THE WIRE ELECTRO DISCHARGE MACHINE SETTING PARAMETERS ANALYSIS INFLUENCING THE MACHINED SURFACE ROUGHNESS AND WAVINESS

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Summary

Wire Electro Discharge Machining is one of the methods, which allows to machine even the hardest materials. Factors which directly influence the quality of WEDM are dielectric conductivity and machines setting parameters. In this paper the influence of dielectric conductivity, dielectric pressure, wire tension and number of passages on the surface roughness and waviness will be presented. Generator setting parameters of were chosen from the internal memory of Robofil 190 machine on which research were held.

1. Introduction

Asking a question “Who invented a electro discharge machining?” there is no simple answer, but it is commonly claimed that it was an invention of Russian scientists couple Natali and Borys Lazarenko. Very often few scientists make a research of the same problem – it this case it was the same, where invention of EDM was a long term process and not immediate development.

In electro discharge machining the removal of the material from the machined item is due to electric erosion which takes place during electric discharges between two electrodes. These electrodes are isolated by liquid dielectric. One of the electrodes is the machined item and the second one is the thin wire usually made of cooper, brass, tungsten or molybdenum with a diameter between 0,02 – 0,05 [mm]. The wire electrode is a single use, it reaches very high temperatures during machining due to electric discharges, than it gets cooled down because of heat exchange with liquid dielectric and finally put on second spool or destroyed by special wheels.

Materials, which can be machined by EDM, must conform to conductivity condition – their conductivity must be greater than 0,01 [S/cm]. To this group all metals and their alloys, big group of ceramic materials, composites can be assigned. Working electrode (wire) and machined item are connected to the impulse generator of constant current. Current intensity vary between 1 and 1000[A] and voltage between few tens to few hundreds volts. There are two types of polarity of working electrode and machined item depending on impulse course, parameters and material of which electrodes are made. “Simple” polarity is characterized by negative connection of working electrode (cathode) and machined item is an anode. Reverse polarity is a connection when machined item is a cathode.

Basic features of WEDM

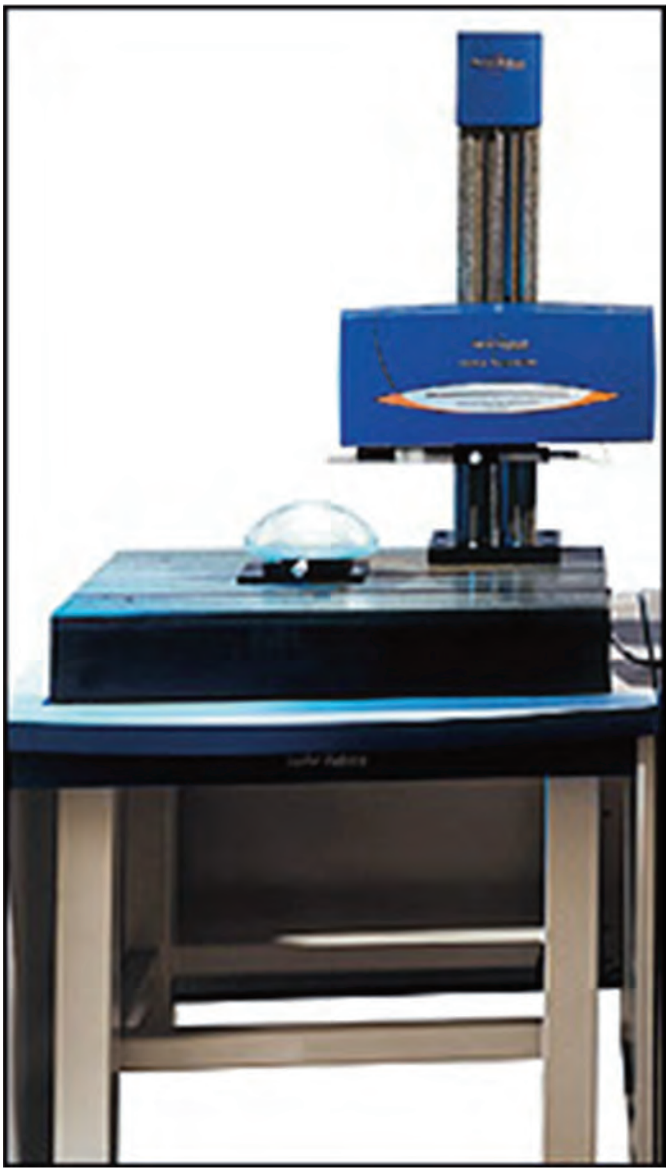
- High accuracy of machining (between 0.02 and 0.001 [mm])
- High smoothness (by few finishing passages implementation)
- Possibility of materials machining independently of their hardness
- Big electrode universality
- Wire is constantly moved from the spool so there is no need of including an electrode use in the cutting process
- Ability of machining even very small details
- No danger of fire or explosion (dielectric is based on water)

