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Analysis of the relationship between the properties of selected materials and the parameters of the EDD process

TRAJER Marcin[1,a], CZESZKIEWICZ Adrian[2,b] and MACHNO Magdalena[3,c *]

[1]Division of Surface Engineering, Faculty of Materials Science and Engineering, Warsaw University of Technology, Wołoska 141, 02-507 Warsaw, Poland

[2]Łukasiewicz Research Network–Institute of Aviation, al. Krakowska 110/114, 02-256 Warsaw, Poland

[3]Department of Rail Vehicles and Transport, Faculty of Mechanical Engineering, Cracow University of Technology, al. Jana Pawła II 37, 31-864 Cracow, Poland

[a]marcin.trajer.dokt@pw.edu.pl, [b]adrian.czeszkiewicz@ge.com, [c]magdalena.machno@pk.edu.pl

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Abstract. The thermophysical properties of the electrodes material significantly impact performance of the electrical discharge machining (EDM). The aim of this article was to investigate the influence of thermophysical properties of selected materials on the EDM process. The effect of the thermophysical properties of these materials on process efficiency factors (material removal rate, linear tool wear) and hole geometry (aspect ratio, radial overcut) was analyzed. The results showed that selected thermophysical properties of the workpiece, such as thermal conductivity, melting point, have the most significant impact on the electro-erosion process. Optimal result parameters (material removal rate: 2.58 mm^3/min, linear tool wear: 4.95 mm, aspect ratio: 8.00, radial overcut: 0.046 mm) and no presence of "bottom cone" were obtained for EDM drilling in Inconel 718 and similarly for AISI 1045 steel. On the other end were high resistance alloys such as tungsten carbide and copper alloy.

Introduction

The electrical discharge machining (EDM) process is one of the unconventional methods of manufacturing. The process has been known since around 1943 [1]. However, efforts are still being made to improve its performance, parameters and the accuracy of the manufactured shapes. Experimental research is still being done to increase material removal rate (MRR), reduce tool wear (TW), and reduce surface roughness (SR) [2-4]. Additionally micro-holes requires high dimensional and shape accuracy without burrs and micro-cracks [5].

In the process of electrical discharge machining the workpiece material is removed as a result of phenomena accompanying electric discharges occurring in the inter-electrode gap area. The gap involves area between workpiece and working tool electrode. Energy transferred during the discharge in a form of spark melts and evaporates the metal. For the occurrence of electrical discharges, the electrodes are connected to the electric pulse generator. Space between the electrodes is filled with a working liquid. Also, the selection of parameters and material of the tool should ensure the removal of more material from the workpiece [6,7]. In addition, the EDM enables processing of electrically conductive materials, regardless of their hardness. This is the most important advantage of EDM process comparing to conventional machining methods. Thanks to that technique can be successfully used to produce parts from modern engineering materials in such industries as aviation, automotive and medical. In addition, due to the high accuracy of obtained geometry (approx. 5 μm), this process is also suitable for the production of micro-shapes, including micro-holes in the diameter range of 1-999 μm [6,8,9].

Currently, aviation, automotive and medical industries use engineering materials that are resistant to high temperature conditions, providing at the same time high strength, and high hardness. Within parts such as jet engines turbine blades are equipped with micro-holes which are made to increase their high temperature operational capabilities (up to 1,373 K). These micro-holes are called "cooling holes". When the jet engine is running, cool air flows through them, further reducing airfoil temperature [10]. However, due to the strength properties of the used materials, as well as the size of micro-holes (0.3 - 5 mm in diameter, depth to diameter ratio (40-600:1), the choice of technology for their production is limited. Currently, one of the most frequently chosen technologies for cooling holes manufacturing is electrical discharge drilling (EDD) [11,12].

In conducted research [13], Authors indicate that the thermophysical properties of the workpiece material and the working electrode affect the machinability the EDM process. At the same time also material of the working electrode have a strong impact on the EDM process. Calculated erosion resistance index shows how important it is to analyze such electrode material properties as thermal conductivity, specific heat and melting point. Similar research results are presented in the analysis of the impact of the thermophysical properties of the electrode material on the EDM process of such materials as AISI 304 stainless steel and Ti-6Al-4V alloy in [14]. The results indicated that the greater resistance of the material is (higher erosion resistance index, harder to EDM) lower overcut and lower taper rate are. According to this analysis, despite the low MRR value, good machining accuracy can be achieved. However, in [15], a significant impact of the thermophysical properties of the workpiece (in this case Inconel 718 superalloy) on the EDM process was demonstrated. In the analysis of the results, attention was paid to the change in the behavior of selected thermophysical properties of the superalloy under the influence of temperature. In this case, the thermal conductivity of the material increases with increasing material temperature. Also in [7], when analyzing the parameters of the post EDM surface layer, the high thermal conductivity of workpiece - steel HTCS was taken into account. The analysis of the results showed that the thickness of the white layer was in the range of 5-34.5 μm and depended mainly on the amount of thermal energy supplied to the workpiece. The amount of thermal energy that reaches the material and the speed of its propagation in the surface layer of the material depends on the thermal conductivity of the material.

