Eleonóra BIGOŠOVÁ[1], Miroslava BARBUŠOVÁ[2]

Supervisor: Ľuboslav DULINA[3]

ZWIĘKSZENIE TRWAŁOŚCI NARZĘDZIA Z WYKORZYSTANIEM METODY DOE ORAZ OPROGRAMOWANIA MINITAB

Streszczenie: DOE (design of experiments) to jedno z najskuteczniejszych narzędzi usprawniających procesy. Wykorzystanie metody DOE do zwiększenia trwałości wymiennych płytek skrawających, jak opisano to w niniejszym artykule, jest jednym z przykładów pokazujących sposób praktycznego zastosowania tej metody oraz możliwości zwiększenia zysku firmy.

Słowa kluczowe: DOE, trwałość, wymienna płytka skrawająca

INCREASING TOOL LIFE USING THE DOE METHOD AND MINITAB SOFTWARE

Abstract: DOE (design of experiments) is one of the most important tools for improving processes. Using the DOE method to increase the removable cutting plate life, as describe this article, is one of the ways to apply this method in practice and to increase the profit of the business.

Key words: DOE, durability, removable cutting plate

1. Design of Experiment

DOE is a systematic approach that allows you to find mutual relationships between the different factors that affect the process or system. This method employs a scheduled series of organized attempts to change these factors. A good experiment should consist of the minimum number of iterations required to obtain the necessary information. Traditionally, experiments are implemented in laboratories, industrial

[1] Eleonóra Bigošová, Žilinská univerzita v Žiline, Strojnícka fakulta, Katedra priemyselného inžinierstva, Univerzitná 8215/1, 010 26 Žilina, eleonora.bigosova@fstroj.uniza.sk
[2] Miroslava Barbušová, Žilinská univerzita v Žiline, Strojnícka fakulta, Katedra priemyselného inžinierstva, Univerzitná 8215/1, 010 26 Žilina, eleonora.bigosova@fstroj.uniza.sk
[3] Ľuboslav Dulina, Žilinská univerzita v Žiline, Strojnícka fakulta, Katedra priemyselného inžinierstva, Univerzitná 8215/1, 010 26 Žilina, luvoslav.dulina@fstroj.uniza.sk

plants or in the agricultural area. The DOE method is a summary of activities that divided into five stages:

- Planning (preparation) of the experiment.
- Custom design experiment.
- Performing an experiment.
- Analysis of results.
- Application of results. [3]

1.1. Minitab

Currently, there are different experiment planning programs that we can use. The practical part of the article is developed using the Minitab software. Minitab has developed statistical software that offers a wide range of quality control tools, basic and advanced statistical methods, and experiment planning. At present, Minitab's statistical software employs thousands of manufacturing and transaction companies around the world to detect deficiencies and improve their processes and manage them. This software has become popular especially for its easy operation. It offers coverage of all statistical tools used in the Six Sigma methodology. In addition to the practice, software is also used in the academic sphere at over 4,000 universities and universities. [1,4]

2. Application of the DOE method at the workplace of turning

The workplace of turning on which the technological test was performed is characterized by the machining of the outer rings of the wheel bearings for the automotive industry. Before to use the DOE method, durability of the removable cutting plate at this workplace was 50 pieces of workpieces. The goal was to achieve the durability of a removable cutting plate up to 100 pieces of workpieces per cutting edge, using the DOE method, which will also represent the tool change interval. [3, 5]

A standard business document that includes all the DMAIC cycle phases was used to design a durability solution for the replaceable cutting plate. It is incrementally supplemented with data according to the time course that was defined in the first phase of the cycle. [2,5]

2.1. Define

In this phase was defined a problem. The aim of the project and the time range were also determined. The aim of the project was to increase the durability of the replaceable cutting plate at the workplace of turning. The biggest problems related to the low durability of the removable cutting plate are:

- The machine is machining fewer pieces.
- Increased tooling.
- The occurrence of a greater number of delays due to frequent VRP exchange.

2.2. Measurement

The measurement phase serves to evaluate the current state of durability of the replaceable cutting plate. The collection of input data of durability of the removable cutting plate was carried out, and the Minitab software graphically evaluated these data.

