Bożena SZCZUCKA-LASOTA
Politechnika Śląska
Wydział Transportu
Katedra Logistyki i Technologii Lotniczych
bozena.szczucka-lasota@polsl.pl

Radosław WOLNIAK
Politechnika Śląska
Wydział Organizacji i Zarządzania
radoslaw.wolniak@polsl.pl

USE OF SOME QUALITY TOOLS FOR OPTIMALISATION OF EXCHANGE GRINDING WHEEL PROCESS

Abstract. The selected quality tools were used in the organization to optimize the process of exchange of the grinding wheel. Test study, conducted in the organization indicated that the wheel may be changed every 270 hours of continuous operation. The use of the calculated cycle in practice has increased the number of manufactured products in the case of non-conforming products. The problem has been solved by using quality tools and analysis of the obtained results. For this purpose, we conducted: brainstorming, Pareto-Lorenz analysis and implemented the Sheward's Charts. The results of the research has helped to identify the causes of the differences arising between the testing process and the actual course of the grinding process and to determine the optimum operating times for each wheel positions.

Keywords: quality of supply, the control plan and research, production, quality tools

1. Introduction

Customers are demanding higher quality product at the lowest possible price, therefore, organizations are seeking to reduce manufacturing costs while maintaining a sufficiently high quality of products. Situation requires proper optimization of processes so they should have the least possible losses level associated with their material and energy consumption and performance of machines and equipment[1]. Since the technologies, products and requirements change, technologists have less and less time to get to know the process and optimize it based solely on their own experience[2]. It turns out that conducted testing process does not always produce the desired results. Bad chosen the wrong boundary conditions in the optimization process may cause the generation of non-compliance in the company and bring profits instead assumed serious financial losses. The same dilemma faced the company, which after the optimization of the grinding wheel replacement on the basis of the research results of the test increased the number of manufactured of non-conforming products. To solve the problem organization established research team, whose goals were: to identify the number and type of generated inconsistencies, determine their causes and develop corrective actions. An additional objective was to reduce production costs in relation to the cost before the introduction of the wrong optimization process.

2. Optimization of the process of exchanging the grinding wheel – preliminary study

The grinding wheel is composed of two materials. The first one of these is the steel hub with a diameter of Ø 250 mm, by means of which the wheel is attached to the spindle. The second one has a suitable size, grain abrasive dusted on the hub outer diameter. The diameter of the circle is the whole diameter of Ø 300 mm.

Grinding wheel is made in a very precise way. Balance of the wheel is carried out in an almost ideal manner, because the slightest wrong balance will "beat" the spindle, and consequently vibration of the machine. During operation, the wheel is rotated at a speed of 25000 rev/min. Vibration determine the quality defects of the product and can lead to damage

[1] Kamen A., Olivier H.: Development and optimization of an adenovirus production process. "The Journal Of Gene Medicine", Vol. 6, S1, 2004, p. 184-192; Benneyan J.C., Lloyd R.C., Plsek P.E.: Statistical process control as a tool for research and healthcare improvement. "Quality and Safety in Health Care", Vol. 12, No. 6, 2003, p. 458-464; Omar M.H.: Statistical process control charts for measuring rating consistency over time. "Technical Report", No. 378, 2007.

[2] Farr A.J., Kathleen P.F.: Quality control validation, application of sigma metrics, and performance comparison between two biochemistry analyzers in a commercial veterinary laboratory. "Journal of Veterinary Diagnostic Investigation", Vol. 20, No. 5, 2008, p. 536-544; Kulkarni V.G.: Modeling and analysis of stochastic systems. CRC Press, 2016, p. 6-23; Mazur A., Gołaś H.: Zasady, metody i techniki wykorzystywane w zarządzaniu jakością. Wydawnictwo Politechniki Poznańskiej, Poznań 2010; Skotnicka-Zasadzień B.: Doskonalenie procesu produkcyjnego w przedsiębiorstwie przemysłowym z zastosowaniem metod projektowania jakości. [w:] Knosala R., Jonecko K. (red.): Statystyczna kontrola jakości jako narzędzie wspomagające wprowadzenie zmian w procesie szlifowania. WSZOP, Katowice 2017, promotor B. Szczucka-Lasota; Innowacje w zarządzaniu i inżynierii produkcji. Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją, Opole 2013; Wolniak R., Skotnicka-Zasadzień B.: Zarządzanie jakością dla inżynierów. Wydawnictwo Politechniki Śląskiej, Gliwice 2010; Wolniak R.: Relationship between selected lean management tools and innovations. Zeszyty Naukowe Politechniki Śląskiej, s. Organizacja i Zarządzanie, z 75, Gliwice 2014, s. 157-266; Wolniak R., Skotnicka B.: Metody i narzędzia zarządzania jakością – Teoria i praktyka, cz. 1. Wydawnictwo Naukowe Politechniki Śląskiej, Gliwice 2011.

to the machine. A wheel manufacturer, ensures that the tool to the point at which the outer diameter due to wear drops below Ø 270 mm, which corresponds to approx. 200 hours of continuous operation, after which the wheel is discarded.