The above examples of the analysis of the results of EDM process researchers indicate that the impact of the thermophysical properties of the electrodes material (workpiece material and tool electrode) significantly affect the selection of machining parameters and the efficiency of the process or the quality of the machined surface. Thus, the impact of these properties of the electrode material on stock removal, process efficiency or the quality of the treated layer is crucial to obtain effective machining.

The aim of this work is to investigate the influence of the thermophysical properties of five materials such as: tungsten carbide VHM, superalloy Inconel 718, carbon steel AISI 1045, copper alloy CuCr1Zr and aluminum alloy AW-2017A on the EDM process. The EDM process was performed using a brass tubular electrode with an outer diameter of 0.4 mm and a working fluid of deionized water. All tests were performed with same electrical pulse parameters such as gap voltage, current, cycle load (pulse on duration / pulse off duration). Moreover drilling process time was identical. The efficiency of the process was analyzed in terms of the material removal rate and linear wear of the working electrode as well as the geometric characteristics of the micro-holes (radial over cut, aspect ratio - the ratio of the hole length to its diameter). Finally, the results were linked to the thermophysical properties of the materials in which the micro-holes were drilled. The summary of test results in selected materials is also intended to show how strongly the thermophysical properties of the workpiece material affect the course of the process and performance factors.

Materials and methods

Material used for workpiece and tool.

Experimental EDM research was carried out in five selected materials:

- tungsten carbide VHM,
- Inconel 718 superalloy,
- AISI 1045 carbon steel,
- CuCr1Zr copper alloy,
- AW-2017A (AlCu4MgSi) aluminium alloy.

The selection of the materials was guided by their diverse thermophysical properties (see Table 1), as well as by their diverse chemical composition. Following scope of the article and the phenomena the EDM process, knowledge of selected thermophysical properties of the workpiece material is important. This is related to the impact of these properties on the EDM drilling process and on the efficiency of that process. For a more accurate analysis of the results, the chemical composition of each material was measured, which is shown in Table 2. The chemical composition was determined using an X-MET8000 X-ray spectrometer (Hitachi High-Tech, Tokyo, Japan).

Table 1. Thermophysical properties of the selected material.

Property (unit)	Workpiece Materials					Electrode Material
	VHM	Inconel 718 [20,21]	AISI 1045 [22,23]	CuCr1Zr [16,17]	AW-2017A [18,19]	Brass [18,19]
Density [g/cm^3]	15.0	8.19	7.82	8.94	2.75	8.55
Melting point [K]	2,273	1,533-1,609	1,793	1,338-1,356	913	1,263
Thermal conductivity [W/(m·K)]	87.9	11.4	48.1	401	134	159
Specific heat capacity [J/(kg · K)]	150-350	435	570	385	873	385

Table 2. Chemical composition of workpiece materials [%].

Chemical element	Workpiece material				
	VHM	Inconel 718	AISI 1045	CuCr1Zr	AW-2017A
Al	0.77	0.57	-	-	91.89
C	-	-	0.43	-	-
Co	6.04	0.1	-	-	-
Cr	0.79	18.4	0.05	0.6	0.08
Cu	-	0.08	0.07	99.27	4.45
Fe	0.61	16.81	98.47	-	0.72
Mg	-	-	-	-	0.76
Mn	-	-	0.71	-	0.92
Mo	-	3.16	<0.01	-	-
Nb	-	5.37	-	-	-
Ni	-	53.63	0.04	-	-
Re	4.48	-	-	-	-
S	-	-	0.01	-	-
Si	-	0.34	0.03	-	0.63
Ta	0.91	-	-	-	-
Ti	-	0.96	-	-	0.17
W	86.4	0.06	-	-	-
Zn	-	-	-	-	0.23
Zr	-	-	0.01	0.04	-

Brass tubular electrodes with external diameters of 0.4 mm and internal diameters of 0.215 mm were used for EDM drilling. Brass has good heat conductivity as well as low electrical resistance.

According to [24], brass is the best tool material for EDM machining. In addition, selected round electrodes are the best for micro-hole drilling [25].

Experimental details.

