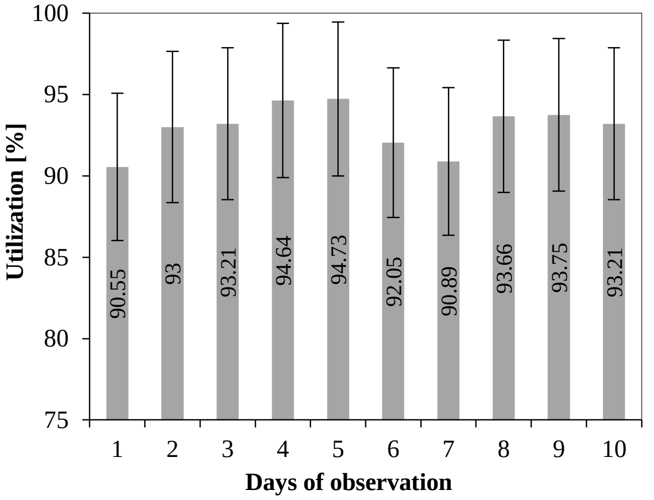

Fig. 8. Utilization of the working day in the following days of observation

The average share of working time in all the examined workstations was 92.97%. The largest share of working time occurred on the fifth day of observation and amounted to 94.73%, and the lowest on the first and seventh day of observation and amounted to 90.55% and 90.89%, respectively.

4.4. Working and non-working day utilization rate due to shifts

The working day utilization rate analysis on single shifts was done based on formulas (6) and (7) and presented in Fig. 9.

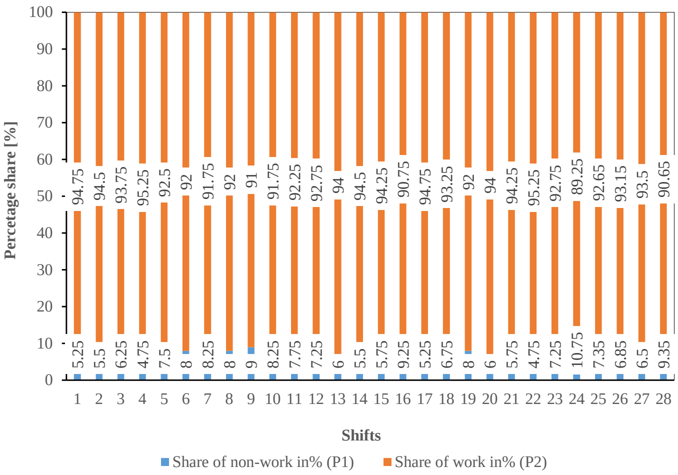

Fig. 9. Utilization of the working day in the following shifts

The utilization of the working day on individual shifts varied and ranged from 95.25% to 89.25%. Shifts no. 4 and 22 were characterized by the working day utilization index of P_2 = 95.25%. The following shifts were also characterized by a high rate of working day utilization: no. 1 and 17, where P_2 = 94.75%, no. 2 and 14, where P_2 = 94.50%. Shifts no. 21 and 15 were characterised by the index P_2 = 94.25%. The lowest rate of the working day utilization was shown by shift no. 24, where P_2 = 89.25%. The reason for the lowest value of the index in this workstation was the employee's inexperience resulting from the short period of employment, also inappropriate motivation to work.

4.5. The average share of individual time fractions, work, and non-work fraction

The result of the analysis of the average share of individual time fractions (P), non-work (P_1) and work (P_2) fraction was shown in Fig. 10.

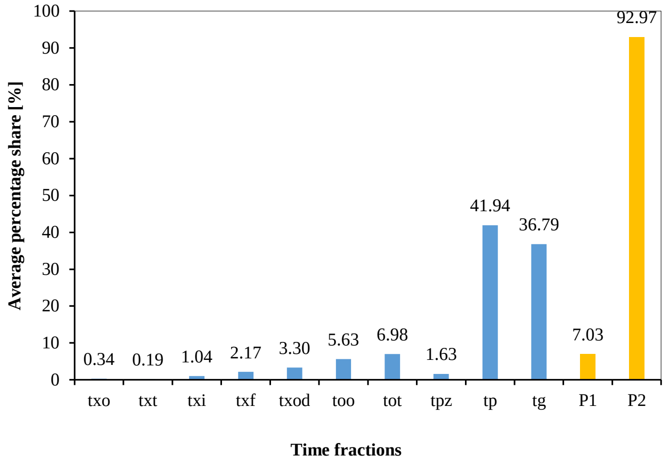

Fig. 10. Average share of individual time fractions, non-work (P_1) and work (P_2) fraction

The average percentage share of working time (P_2) for all shifts was quite high and amounted to 92.97%. The shifts that significantly exceeded the P_2 value were following 1, 2, 3, 4, 13, 14, 15, 17, 20, 21, 22, 26, and 27 (13 from 28, 46.43% all shifts). Taking into account the type of machines, the average share of working time was exceeded by burner no. 6 - 93.65%. The lowest working time utilization was on shift no. 24 and amounted to P_2 = 89.25%. Significant differences in the working time share were caused by different operators' qualifications and the skill in selecting work parameters acquired by many years of practice.

The average value of main time (t_g) was 36.79%. The auxiliary time (t_p) at individual workstations was much higher than the main time, on average by 5% (41.94%). This was mainly due to the cutting of thin sheets and the complexity of the production process.