The cost of a new grinding wheel is the amount of 20 000 zł. Preliminary analysis shows that attempts to regenerate the used wheels are unprofitable. The cost is estimated at more than 15 000 zł. In addition, the used wears regenerate faster than the original. For the estimated costs we not included the costs of collection and transport of used wheels.

2.1. Preliminary tests

Preliminary testing in the company of the four positions, in which were mounted grinding wheel, we selected one on which the study was conducted. The study involved testing the monitored operation in the case of grinding wheel.

In the first stage the wheel worked in accordance with the manufacturer's instructions, ie. 200 h. After this, the measurements of thickness of wear on the wheel were conducted. It also examined whether the elements are produced in accordance with the specification (technical drawing).

In a next step wheel worked over time assumed by the manufacturer. We measure the thickness of the abrasive layer in time and monitored quality of products, in terms of their compliance dimensional.

2.2. Results of preliminary tests

Measurements made in preliminary test allow us to conclude that after 200 hours of work on the wheel remains 20 mm abrasive material that could be used, before the wheel is replaced.

The result obtained in the station 1 indicates that the wheel can operate for 270 hours. Following work time for 70 hours does not affect the geometry of the obtained products. The result confirms that the life of the serviced wheel is about 70 hours longer than originally assumed by the manufacturer. By contrast, over 270 hours of working in the case of the grinding wheel, manufactured products do not meet the initial requirements dimension, despite the fact that on the wheel remains the abrasive layer (having a thickness of 2 mm). For safety, it was assumed that the wheel manufacturing process can be operated 260 hours, about 10 hours or less, than the time of the test.

2.3. Production of non-conforming products

Results of preliminary tests influenced the decision-making process of the Supreme Executives, which in all positions ordered the replacement of the grinding wheel after 260 hours of operation.

Table 1

Number of non-conforming products before and after the extension of the life of the grinding wheel

	Time					
	Before changes					After change
	5 month before	**4 month before**	**3 month before**	**2 month before**	**1 month before**	**1 month after**
Number of pieces, including :	44643	44437	43854	44222	44125	44544
Number NG [number]	36	32	12	20	35	**1003**
Number NG [%]	0.08%	0.07%	0.03%	0.05%	0.08%	**2. 25%**

Source: Jonecko K: Statystyczna kontrola jakości jako narzędzie wspomagające wprowadzenie zmian w procesie szlifowania. WSZOP , Katowice 2017, promotor B. Szczucka-Lasota

Analysis of the data from the register of non-conforming products indicates that the extension of working wheels on machines for 60 hours increased the number of manufactured products not complying with the requirements (Table 1).

The results of the test there is in Table 1. The results indicate that the longer the life of the wheel the quantity of manufactured non-conforming goods increased significantly. Before making changes to this amount was less than 1%, the changes contributed to an increase in non-compliant products in excess of 2%.

3. Purpose and scope of the study

The test results presented in Chapter 2 formed the basis for the formulation of the research problem, which is to determine the causes of non-compliance and the optimal time of the exchange the grinding wheel.

To do this, they set up a team, conducted brainstorming, analysis of Pareto-Lorenz, those types of non-compliance and their percentage and the number of irregularities produced on the machine. In the process it was implemented Seward's Cards. In the next steep the analysis of the obtained results was conducted.

The article presents selected results of the analyzes, which helped to identify the causes of the differences arising between the initial testing process and the actual course of the grinding process and to determine the optimum operating times for each wheel positions and also contributed to the elimination of inconsistencies in the production process. Also the publication outlines the action that caused the reduction of cost of production in the process of grinding parts.