In WEDM water is mostly used as dielectric due to it's low viscosity what influences the facility of cut material debris removal.

2. Research

Research were made using WEDM machine ROBOFIL 190 made by Charmilles Technologies (Pic. 1.). Biggest item that can be machined using Robofil 190 is cubicoid with dimensions of 400x250x400 [mm] and maximum angle of wire electrode relative to horizontal direction is +/- 30 deg. Productivity of the machine is up to 250 [mm^2/min] and it can be programmed manually by keyboard or by floppy disc. Material roughness and waviness were measured using FORM Talysurf Series 2 machine production of Taylor Hobson GB (Pic. 2).

Pic. 1. ROBOFIL 190 Machine



Pic. 2. FORM TALYSURF Series 2

Cubicoid, from which samples were cut, had a dimensions of 300x100x60[mm] and it was made of tooling steel NC 10 which was thermally treated to 62 HRC of hardness (Pic. 4.). This material is characterized by big resistance to grinding and it would be very hard to machine by any conventional method, furthermore for some methods it would be even impossible to machine. Elements which were cut off from the cubicoid had a dimension of 10x100x10 [mm] and they are shown in the picture 3. On shape which has left in the cubicoid further machining was performed. During research 25 samples were performed and for each of them different setting parameters were chosen.

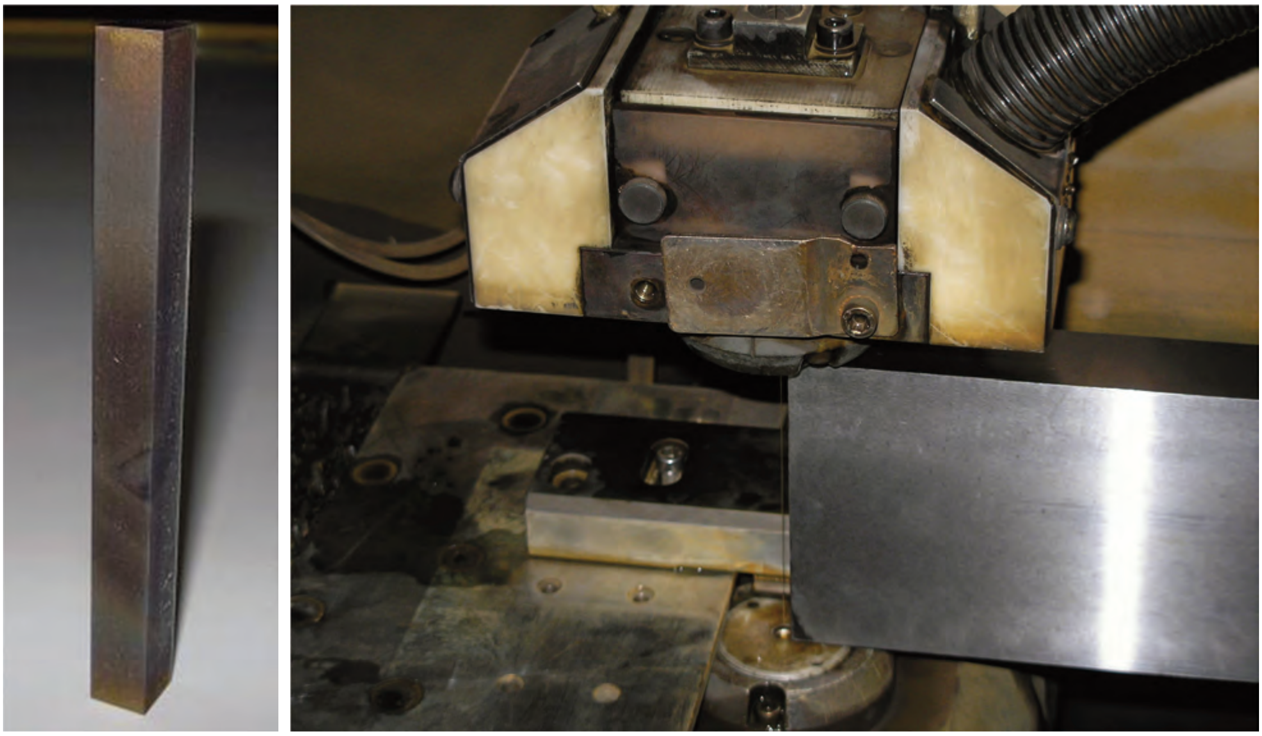
Parameters which were changed:

- liquid dielectric conductivity
- liquid dielectric pressure
- wire tension
- number of wire passages

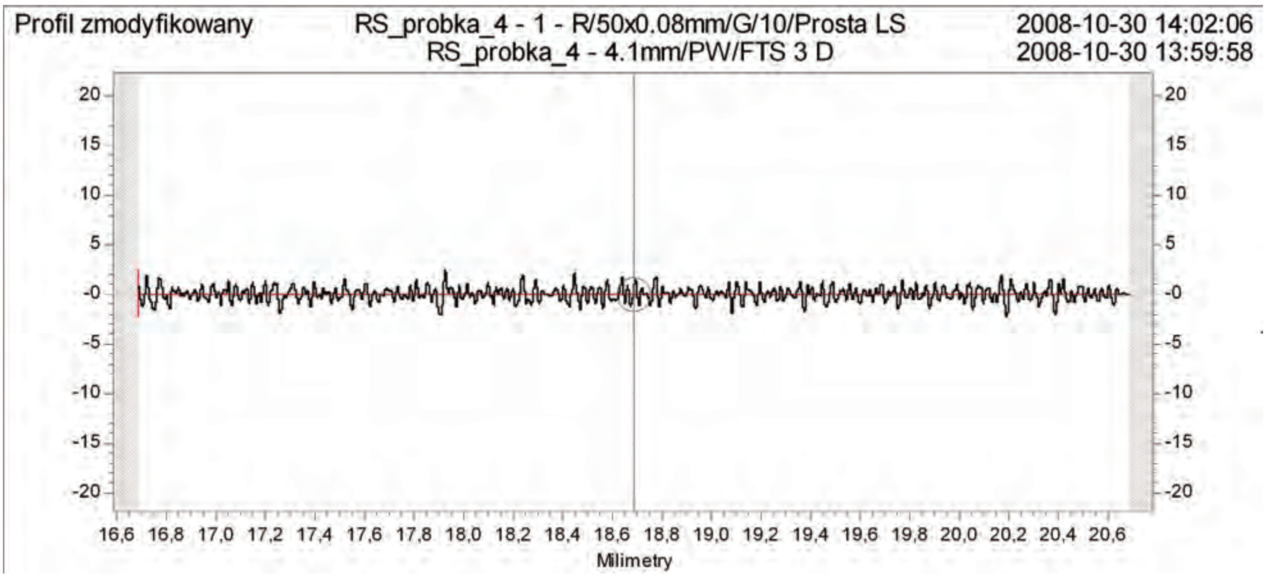
WEDM machine generator setting parameters were taken from the internal machine memory and they were identical for every machining, depending on the number of passages. Dielectric conductivities were respectively: 15, 40, 70, 100 and 150 [μS/cm], dielectric pressures: 0.6, 0.75, 0.9, 1.05 [MPa], wire tension was changed from 10 to 14 [N] with separation of 1 [N], number of wire passages was 1 for rough machining and 5 for a finishing machining.