The average value of maintenance time (t_{ot}) was high and amounted to 6.98%, which should be justified by a large number of pieces and various types of sheet metal in the patterns produced. Operators often had to change cutting parameters and nozzles, which increased the value of this time fraction.

The average share for organizational service time (t_{oo}) was 5.63%. Such the percentage value of the fraction time was caused by business calls that occurred quite often due to urgent orders and necessity leaving the workplace to took work orders and recorded the activities performed. Although the technological conditions were unchanged and carefully developed, they were often neglected due to the haste and routine of some employees during quality assessment by visual inspection (Knop, 2020). This was the reason for nonconformities and, consequently, the necessity to make reworks. Level of product quality (Siwiec and Pacana, 2021) measured by six sigma metric - First Time Yield (FTY) indicator (Borkowski et al., 2012) certainly was decreased.

The average share of time losses caused by the fault of employees (t_{xi}) was 1.04%. Losses due to the employee's fault often indicated a lack of work motivation. They most often occurred for the following reasons:

- extending the break,
- leaving the workplace to arrange private matters,
- improper attitude to the work performed, and hence the need to rework defective pieces,
- leaving work early.

The factors that were increasing the percentage share of the work fraction include:

- fulfilment of the production contract for the recipient,
- high quality requirements,
- discipline of employees at most workstations,
- assisting by apprentices in preparing workstations for work.

5. Summary and conclusion

The analysis of the use of the working day based on snapshot observations on the tested group of laser burners showed that analysed workstations and operators' teams were characterized by a high level of the utilization rate of working time. The high discipline of the whole operators during work was showed despite the uncertain future. Research results were indicated that the ratio of the main time to the auxiliary time was an unfavourable phenomenon that was shorter on average, by approx. 5%, which was caused by the specificity, and complexity of the production process itself caused it. Indicated also differences in the working time utilization on the analysed machines, which were caused by different operators' qualifications, and the skill in selecting work parameters acquired by many years of practice. Research results emphasized that employees' inexperience resulting from the short period of employment and inappropriate motivation to work was the reason for the lower value of the working day utilization index due to shifts. A respectively high share of the maintenance time fraction due to a large number of pieces and various types of sheet metal was noticed and unfavourable impact of organizational service time on the working time due to business calls, haste, and routine of some employees. Research results also indicated that losses due to the employees' fault resulted most often from a lack of work motivation.

In order to reduce the loss of time and improve the use of working time on a working day, organizational and technical changes are necessary, as well as changes aimed at improving employee motivation and commitment to the work performed. Trainings realised by the most experienced employees and a better motivation system will be necessary. Implementation of lean concept tools such as work standardization (Mor et al., 2019), visual control system, performance indicators in the supply chain (Mor et al., 2018), and OEE indicator can also bring the expected results in the form of reduction of time losses and improving the index of working time utilization and the general organizational efficiency and effectiveness.

It needs to be highlighted that minor disruptions to workflow are rather inevitable. Their elimination requires actions aimed at detailed monitoring of these short time losses and define their causes. The implementation of MES and CMMS systems to production monitoring and control in the analysed company can help solve this problem. Those systems will allow for continuous monitoring of production processes and obtaining relevant information about them and providing them to operators and employees of the maintenance department in real time. Due to those systems, it will be possible to immediately react to any undesirable phenomena such as short time losses. To reduce time losses to a minimum, a great commitment of the maintenance department and machine operators is required. Systematic and daily work performed by these groups of workers should be connected with the performance of tasks to prevent degradation in the quality of machine and devices work and the occurrence of failures or, if they occur - to remove them in a fast and durable way.

Snapshot observation, like any other method of work time study, has its advantages and disadvantages as well as limitations that researchers must be aware of before using it. The article highlighted the benefits of using it consisting of an indication of the weak points in the process due to the level of time losses. Not all losses certainly can be eliminated immediately, it requires time and organizational and technical changes, and improvement in the motivation system, but the very view of the scale of the problem and its causes was a great benefit from the use of this method by the examined company.

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分析机器的工作时间利用率以进行改进

關鍵詞
工作时间管理
工作时间学习
工作时间法
快照观察
时间损失
改进

摘要
本文是使用快照观察的案例研究，以分析导致选定激光燃烧器站时间损失的因素，并提出可以增加工作时间有效利用的变化。本文的目的是确定在所检查的工作场所中最佳和最差的工作时间利用率，分析损失的时间量并找出造成损失的原因，并提出可提高工作时间利用率的解决方案。根据快照观察，区分了工作日中的步骤 2 主要-工作时间和非工作时间分数以及 10 个详细时间分数，并计算了它们在所分析工作站中的百分比。根据机器类型，观察天数，单班制，分析工作日时间利用率，并对所选结果取平均值。本文指出，组织和技术方面以及员工的过失是造成时间损失的主要原因。研究表明，经过广泛检查的工作站组的特点是工作时间利用率高。不利的现象是主要时间与辅助时间之比，工作站维护时间比例的高比例，互操作运输的组织不正确，工人的积极性，仓促性和日常性低。发现要进一步提高工作效率和减少时间损失，需要注意优化员工的工作条件，培训，激励系统，并在生产中实施精益概念工具和 MES / CMMS 解决方案。