4. The results of research

According to the data (Table 1 – chapter 2) the quantity of non-conforming elements was 1003 pieces. First, we appointed a team that set a schedule of activities. According to the schedule in the first we determined the nature and causes of discrepancies produced. As a result of the data analyzed, it was found that almost 98% of non-compliance are disadvantages associated with the wrong dimensions (Figure 1). As a result of brainstorming, it was found that the cause of the changes in working time and period of grinding wheels. These defects were registered only after changes in the technological process. Previously, this type of defect is not recorded. The amount of the remaining types of non-compliance was 23 pieces. This result is consistent with the data obtained in the months preceding the change.

Analysis of the data on the figure (Figure 1) clearly indicates that changing the time interval for operating the wheel has adversely affected the geometry of the products obtained.

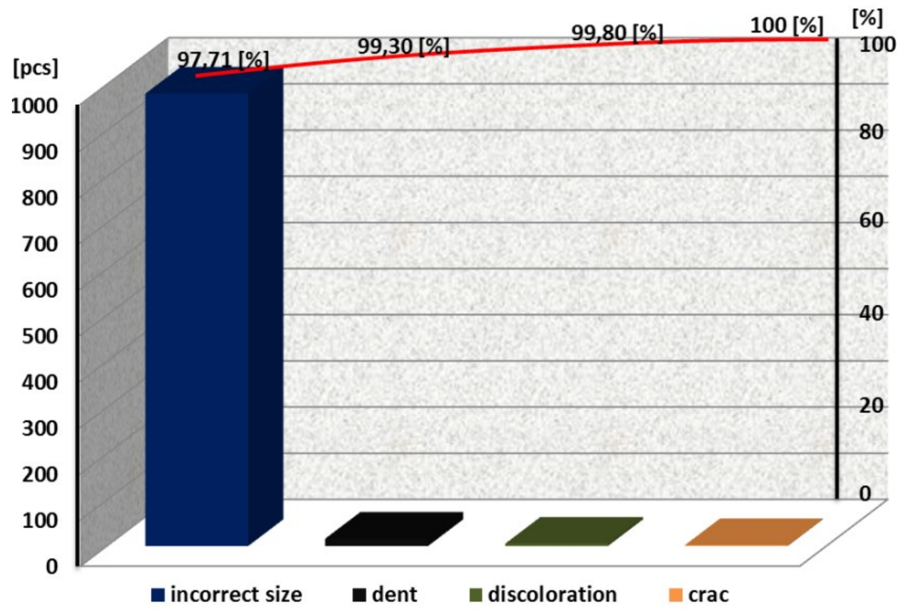

Fig. 1. Incorrect type of products – Pareto-Lorenz chart
Source: Own work based on: Jonecko K: Statystyczna kontrola jakości jako narzędzie wspomagające wprowadzenie zmian w procesie szlifowania. WSZOP, Katowice 2017, promotor B. Szczucka-Lasota.

Further studies deal with the limited analysis of disadvantages associated with the wrong dimensions. Using data from the registry inconsistencies we developed diagram (Fig. 2) and established as non-compliant elements from a given position.

On this basis, it was found that more than 50% of the defects from the wheel marked No. 4, mounted on the post production of filters of oval shape. The level of defects in other machines is similar and comprised between 16 and 17%. The results clearly show that the change in criteria for the exchange of grinding wheel had a negative impact on the production process and the highest percentage of non-compliant products is from the machine 4. It can therefore be concluded that the replacement of wheels should occur much earlier.

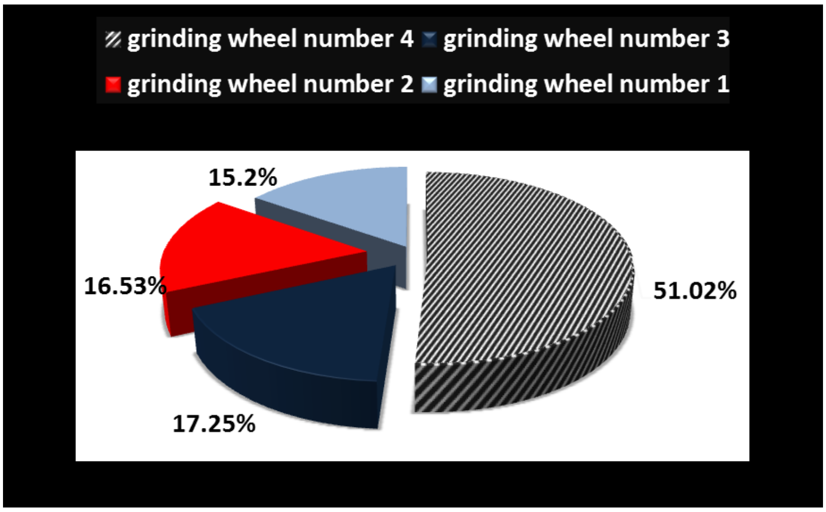

Fig. 2. Number of elements inconsistent dimensionally manufactured by a particular grinding wheels
Source: Own work.