Research matrix was based on method invented by Japanese engineer and statistic Genichi Taguchi and was generated using statistics program Minitab 15. In this software experiment matrix was created for four variables (conductivity, pressure, tension, number of passages) and five levels of these variables. Matrix for 25 runs was generated using mentioned method (it is also worth saying that if all possible combinations were run – there would be 625 of them).

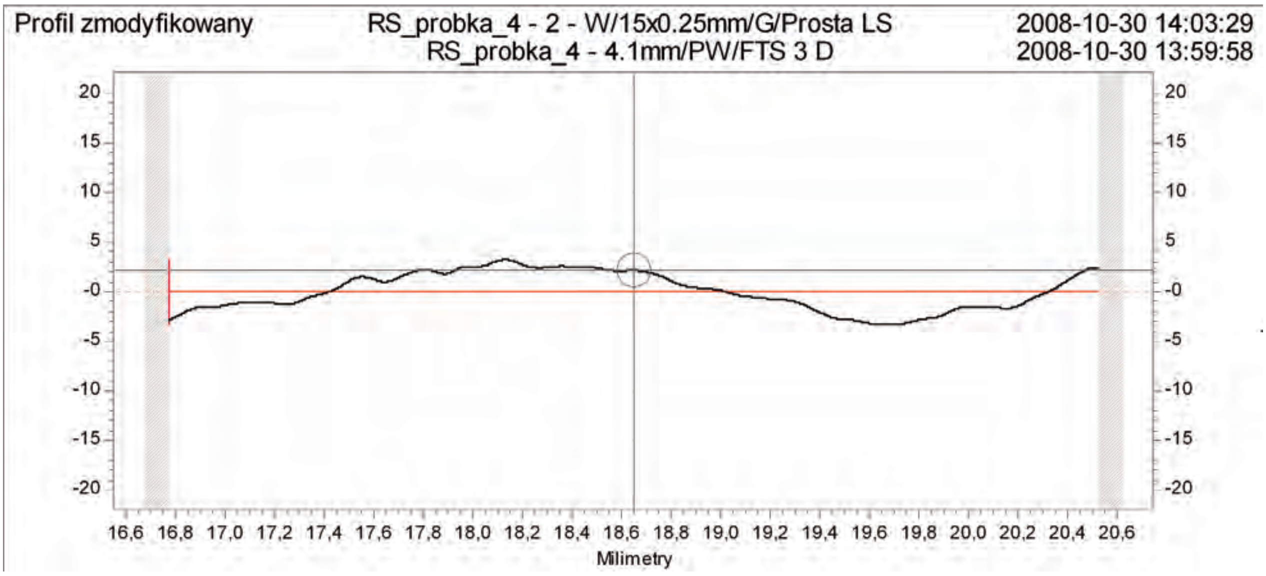
After machining of all 25 samples their roughness and waviness was measured using Form Talysurf Series 2 machine in the direction that conformed to wire electrode run. Diagrams of primary profile, roughness and waviness of surface were obtained and measurements were taken on the length of 4 [mm]. To illustrate the results roughness diagram of sample no. 4 was shown in the picture 5 and waviness diagram in the picture 6.