The micro-holes were made by electrical discharge machining on the custom made EDM machine. It is equipped with transistor controlled generator as well as NC controlled. In each type of workpiece 9 blind micro-holes were made. The drilling parameters in each material were the same and were selected in such a way as to ensure correct machining (minimize short circuits). The number of holes was chosen to reduce outliers from results evaluation. During the process, the tool electrode moved towards the workpiece with a feed rate controlled by gap voltage value and rotated at a constant rotational speed. The working fluid was fed with constant pressure through a channel in the electrode to the gap area between the electrode and the workpiece. The rotation of the working electrode and the continuous flow of working liquid under the narrow inter-electrode gap were intended to improve the stability of the process. These solutions improve the removal of erosion products (debris, air bubbles), reducing the possibility to occur short circuits or arc discharges. During the test, a new electrode was used in each of the tested materials in order to ensure the same working conditions for each workpiece material. To ensure electrical discharges to occur, both electrodes (tool and workpiece) were connected to an electrical pulse generator. Each hole was made with a fixed spindle displacement in the Z axis. Fig. 1 shows a diagram of the test stand.

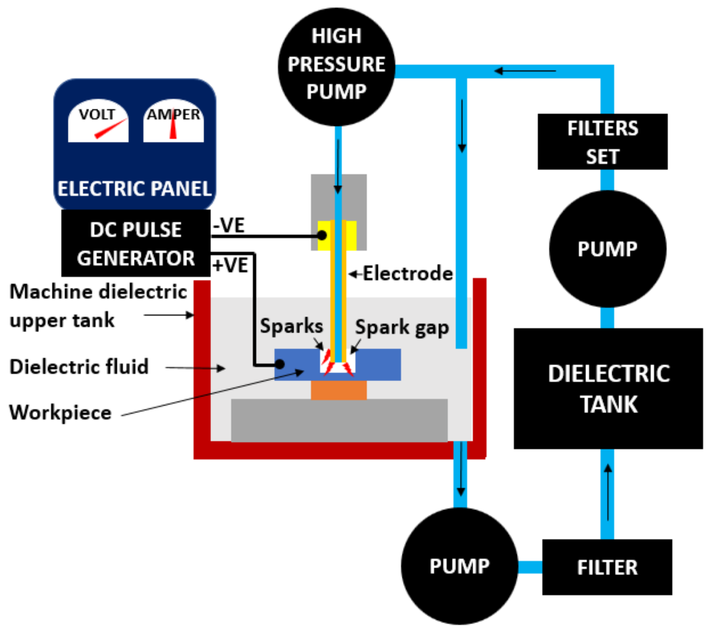

Fig. 1. Scheme of the EDM process test stand.

The drilling process was performed using the following conditions: current amplitude: 10 A, open voltage: 40 V, pulse on duration: 30 µs, pulse off duration: 30 µs, tool rotation speed: 500 rpm, capacitance: 1425 nF, working fluid: deionized water, working fluid temperature: 294 K, electrical conductivity of the working fluid: 10 µS/cm, working fluid pressure: 11 MPa, initial interelectrode gap: 100 V, the value of the spindle displacement in the Z axis: 8.9 mm, load cycle: 50%.
In this work below response parameters were analyzed:

- material removal rate (MRR), was calculated from the following equation:

$$MRR\ (mm^3/min) = V/t. \tag{1}$$

Where: V – volume of material removed, t – drilling time,

- linear tool wear (LTW, mm), determined as the shortening of the electrode along its length and measured after each hollow hole,
- the radial overcut (ROC), was calculated according to the below formula:

$$ROC\ [mm] = (D_{hole} - D_{electrode})/2. \tag{2}$$

where: D_{hole} – average input diameter, $D_{electrode}$ – outer diameter of the tool electrode, aspect ratio (AR), was calculated according to the formula:

$$AR = H_{depth}/D_{hole}. \tag{3}$$

where: H_{depth} – drill hole depth.
Diameter measurements were made using an Alicona C200 microscope (Alicona Imaging GmbH, Raaba/Graz, Austria). A dedicated lens with a high focal length was used for scanning. The vertical scanning resolution was 3 µm. The volume of material removed as well as holes geometry was measured using the GOM Inspect program (ZEISS, Oberkochen – Germany). The volume of the shallowest holes (< 1 mm deep) due to large on fluence of conicity on the volume of hole was directly measured using a volume measuring tool. In contrast, the volume of the deepest holes (> 1 mm deep) was measured as follows:

- a cylinder was created from the scanned hole, using the "best fit 3 sigma" method, which allowed the cylinder to be sufficiently matched to the scanned shape of the hole,
- cylinder diameter was measured,
- hole depth was measured,
- the volume of the hole (V_{hole}) was calculated using the formula:

$$V_{hole} = P_p \cdot H. \tag{4}$$

where: P_p [mm^2] – the surface area of the hole measured at depth 0.1 mm, H [mm] – hole depth.
In the case of holes made in aluminum alloy, due to their significant depth (H_{depth} > 6 mm), the holes had to be cut along the axis. This made it possible to measure accurately the depth of these holes.
The measurement results of the experimental studies are given in Table 3. Table 4 shows the calculated standard deviation for the determined result factors.