The results also indicate that the initial tests did not take into account the machines on which the wheel is mounted. Number of non-compliant elements from the machine 4 is much higher than from the others. This machine is designed for the production of oval, and not, as assumed in the test round parts.

In order to determine the most optimal lifetime of the wheels, the company implemented the methods of statistical process control, based on the cart mean and chart range. Analysis of the range cards indicates that the repeatability of the process is maintained and is normal.

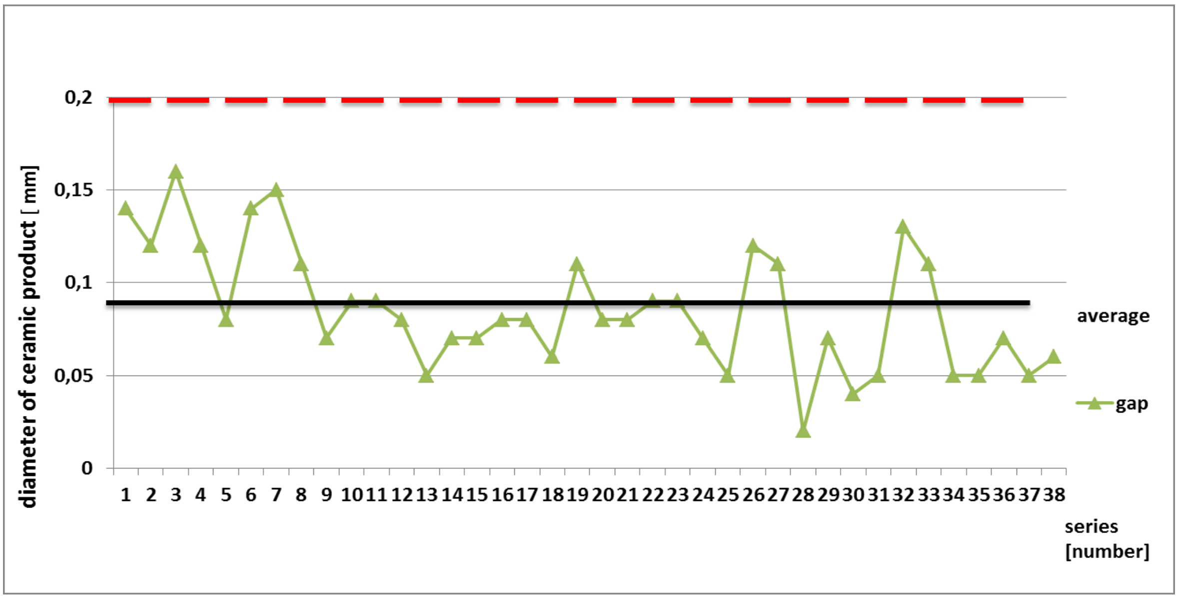

Fig. 3. Range cart measuring external diameters of ceramic filters
Source: Own work.

Range cards did not indicated disorder in the process. Therefore further in the next part of the publication we only show the measurement results recorded and the average card, which clearly point to the need to replace the grinding wheel. Figure 4 shows the recorded dimensions of the filters in the subsequent series of measurements. These series show that the process is stable and is comparable for each measurement series. For the 5 series of measurements we plotted the graph of averges, applied to the control limits and warning lines (Figure 5).