Pic. 3 and 4. Respectively: one of the elements which was cut off from the base material and cubicoid



Pic. 5. Roughness profile of the sample no 4



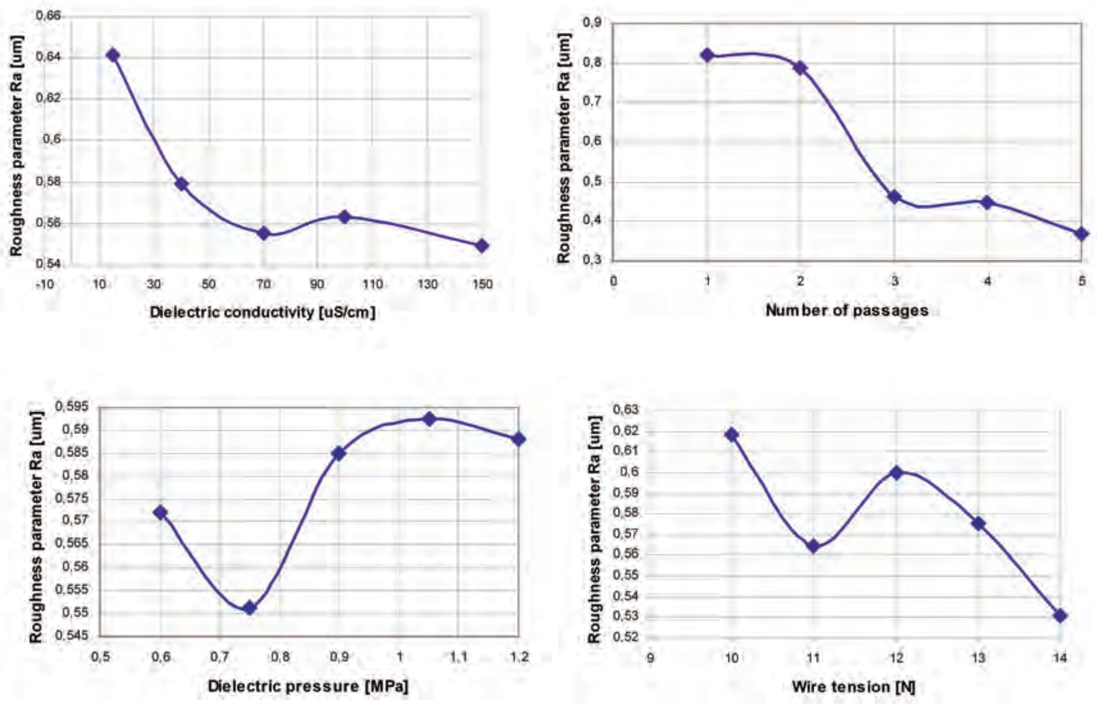
Pic. 6. Waviness profile of the sample no 4

Table 1 shows the experiment matrix generated by Minitab software using Taguchi method with given values of surface roughness parameter *Ra* and waviness parameter *Wa* for every sample.