Table 3. Results of the experiments (average value).

Workpiece material	Results			
	V [mm^3]	t [s]	D_{hole} [mm]	H_{depth} [mm]
Tungsten carbide VHM	0.05	24	0.47	0.37
Inconel 718 superalloy	0.75	18	0.49	3.94
Carbon steel AISI 1045	0.53	19	0.50	2.67
Copper CuCr1Zr	0.11	47	0,48	0.67
Aluminium alloy AW-2017A	1.32	12	0.51	6.39

Table 4. Calculated standard deviation values for the result factors.

Material workpiece	MRR	LTW	ROC	AR
	Standard deviation			
Tungsten carbide VHM	0.018	0.0058	0.0033	0.0067
Inconel 718 superalloy	0.150	0.0724	0.0025	0.0815
Carbon steel AISI 1045	0.081	0.0727	0.0064	0.0853
Copper CuCr1Zr	0.008	0.0155	0.0025	0.0326
Aluminium alloy AW-2017A	0.162	0.0845	0.0057	0.1496

Results and Discussions

Influence of the thermophysical properties of the electrode material on the efficiency of the process

In the EDM process, performance parameters such as material removal rate (MRR) and linear tool wear (LTW) play a key role [6]. Manufacturers are looking MRR increase options. At the same time tool wear generates about 50% of the crafting costs. Therefore TW reduction is expected. In addition, when producing micro-holes, electrode wear can be as high as 100%. As can be seen in the MRR result tables below, the process efficiency was different for each of the micro-holes analyzed. The highest material removal efficiency is observed for the AW-2017A aluminum alloy (about 6.5 mm^3/min) (Fig. 2a). Also, the other analyzed output factors turned out to have the highest values compared to the other materials (LTW - 2.25 mm, Fig. 2b, AR - 12.49, Fig. 2c). It is also worth mentioning that deep micro-holes production process, the material removal rate parameter is strongly related to the aspect ratio of the hole. This dependence is observed by analyzing the results in Fig. 2a and Fig. 2c.

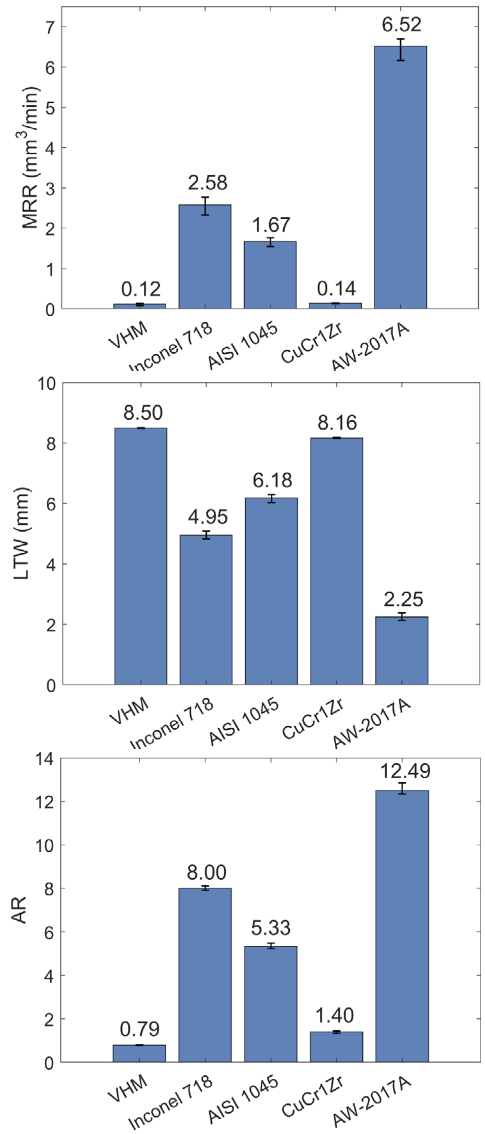

Fig. 2. The results of the EDM process factors: a) material removal rate (MRR), b) linear tool wear (LTW), c) aspect ratio (AR).