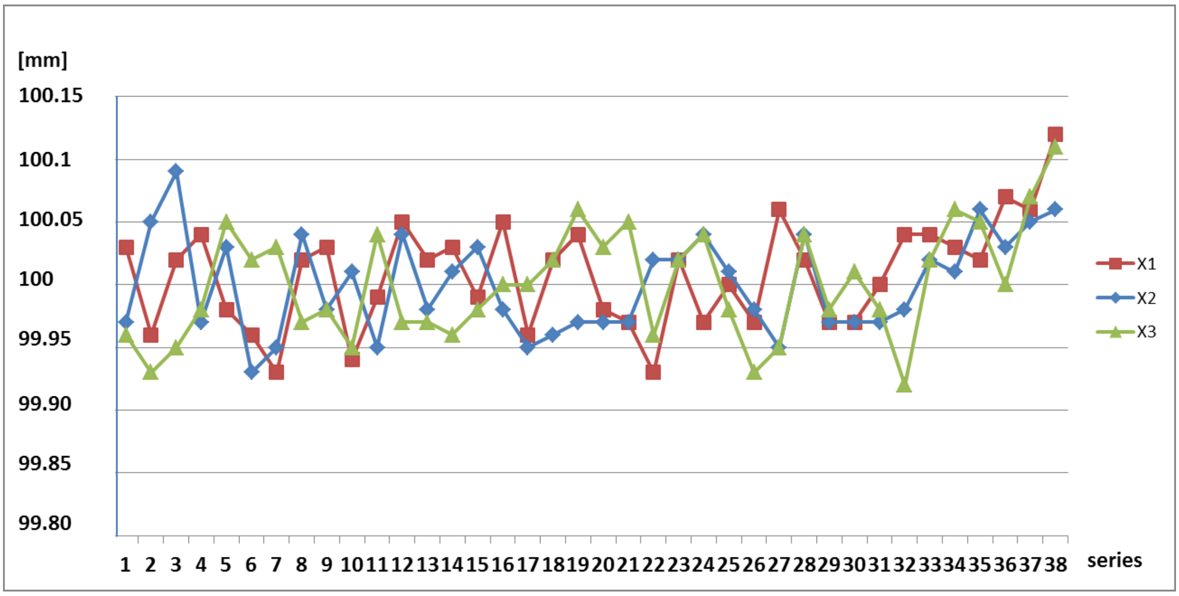

Fig. 4. Examples of recorded 3 consecutive measurement series
Source: Own work.

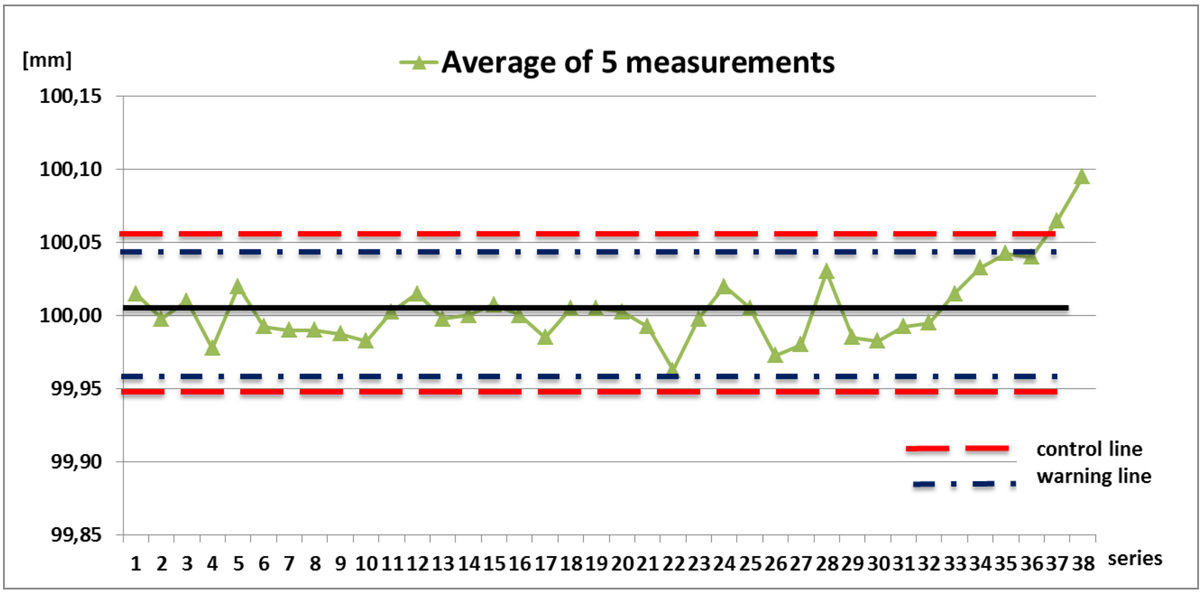

Fig. 5. Average of 5 series
Source: Jonecko K: Statystyczna kontrola jakości jako narzędzie wspomagające wprowadzenie zmian w procesie szlifowania. WSZOP, Katowice 2017, promotor B. Szczucka-Lasota.

Analysis of the averages card, indicating that the measurement series no. 35 the process was stable and was not observed at that time no irregularities. Measuring points contained between the lines warning, which confirmed that the process is carried out in a proper manner. In a series of 36 there was a sharp increase in the external dimension of the product (surface treated) until the crossing in 36 measurement series, the upper warning line, and ultimately in a series of 38 of the upper control line. This is the effect that a direct result of consuming the tool of a grinding wheel.