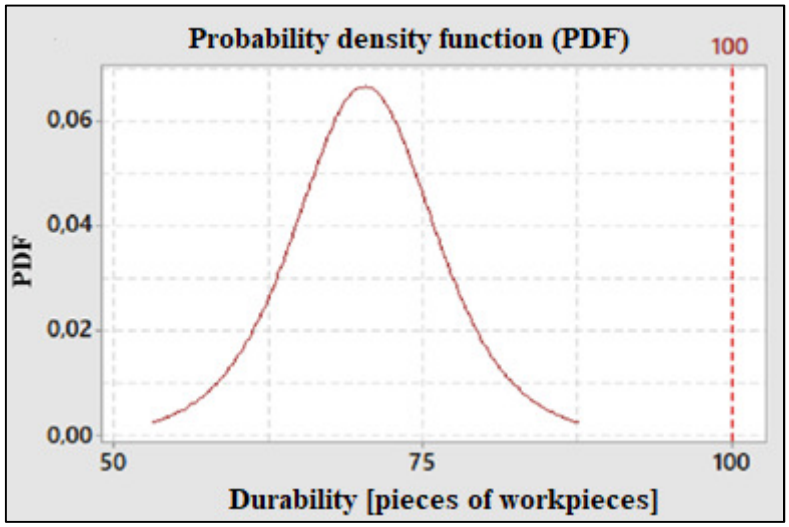

Figure 1. Probability density function – current state (output from Minitab)

Table of Cumulative Failure Probabilities

		95,0% Normal CI	
Time	Probability	Lower	Upper
100	0,999635	0,996534	0,999962

Figure 2. Table of probability before using DOE (output from Minitab)

From the graph and data that Minitab has evaluated, it can be seen the 99.96 % probability that 100 pieces per cutting edge do not machined no one removable cutting plate. It follows that the aim of 100 pieces of workpiece per cutting edge cannot be achieved. Even though the aim is not met, the project continued, because any increase in durability of the replaceable cutting plate will have a positive impact on the cost savings of this tool.

2.3. Analysis

In the analysis phase, it is important to look for possible causes that create a problem. In table. 1, it can be seen all the parameters that affect the surface of workpiece. Each parameter represents 1 row of the turning program. The parameter boundaries are divided into three levels:

- Level -1 represents the lowest boundary.

- Level 0 represents the middle boundary.
- Level 1 represents the upper boundary of the parameter.

Table 1. Boundaries of all parameters

Parameter	Boundary		
	-1	0	1
Operating speed [m.min^{-1}]	960	0	980
N 140 [mm]	0,3	0,37	0,45
N 260 – N310 [mm]	0,4	0,48	0,55
N 320 [mm]	0,23	0,28	0,33
N 330 – N 340 [mm]	0,25	0,32	0,38
N 390 [mm]	0,35	0,4	0,45
N 140 [mm]	0,25	0,3	0,35

The Taguchi function generated the necessary experiments for this project. After all the necessary settings, a table of 18 experiments with a different combination of factors was displayed. Subsequently, parameter of durability was added to the table.

Table 2. Experiments created using Taguchi analysis (output from Minitab)

	C1	C2	C3	C4	C5	C6	C7	C8
	Operating speed	N140	N260-N310	N320	N330-N340	N390	N410	Durability
1	960	0,30	0,40	0,23	0,25	0,35	0,25	85
2	960	0,30	0,48	0,28	0,32	0,40	0,30	93
3	960	0,30	0,55	0,33	0,38	0,45	0,35	100
4	960	0,37	0,40	0,23	0,32	0,40	0,35	90
5	960	0,37	0,48	0,28	0,38	0,45	0,25	95
6	960	0,37	0,55	0,33	0,25	0,35	0,30	97
7	960	0,45	0,40	0,28	0,25	0,45	0,30	91
8	960	0,45	0,48	0,33	0,32	0,35	0,35	96
9	960	0,45	0,55	0,23	0,38	0,40	0,25	93
10	980	0,30	0,40	0,33	0,38	0,40	0,30	96
11	980	0,30	0,48	0,23	0,25	0,45	0,35	94
12	980	0,30	0,55	0,28	0,32	0,35	0,25	100
13	980	0,37	0,40	0,28	0,38	0,35	0,35	80
14	980	0,37	0,48	0,33	0,25	0,25	0,25	73
15	980	0,37	0,55	0,23	0,32	0,30	0,30	72
16	980	0,45	0,40	0,33	0,32	0,25	0,25	80
17	980	0,45	0,48	0,23	0,38	0,30	0,30	83
18	980	0,45	0,55	0,28	0,25	0,35	0,35	81

After the collection data of durability of the replaceable cutting plate, the impact of each parameter on its durability was evaluated from all experiments. From the graph in Figure 3, it can be seen that the greatest impact on durability had the Operating speed and Feed (N140) from the turning program that represents the machining of the face. The parameters that have the greatest impact were further worked. Parameters that did not have a great effect on durability, in this case, the other feeds in the turning program, were set on the machine as constants and were no longer working with them.