In the case of the electro-erosion process, one could conclude that the thermal conductivity of the workpiece material has the main influence on the material erosion process. This is related to the nature of the process. The nature of thermal phenomena that accompany electrical discharges and related extremely high temperature of the created plasma channel, approx. 4,000 – 8,000 K [26]. The consequence here is the non-stationary propagation of heat from the so-called surface sources, which are formed on the surfaces of the electrodes under the pressure of the plasma channel generated during the electro-erosive discharge. However, the analysis of the results shown in Fig. 2a for the MRR shows that it is the melting temperature that drives the performance of the EDM process. The highest MRR value (6.52 mm^3/min) was achieved for aluminum alloy. The thermal conductivity of this material (134 W/(m·K)) is similar to the thermal conductivity of tungsten carbide material (87.9 W/(m·K)). CuCrZr copper alloy, on the other hand, has an even better thermal conductivity than these materials (401 W/(m·K)). After analyzing the remaining thermophysical properties, the AW-2017A alloy has the lowest melting point (913 K) compared to the other analyzed materials (even lower than the melting point of the tool electrode material). This shows that the melting temperature of material is its property, which has a significant impact on the EDM process.

Further analysis of the results confirms the above statement. Analyzing the obtained results, VHM tungsten carbide also has good thermal conductivity (105 W/(m·K)). However, this material has a high melting point (approx. 2,273 K). The same applies to the CuCr1Zr chromium-circus alloy. This alloy also has good thermal conductivity (401 W/(m·K)), but has a high melting point (in the range of 1,338 - 1,356 K). A similar effect on the MRR of the thermal conductivity and melting point of materials can be observed for super alloy Inconel 718 and carbon steel AISI 1045 (thermal conductivity: 11.4 W/(m·K) and 48.1 W/(m·K), respectively, and melting point: 1,533-

1,609 K and 1,793 K, respectively). From the graph of Fig. 2a, it can be concluded that the material removal rate has similar values obtained for drilling in these materials.

Comparable conclusions were presented in [14], The authors indicate that material properties such as the melting point, the specific heat capacity and thermal conductivity affect the material removal rate during electro-erosion treatment of the material. The increase in these properties of the workpiece material cause its lower machinability by EDM, according to the index of resistance to the material erosion process given in [13]. In order to check how well selected materials can be machined by the EDM process, the erosion resistance index was calculated. The erosion resistance index (ER_{index}) calculations were made using the following formula (5) and are summarized in Table 5.

$$ER_{index} = \lambda \cdot c \cdot T^2. \tag{5}$$

where: λ – thermal conductivity (W/(m·K)), c – specific heat capacity (J(kg·K)), T – melting point (K). Calculated values of the erosion resistance index for individual materials presented in Table 5. The values of λ, c, T for the ER_{index} calculation were taken from Table 1 (in the case of a range of values, the maximum value in the range was considered). Equation (5) was used in accordance with the formula for calculating the machinability index by EDM presented in [13]. This formula shows that the square of the material's melting point has the greatest effect on the EDM's machinability of the material.

Table 5. Erosion resistance index of analyzed material (ER_{index}).

Tungsten carbide VHM	Inconel 718	Carbon steel AISI 1045	Copper CuCr1Zr	Aluminium alloy AW-2017A	Brass
Erosion resistance index ER_{index} [x 10^{10} $J^2/(m \cdot s \cdot kg)$]					
15.90	1.28	8.81	28.40	9.75	9.76

The calculated index of resistance to the EDM process confirms that its higher values for tungsten carbide VHM and CuCr1Zr alloy indicate that their EDM machinability is reduced. On the other hand, lower ER_{index} values for Inconel 718 superalloy, AISI 1045 carbon steel and AW-2017A aluminum alloy confirm the higher MRR value obtained. Also, according to the interpretation of the ERindex, a higher value indicates that a given material can be used as a tool electrode material. Certainly, the brass electrode is one of the most appropriate for the machining of Inconel 718 superalloy (the lowest ER_{index} obtained for Inconel 718, and the highest obtained ER_{index} for CuCr1Zr alloy). This is also confirmed by the obtained higher slenderness values (AR about 8) of the micro-holes hollowed out in this nickel-based superalloy.

In addition, the erosion resistance index informs how much wear of the working electrode can be expected when machining a given material. If the ER_{index} is higher, the material removal rate due to its poor EDM machinability will be lower. The working electrode will have to work longer and wear out more to remove the required amount of material.

It is also worth noting that the same drilling parameters and the same type of working electrode (with the same geometry, made of the same material) were used for the experimental research. The obtained results therefore show that the selected parameters and the type of working electrode are appropriate for drilling micro-holes in the AW-2017A alloy. This could also have influenced the most effective parameters for this material, such as MRR and LTW. The selected parameter values in this case ensured the stability of the process. In addition, the authors [14] also draw attention to the importance of thermal conductivity of the tool electrode material. The greater thermal conductivity of the working electrode material causes more heat to be dissipated in it. That turns in to the lower energy density of the electric discharge by that creating smaller craters on the surface of the workpiece. Analyzing Fig. 2a, lower MRR values for Inconel 718 and carbon steel AISI 1045 can be associated with much lower thermal conductivity of these materials compared to the thermal conductivity of the working electrode material (λ lower by approx. 90% for Inconel 718 and approx. 70% for AISI 1045).

