INFLUENCE OF MATERIAL REMOVAL RATE ON MACHINED SURFACE ROUGHNESS IN WEDM OF SINTERED CARBIDES

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Currently, emphasis is placed on the quality of production in connection with its efficiency. The emphasis is mainly on machining processes in which the material removal rate is low. These machining processes include wire electrical discharge machining (WEDM). This is a technology that allows material removal using cyclically repeated electrical discharges. It is characterized by high production quality, but low productivity and process efficiency. This is due to the very nature of the electrical discharge process in conjunction with inappropriate settings of the main technological parameters. Therefore, their optimal setting is important to achieve favourable efficiency of the machining process. Moreover, low material removal rate is a particular problem of WEDM technology when machining sintered carbides. This is because these materials exhibit a greater degree of inhomogeneity of the structure and a significant reduction in material removal rate associated with it. The aim of the experimental research was therefore to analyse the mechanisms and interdependence of the quality of the machined surface in terms of roughness parameters and material removal rate in WEDM of tungsten carbide with Co binder. In addition, through graphical optimization, to define the qualitative area in which favourable values of the eroded surface roughness parameters Ra and Rz and at the same time a sufficiently high material removal rate is achieved.

KEYWORDS

efficiency, Metal Removal Rate (MRR), optimization, roughness, sintered carbide, technological parameters, Wire Electrical Discharge Machining (WEDM).

1 INTRODUCTION

An important criterion of current technical practice is the high quality of material processing and at the same time ensuring high productivity [Boominathan 2025]. Meeting the given criteria is a necessary step towards achieving high efficiency of the production process [Hnatik 2025]. In this regard, researchers are focusing in particular detail on machining methods in which the material removal rate is low. They are trying to solve this problem using various approaches from numerical to experimental [Straka 2022]. Optimization methods are also a suitable tool in this endeavour [Lee 2024], define the qualitative area in which favourable values of the roughness. They can achieve relatively favourable results. One of the machining methods that shows a low material removal rate is the wire electrical discharge machining (WEDM) technology [Ulhakim 2025]. This is a technology that occupies an important position in current mechanical engineering production, especially in areas where high demands are placed on the quality of the machined surface in terms of both micro and macro geometry [Selvakumar 2016]. It is standardly used in the piece production of forming tools and the production of molds for pressure casting. In addition to this main area of its use, the technology can also be applied in the production of parts with complex geometric shapes [Swiercz 2017]. These are mainly parts that cannot be machined by other, either classical or progressive methods. It is also used in the machining of materials with high hardness [Kiyak 2022], which are difficult to machine or not machined at all by other technologies [Harnicarova 2019]. It also finds its application in the production of special parts for industries with high demands on precision [Kumar 2026] and surface quality, such as the aerospace and automotive industries [Panda 2014].

Although WEDM technology seems to have a wide range of uses, its limiting application factor is the electrical conductivity of the machined material [Hasova 2016]. Electrically non-conductive materials can be machined by WEDM technology only by applying specific procedures that have an even more significant impact on reducing the material removal rate.

Another specific problem with WEDM is the machining of sintered carbides. This is mainly due to the significant inhomogeneity of the structure, which is manifested by a change in electrical conductivity in partial parts of the base material [Belouettar 2024]. This leads to a slowdown in the material removal rate, due to the instability of the discharge electric arc.

The aim of the experimental research was therefore to analyse the relationship between the quality of the machined surface and the material removal rate in WEDM of tungsten carbide with Co binder. As part of the research carried out, it was necessary, first of all, to examine in detail the mechanisms of material removal in the context of its chemical composition. In the next step, to examine the influence of the chemical composition on the material removal rate and at the same time the impact on the quality of the machined surface in terms of the roughness parameters Ra and Rz [Mouralova 2016]. By determining mathematical regression models [Krenicky 2022], to describe the mutual links between the quality of the machined surface and the material removal rate depending on the setting of the main technological parameters [Oniszczuk-Swiercz 2020, Krenicky 2022]. The setting of the main technological parameters of the electroerosion process must respect the criterion based on which high quality of the machined surface and at the same time high value of material removal rate are required. However, due to the high number of input factors of the electroerosion process, this is a relatively difficult task. Subsequently, using the method of graphical optimization [Djordjevic 2026, Evin 2020, Habib 2017], define the qualitative area in which favourable values of the roughness parameters of the eroded surface Ra and Rz are achieved and at the same time a sufficiently high material removal rate in WEDM of sintered carbides. The achieved results should significantly contribute to improving the competitiveness of WEDM technology, especially in areas where it is commonly used for machining sintered carbides.

2 MATERIAL AND METHODS OF THE EXPERIMENT

2.1 *Experiment preparation*

As is generally known, the primary factor contributing to the poor quality of the machined surface after WEDM in terms of roughness parameters and low material removal rate is, in addition to the chemical and structural inhomogeneity of the base material, also the inappropriate choice of the main technological parameters. These subsequently, in combination with an inappropriate type of wire tool electrode, have a significant share not only in the poor quality of the machined surface after WEDM but also in the low material removal rate and overall efficiency of the electroerosion process [Straka 2024]. Therefore, in order to achieve favourable results in all directions, it is necessary to look for suitable combinations of input factors of the electroerosion process.