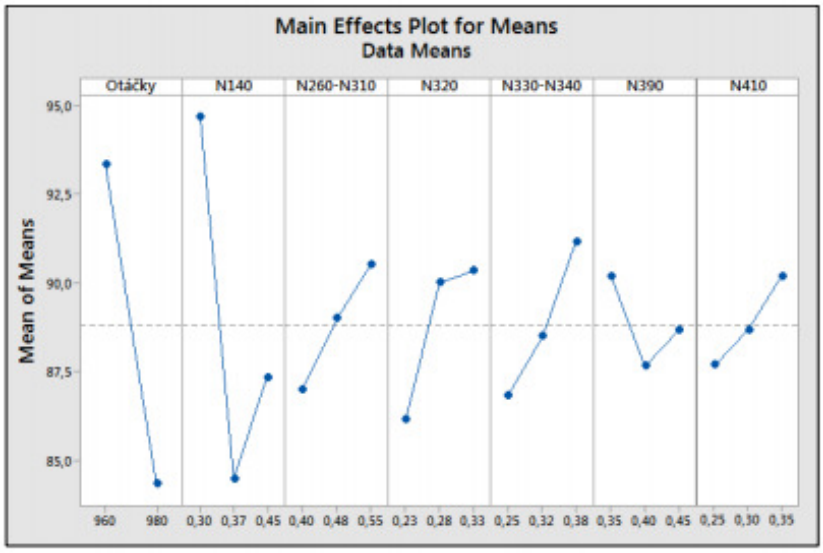

Figure 3. Graphical analysis of the effects of individual factors (output from Minitab)

2.4. Improvement

In the improvement phase, the best combination of parameters was determined to get as close as possible to the target. For Operating speed and Feed (N140), the upper, middle and lower boundaries are determined from the graph. After determining the main parameters that affect the durability of the removable cutting plate, a table with 9 experiments was generated using Full Factorial. It took into account not only the durability but also the machine time (columns C7 and C8).

Table 3. Experiments created using Full Factorial (output from Minitab)

	C5	C6	C7	C8
	Operating speed	N140	Durability	Tact time
1	930	0,30	73	40,3
2	930	0,32	86	40,3
3	930	0,34	90	40,2
4	950	0,30	73	40
5	950	0,32	100	39,7
6	950	0,34	70	39,5
7	970	0,30	77	39,2
8	970	0,32	105	39,6
9	970	0,34	100	39,5

In order to determine the best combination of factors for achieving the highest durability of the removable cutting plate, Response Optimizer was used. Using this application, the software identified the best combination of factors to achieve the aim. The tact time ranged from 38,957 s to 40,022 s. The durability that the removable

cutting plate can achieve ranges from 79 to 131 workpieces, but maximum values of this parameter can be achieved only rarely.

Response	Fit	SE Fit	95% CI	95% PI
Tz	39,489	0,167	(38,957; 40,022)	(38,599; 40,380)
Trvanlivosť	105,08	8,26	(78,79; 131,36)	(61,10; 149,06)

Figure 4. Interval of parameters operating speed and feed N140 (output from Minitab)

The new exchange interval is always set as the smallest rounded CI value. In this case, there was a new interchange interval of 80 pieces of workpieces per cutting edge. The newly set exchange interval has been tested in practice. Data, which were collected after the use DOE method was evaluated using the Minitab software.

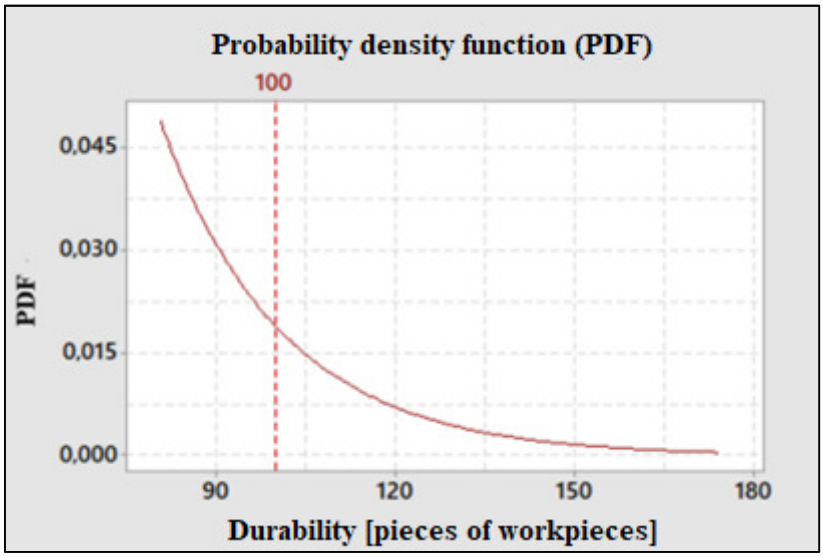

Figure 5. Probability density function improved state (output from Minitab)

The curve in the graph of Figure 5. shows breaking of removable cutting plate. After using the DOE method, it can be seen that by adjusting the values that affect the durability of removable cutting plate, there are several removable cutting plates that can machined 100 pieces of workpieces per cutting edge. There are no number of removable cutting plates that would machine fewer than 80 pieces of workpieces per cutting plate. Practical testing of the newly set replacement intervals ensured that 80 pieces of workpieces per cutting edge work is the best value we can achieved in this process. [1,6]

2.5. Control

The aim of this phase is to ensure the sustainability of the solution and to ensure compliance with the improved process and his regular monitoring.