Influence of the thermophysical properties of the electrode material on the accuracy of micro-holes.

In the case of the analysis of micro-holes and their subsequent functionality in production parts, their high dimensional and shape accuracy is crucial. For this purpose, the radial overcut parameter of the micro-holes (ROC) was investigated (Fig. 4). The obtained results show that the ROC values are in the range of 0.03 - 0.06 mm. It can therefore be assumed that this parameter has similar values for analyzed materials. It can also be assumed that drilled holes are characterized by good dimensional accuracy.

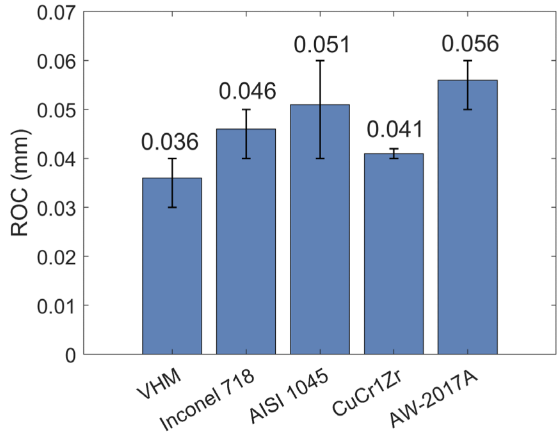

Fig. 4. The results of the geometric factor: radial overcut (ROC).

In addition, SEM images of the entrance of the wells showed the formation of a heat affected zone (HAZ) around the holes (Fig. 5). In case of VHM The HAZ layer includes also a material which has been melted but not fully removed and solidified at the edge of the hole. Such build-up material was not observed for neither Inconel 718 nor steel AISI 1045 which represent similar level of thermal conductivity. Large HAZ collar might result from heat being given off by a significant amount of re-solidified material formed at the edge of the hole drilled in the tungsten carbide. However, this certainly needs further investigation.

The SEM images for drilling in tungsten carbide and CuCr1Zr alloy show unremoved material at the bottom of the hole. In the literature, this phenomenon is called the “residual cylinder” [25] or “cone” [27].

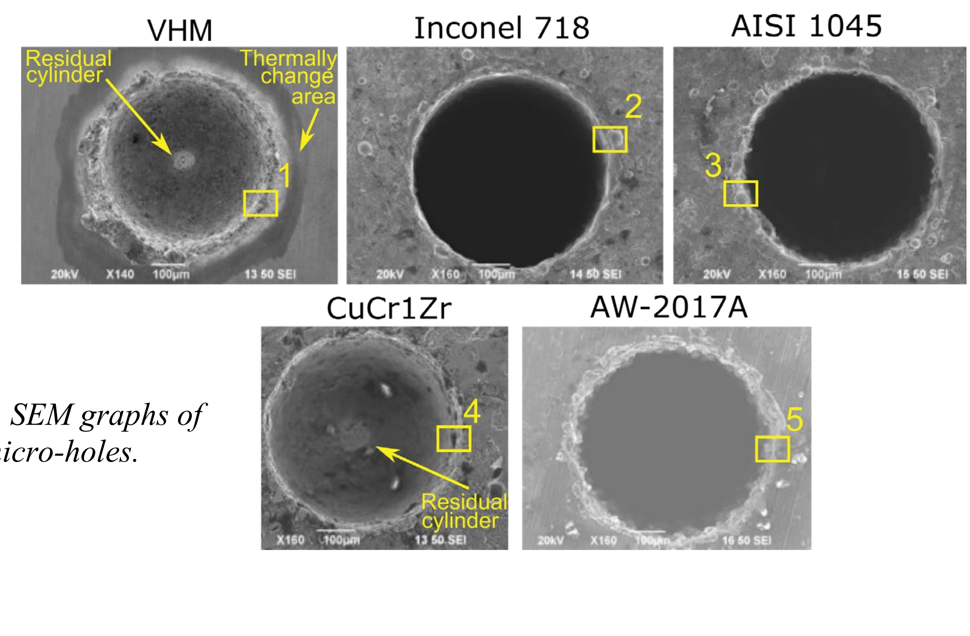

Fig. 5. SEM graphs of micro-holes.

Analysis of the hole entry shows clearly solidified material that has not been removed (Fig. 6). In addition, SEM photos and scans of the hole entry showed the so-called "residual cylinder" formed at the bottom of micro-holes drilled in tungsten carbide and copper alloy. This finding will be analyzed further in the article.