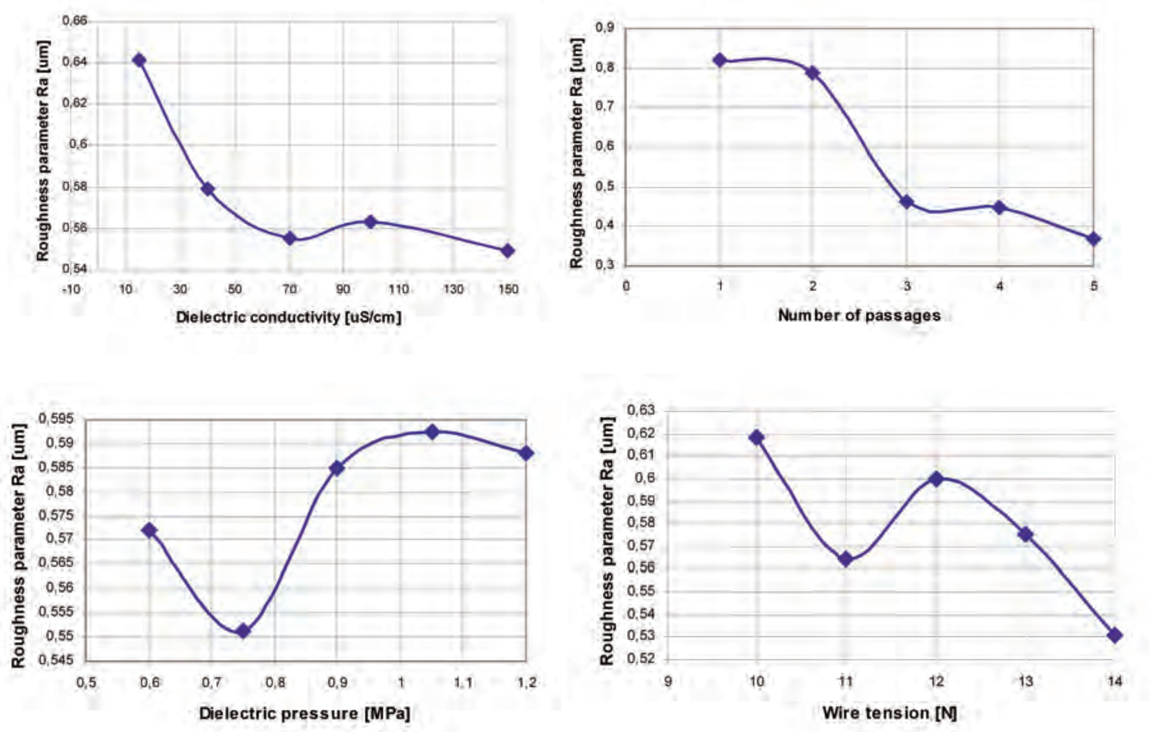
Table 1

Sample number	Dielectric conductivity	Number of passages	Dielectric pressure	Wire tension	Roughness parameter *Ra*	Waviness parameter Wa
	µS/cm		MPa	N	µm	µm
1	15	1	0,6	10	0,9712	1,171
2	15	2	0,75	11	0,7859	0,5198
3	15	3	0,9	12	0,5601	0,5341
4	15	4	1,05	13	0,547	1,7045
5	15	5	1,2	14	0,3438	1,3047
6	40	1	0,75	12	0,7837	1,05
7	40	2	0,9	13	0,8329	0,5501
8	40	3	1,05	14	0,4198	1,0948
9	40	4	1,2	10	0,4796	1,3427
10	40	5	0,6	11	0,3807	2,2676
11	70	1	0,9	14	0,763	0,6842
12	70	2	1,05	10	0,7954	0,7938
13	70	3	1,2	11	0,4937	0,6841
14	70	4	0,6	12	0,4166	3,4424
15	70	5	0,75	13	0,3089	3,2659
16	100	1	1,05	11	0,7854	0,8407
17	100	2	1,2	12	0,825	1,0803
18	100	3	0,6	13	0,3884	2,5237
19	100	4	0,75	14	0,4252	3,8492
20	100	5	0,9	10	0,3915	3,1242
21	150	1	1,2	13	0,7984	0,8376
22	150	2	0,6	14	0,7026	1,3787
23	150	3	0,75	10	0,4526	0,6192
24	150	4	0,9	11	0,3773	0,5542
25	150	5	1,05	12	0,415	1,2573

These values were put into the Minitab to check the influence of each of the four process variables into the surface roughness and waviness. Roughness diagrams are shown in the picture 7 and waviness parameter diagrams in the picture 8.