The results show that after 36 measurements (corresponding to 240 hours of work), the adverse effect of consumption of the grinding wheel on the workpiece. On this basis, it can be concluded that the wheel must be replaced after 240 hours of operation.

5. Conclusion

As a result of the study we found that:

1. Most non-compliant elements were produced on the machine 4. In this machine the grinding wheel will be replaced every 200 hours, according to the manufacturer's instructions.
2. Introduction of average cards and range cards allowed to determine the time allowed for safe use of the grinding wheel. This time is set at 240 hours. Until then, the abrasive wear on the wheel does not affect the quality of the manufactured items.
3. It was agreed that the wheel in grinding machines 1-3 will be exchanged after working 36 production shifts (240 hours).
4. Four wheel removed from the machine after 200 hours of operation will not be disposed of, but used for one of the other machines, to be worked 240 hours.

The conducted analysis of the data allowed the optimization in the case of management of the process of grinding, including: detecting interference in the process of finding the cause of the problems affecting the quality of our products, allowed to choose the optimal settings for the process and manufacturing processes compared to the 4 positions.

Table 2

The estimated costs of replacing the wheels on machines 1-3

	Original state – working wheel 200 hours	**State after the introduction of changes in technology – work wheel 240 hours**
The cost of the new wheel	20000	20000
Work time [h]	200	240
Work time [days]	10	12
The number of work days in a year	252	252
The number of exchanged wheels in a year	25	21
The estimated cost of replacing the wheels in a year	500 000 (for 1 machine) 1 500 000 (for 3 machines)	420 000 (for 1 machine) 1 260 000 (for 3 machines)

In the comparison of costs presented in the paper, we compare costs before the introduction of optimization and after the optimization process; involving the exchange of the grinding wheel after 240 h. But it does not take into account the possibility of using the wheels of the machine 4, which should also contribute to savings in the company (Table 2). As a result of optimizing the production process the annual savings for the company is estimated at over 240 000 zł in relation to its original state. This is confirmed by calculation presented in the table 2. It is noted that less frequently replacing the wheels also lowers equipment downtime and production. So real savings for the company are higher than the results directly from the data presented in Table 2.

Bibliography

1. Kamen A., Olivier H.: Development and optimization of an adenovirus production process. “The Journal of Gene Medicine”, Vol. 6, No. S1, 2004, p. 184-192.
2. Benneyan J.C., Lloyd R.C., Plsek P.E.: Statistical process control as a tool for research and healthcare improvement. “Quality and Safety in Health Care”, Vol. 12, No. 6, 2003, p. 458-464.
3. Omar M.H.: Statistical process control charts for measuring rating consistency over time. “Technical Report”, No. 378, 2007.
4. Farr A.J., Kathleen P.F.: Quality control validation, application of sigma metrics, and performance comparison between two biochemistry analyzers in a commercial veterinary laboratory. “Journal of Veterinary Diagnostic Investigation”, Vol. 20, No. 5, 2008, p. 536-544.
5. Kulkarni V.G.: Modeling and analysis of stochastic systems. CRC Press, 2016, p. 6-23.
6. Mazur A., Gołaś H.: Zasady, metody i techniki wykorzystywane w zarządzaniu jakością. Wydawnictwo Politechniki Poznańskiej, Poznań 2010.
7. Skotnicka-Zasadzień B.: Doskonalenie procesu produkcyjnego w przedsiębiorstwie przemysłowym z zastosowaniem metod projektowania jakości, Knosala R. (red.).
8. Jonecko K: Statystyczna kontrola jakości jako narzędzie wspomagające wprowadzenie zmian w procesie szlifowania. WSZOP, Katowice 2017, promotor B. Szczucka-Lasota.
9. Innowacje w zarządzaniu i inżynierii produkcji. Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją, Opole 2013.
10. Wolniak R., Skotnicka-Zasadzień B.: Zarządzanie jakością dla inżynierów. Wydawnictwo Politechniki Śląskiej, Gliwice 2010.
11. Wolniak R.: Relationship between selected lean management tools and innovations. Zeszyty Naukowe Politechniki Śląskiej, s. Organizacja i Zarządzanie, z. 75, Gliwice 2014, s. 157-266.
12. Wolniak R., Skotnicka B.: Metody i narzędzia zarządzania jakością – Teoria i praktyka, cz. 1. Wydawnictwo Naukowe Politechniki Śląskiej, Gliwice 2011.