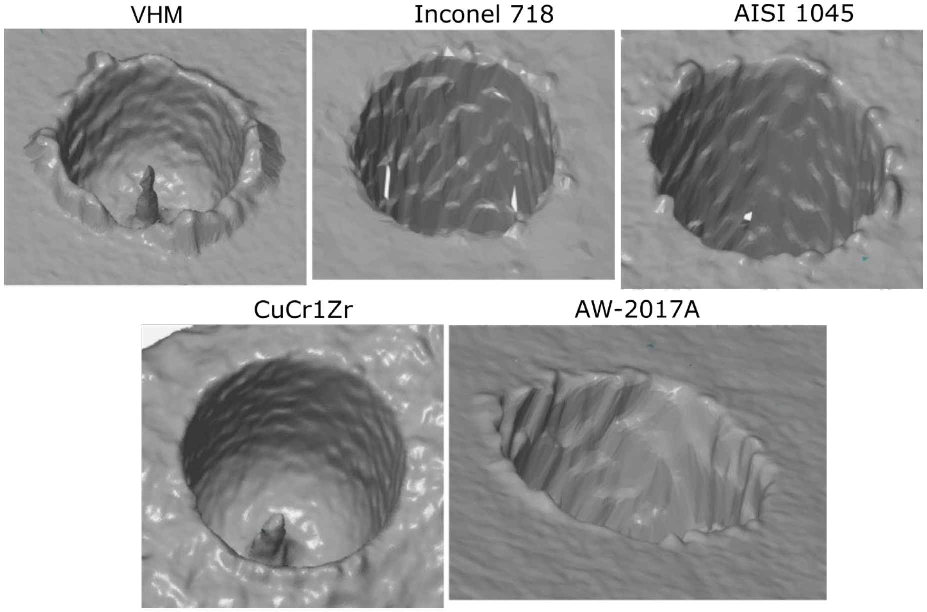

Fig. 6. Visualization of the entrance of micro-holes based on measurements.

Hole edge analysis (see in Fig. 7) showed that the smoothest edge was obtained for Inconel 718 superalloy and aluminum alloy. It is due to the good EDM machinability of these materials. Both have ER_{index} values lower or similar to brass. That is linked to the proper selection of the electrode material. On the other hand, on the edge of holes drilled in other materials, many defects such as microcracks and burrs. That is due to high ER_{index} and not optimized process parameters.

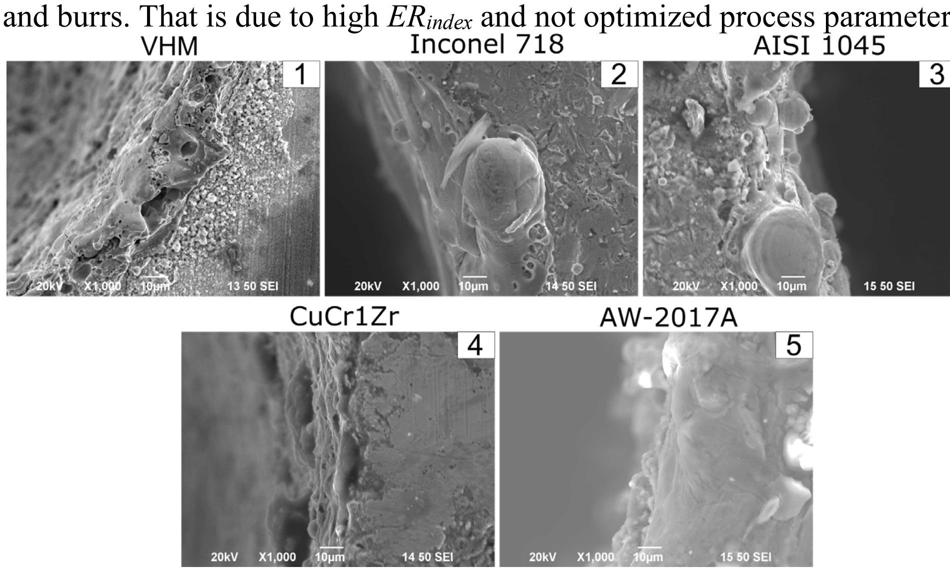

Fig. 7. Magnification of fragments marked as 1, 2, 3, 4, and 5, respectively, in Fig. 5.

In addition, VHM, CuCrZr and AW-2017A micro-holes cross-section reveals presence of residual cylinder located in the center of the hole bottom (Fig. 8). It represents not completely removed material. The measured height of the "residual cylinder" formed at the bottom of the holes drilled in the tungsten carbide, CuCr1Zr alloy and AW-2017A alloy was on average 0.30 mm, 0.17 mm and 0.25 mm, respectively.