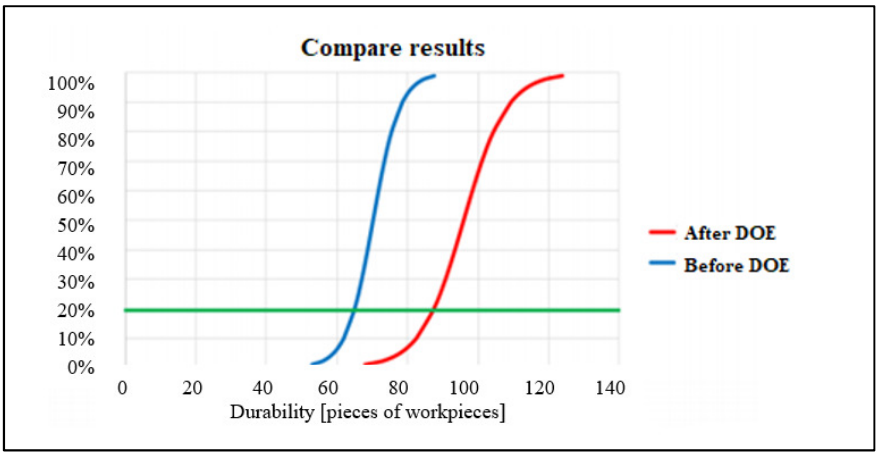

Figure 6. Compare results

From the chart on Figure 6. It can be seen the state of durability of removable cutting plate before using the DOE method and after that, too. With 20% of the loosing tool, which is accepted by the technologist, the number of machined pieces increased from 65 to 87. After using the DOE method, the replacement interval was set form the original 50 pieces of workpieces per cutting edge to 80 pieces of workpieces per cutting edge. Sustainability of the solution is ensured by regular inspection of the surface quality and dimensions of machined pieces of workpieces. [1]

3. Conclusion

The main aim of using the DOE method was to increase the durability of the removable cutting plate. A standard business document was used for work up a design part. This document consists of four phases of the DMAIC cycle. The article provides a theoretical overview of the DOE method and the Minitab software. The core of the article consists of the proposal design of durability of the removable cutting plate. The significant saving of the total annual costs has been achieved by increasing the durability of the removable cutting plate. The DOE method was used on the only one removable cutting plate in the only one process. If such projects will be performed to others removable cutting plates and the other processes, a much higher savings can be achieved of the total annual cost of tools.

This article was created with support of VEGA project: VEGA 1/0936/16.

REFERENCES

1. BIGOŠOVÁ, E.: Zvýšenie trvanlivosti náradia využitím metódy DOE: diplomová práca. Žilina: Žilinská univerzita v Žiline, 2017. 82 s.
2. HODOŇ, R., GRZNÁR, P.: Dynamic model creation for the value stream mapping. Bielsko-Biala: In: Projekt interdysciplinarny projektem XXI

wieku:monografia. Bielsko Biala: Wydawnictwo Akademii Techniczno-Humanistycznej, 2017. - ISBN 978-83-65192-80-7. - S. 411-417.
3. HORNÍKOVÁ, A.: Navrhovanie a vyhodocovanie experimentov s aplikáciami. Bratislava: IURA Edition, 2009, 334 s., ISBN 978-80-8078-281-8.
4. Minitab 17 – příručka uživatele – 1st edition. 2015. Copyright SC&C Partner spol. s. r. o. 2015.
5. HORVÁTHOVÁ, B., GAŠO, M.: New technologies for ergonomic workplace evaluation. Bielsko Biala: Wydawnictwo Akademii Techniczno-Humanistycznej, 2017. - ISBN 978-83-65192-80-7. - S. 419-424.
6. SKOKAN, R., BUČKOVÁ, M.: Application of logistics FMEA in the selected enterprise. Bielsko-Biala: In: Projekt interdyscyplinarny projektem XXI wieku: monografia. Bielsko Biala: Wydawnictwo Akademii Techniczno-Humanistycznej, 2017. - ISBN 978-83-65192-80-7. - S. 497-504.