Pic.7. Diagrams showing roughness parameter Ra in the function of every of the 4 variables



Pic.8. Diagrams showing waviness parameter Wa in the function of every of the 4 variables

The subject of future investigation will be to measure the influence of wire tension of samples barreling in the height direction using CNC measuring machine. Another part of research will be simulation of liquid dielectric flow in the working gap using computational fluid dynamics software in order to determine the optimal pressure and to understand how the base material debris are moved out of the working electrode.

3. Conclusion

The aim of the research was to measure how the machine setting parameters influence the quality of the surface of the cut. By quality it is meant roughness and waviness. The measure of the surface roughness is the roughness parameter *Ra* which can be expressed as medium arithmetic deviation of profile from the middle line:

$$Ra = \sum \frac{y_n}{n}, \tag{1}$$

Sample waviness was measured using the waviness parameter *Wa* in other words medium arithmetic deviation of waviness profile:

$$Wa = \frac{1}{n}\sum_{y=1}^{n} |h_{wi}|, \tag{2}$$

Conductivity – results which are presented by this variable seem to be the most interesting. It can be noticed that surface roughness decreases when dielectric conductivity increases. Very expensive dejonizators have been used on the WEDM machines, which purpose is to keep dielectric conductivity on specified low level, because it's been commonly claimed that this parameter has a key influence on electro erosive machining including roughness and waviness. Presented research show that idea of very low dielectric conductivity should be reconsidered. Picture 8 shows the influence of dielectric conductivity on the surface waviness. During conductivity increase from 20 to 100 [μS/cm] the waviness parameter increases than decreases to initial level. Conclusion is that liquid dielectric conductivity does not strongly influence the surface waviness so keeping conductivity at a very low level does not have a strong meaning even if *Wa* parameter value is crucial to the customer.

Number of passages – opposite to conductivity influence on surface waviness in this case increase of passage numbers has a negative influence to *Wa* parameter, so optimal solution would be to restrict the number of passages to 3. In terms of surface roughness the results seem to be obvious – every next wire electrode passage roughness decreases – that's the main reason of multiple wire passages.

Dielectric pressure – presented research proved that dielectric pressure doesn't have a measurable impact on surface roughness but it has an impact on the waviness – it decreases. It can be explained by the fact that bigger pressure at the machine dielectric nozzle stiffens the wire, so it vibrates with the smaller amplitude. Bigger pressure also causes that machined material debris are much faster removed from the working gap, what significantly influences the surface quality.

Wire tension – similarly to the pressure this variable also doesn't have a measurable impact on the surface roughness. It can be noticed that roughness parameter insignificantly decreases. It can be explained by the fact that more tensed wire vibration amplitude decreases what directly influences the roughness and waviness. In the waviness parameter diagram shown in the picture 8 it can be noticed that firstly *Wa* parameter value decreases and after reaching the value of 11[N] of wire tension is starts to increase. This can be the area of further research.

References

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R. Serwinski

WPŁYW PARAMETRÓW NASTAWCZYCH WYCINARKI ELEKTROEROZYJNEJ NA CHROPOWATOŚĆ I FALISTOŚĆ POWIERZCHNI CIĘCIA

Streszczenie

Obróbka elektroerozyjna pozwala na obróbkę nawet najtwardszych materiałów, przez co z łatwością można ją stosować w przypadkach gdzie zastosowanie konwencjonalnych metod obróbki jak na przykład frezowanie czy szlifowanie byłoby bardzo trudne lub nawet niemożliwe. Czynnikami, które bezpośrednio wpływają na jakość wycinania elektroerozyjnego (WEDM) są przewodność dielektryka oraz parametry nastawcze obrabiarki. W poniższej pracy zostanie przedstawiony wpły czterech zmiennych: przewodności dielektryka, ciśnienia dielektryka, naciągu elektrody roboczej oraz ilości przejść na chropowatość i falistość powierzchni cięcia. Parametry nastawcze generatora zostały dobierane z wewnętrznej pamięci obrabiarki Robofil 190 na której również przeprowadzana była obróbka.