The formation of the "residual cylinder" is influenced by the geometry of the working electrode - the tubular electrode, what has been explored in [25]. The front of the working electrode, due to the internal channel has a ring shape. Therefore, during the machining process, the heating of the material in the middle was lower comparing to material below the electrode “ring”. At the same time center of the hole receives more flushing what additionally cools that area. Thus, such conditions together with specific workpiece material properties prevented the effective removal of material in this area. In [27], it is explained that the "residual cylinder" is formed as result of the increased current density in the outside corner of the tool electrode tip. This increases the discharge frequency in the area of the bottom edge of the hole, and a lower frequency in the area on the bottom center. Uneven material removal together with higher flushing results in unremoved cone-shaped material. What interesting, remaining cylinder height increases together with the depth of the hole. In the analyzed test results, clearly visible that the cylinder remaining at the bottom in the holes has different shape or does not exist for different materials. Taking in to account that all holes were drilled with same material electrode and same parameters- all should present similar cone shaped bottom- assuming electric field is a main driver for that. Therefore it is suspected that “bottom cones” present in tungsten carbide and CuCr1Zr alloy results from the low machinability of these materials by EDM. When machining these materials, their thermophysical properties made stable machining much more difficult. What interesting, the aluminum alloy, in which the drilling was the fastest, the remaining cylinder at the bottom of the hole has comparable size to the one in carbide. That might be driven by high (the highest for selected materials) specific heat capacity. That parameter might prevent material removal similarly to high melting temperature of the VHM and high thermal conductivity of the copper alloy. Different properties produce similar result.

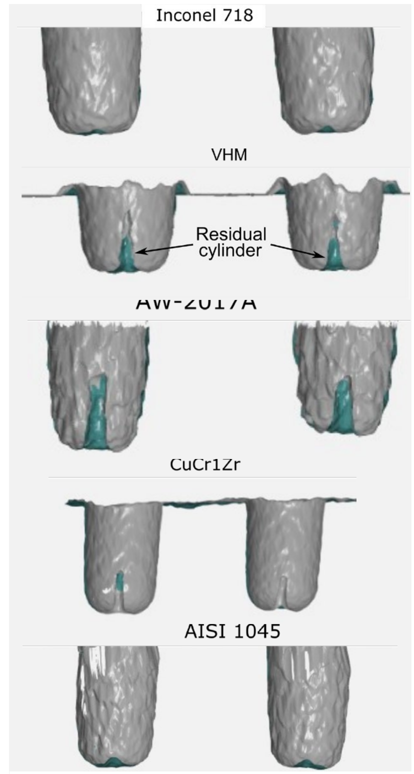

Fig. 8. Cross-sections of the bottom of the micro-holes.

Interestingly, both the Inconel 718 superalloy and AISI 1045 alloy present almost lack of a “residual cylinder” at the bottom of the holes drilled. This can be related to the lowest ER_{index} (for Inconel 718: ER_{index} = 1.28, for AISI 1045: ER_{index} = 8.81). At the same time ER_{index} of the working electrode material is higher brass ER_{index} = 9.75. This shows that in order to improve the accuracy of the bottom of the hole, the appropriate combination of electrodes is crucial. Despite the highest MRR value was obtained for aluminum alloy, the accuracy of the holes in this material requires improvement. On the other hand, the accuracy of holes drilled in Inconel 718 superalloy and AISI 1045 steel is acceptable, despite the lower efficiency of the EDM process.

Summary

The paper analyzes the impact of thermophysical properties of selected materials on the EDM performance. The analysis of the results showed that these material properties significantly affect the analyzed measures of the process such as MRR, LTW, AR. The greatest influence of properties such as melting point and thermal conductivity was observed on the EDM drilling process of micro-holes. The most important conclusions are as follows:

1. The best values were obtained for EDM drilling in aluminum alloy: MRR = 6.52 mm^3/min, LTW = 2.25 mm, and AR = 12.49. However, the accuracy of the geometry of micro-holes in this

material turned out to be unsatisfactory. Unremoved material in form ”residual cylinder” remained at the bottom of the hole.
2. Optimal values and high dimensional and shape accuracy (almost no “residual cylinder“ at the bottom of micro-holes) obtained for micro-holes drilled in Inconel 718 superalloy. Followed by: similar values and almost lack of „residual cylinder” presence in AISI 1045 steel.
3. Acceptable the EDM drilling process performance in Inconel 718 and AISI 1045 steel, was confirmed by the calculated erosion resistance index. The values of this index were the lowest for these workpiece materials (ER_{index} equal to 1.28 and 8.81, respectively for Inconel 718 and AISI 1045 steel), and were also lower than the value of this index for the working electrode material (ER_{index} = 9.76).
4. The results of the research carried out as part of this article show that other properties of modern engineering materials should also be taken into account during EDM process optimization.

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