At the same time, its thorough preparation is key to obtaining relevant results of experimental research [Panda 2020]. Since electroerosion machining is a financially and time-consuming experimental process, the occurrence of errors caused by insufficient preparation would lead to a significant extension of the implementation of the experiment and thus to an increase in its economic complexity [Rimar 2023].

For the above reasons, a detailed preparation of the experiment was carried out based on a thorough preliminary analysis of the current state of the problem being solved. The preparation also included a detailed search of available scientific papers and research results of renowned authors dealing with the given problem [Selvarajan 2023, Singh 2024, Wang 2025, Zhang 2025]. Based on the knowledge thus acquired, the experiments were subsequently carried out based on the design of experiments (DoE) methods and a precisely defined database of input factors necessary for their implementation.

2.2 *Technical support of the experiment*

Experimental samples were made on an electrical discharge machine with the type of designation AccuteX AU-500iA from AccuteX Technologies Co., Ltd. (Fig. 1). This is an electric discharge machine that, thanks to the unique intelligent AccuteX servo control technology with the application of multiple detectors, achieves high material removal rates, good reliability, while enabling highly efficient automatic and autonomous machining. Its intelligent control system ensures high accuracy for any shape, while its technology enables fast machining even in applications with variable conditions. It is also equipped with the SD Master system, which stabilizes the electrical discharge process and at the same time allows for high repeatability in the range of ± 1.5 µm. The MST function, in turn, allows for surface quality in terms of roughness parameter up to Ra = 0.18 µm, even for workpieces with a thickness of more than 50 mm.

Figure 1. AccuteX AU-500iA EDM machine from AccuteX Technologies Co., Ltd. used to produce experimental samples

The following Table 1 lists the main technical parameters of the AccuteX AU-500iA electric discharge machine from AccuteX Technologies Co., Ltd., which was used to produce experimental samples.

Table 1. Main technical parameters of the AccuteX AU-500iA electrical discharge machine from AccuteX Technologies Co., Ltd.

AccuteX AU-500iA	
Number of axes	5 (*X*, *Y*, *Z*, *U*, *V*)
Working range of *X* / *Y* / *Z* axis (mm)	500 / 300 / 300
U / *V* axis feed (mm)	100/100
Maximum workpiece dimensions (mm)	990 × 560 × 295
Maximum workpiece weight (kg)	400
Bevel angle and height (mm)	±22.5°/100
Wire diameter (mm)	0.15 – 0.33
Dielectric volume (l)	850
Power supply	3× 220 V, 50/60 Hz
Rated power input (kVA)	13
Rated machine power (kW)	10
Device dimensions *L* x *W* x *H* (mm)	2 950 x 2 560 x 2 210
Device weight (kg)	3 500

The quality of the machined surface of the experimental samples after WEDM in terms of surface roughness parameters Ra and Rz was determined using a contact roughness tester Mitutoyo SJ 400 from the Japanese company Mitutoyo (see Fig. 2).

Figure 2. Mitutoyo SJ 400 contact roughness tester used in the experiment

This is a measuring device with a range of ±1000 µm and a measurement accuracy of 0.01 µm. The measurement was performed on a length of 8 mm. The following Tab. 2 lists the main technical parameters of the contact measuring device Mitutoyo SJ 400 used in the experiment.

Table 2. Basic technical parameters of the Mitutoyo SJ 400 roughness tester

Mitutoyo SJ 400	
X-axis measurement range (mm)	25
Z-axis measurement range (µm)	800; 80 ; 8
Resolution (µm)	0.01 ; 0.001 ; 0.0001
Measuring force (mN)	0.75 ; 4.0
Measurement speed (mm.s^{-1})	0.05 to 1.0
Smallest Cut-off (µm)	2.5
Standards support	DIN EN ISO, VDA, JIS,

The measurement process of selected roughness parameters of the eroded surface of experimental samples made of sintered carbide with Co binder is shown in Fig. 3.

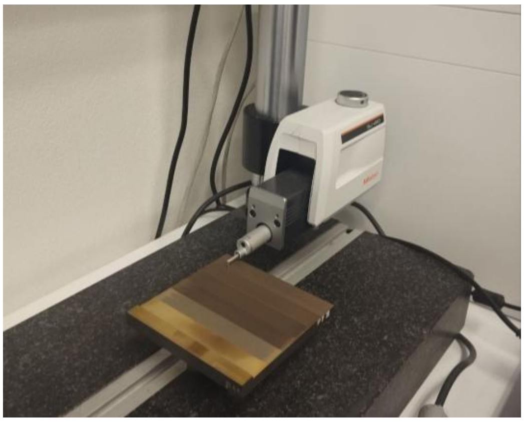

Figure 3. Measurement of roughness parameters Ra and Rz of the eroded surface of experimental samples made of sintered carbide with Co binder

2.3 *Material of experimental samples*

To produce experimental samples using WDM technology, sintered carbides labelled F10 and G30 were used. These are hard metals made of tungsten carbide with a Co binder, which are used in mechanical engineering practice mainly for the production of cutting tools. In the case of sintered carbide labelled F10, it is a material with universal use. Its basis is tungsten carbide with a 10 % Co binder. It is used for applications where a compromise between the hardness of the material and its impact resistance is required. It resists wear well at medium and high machining speeds. Sintered carbide F10 is used in technical practice for the production of tools such as turning knives, milling cutters, drills, grooving tools, etc., which are intended for machining semi hard materials (with a hardness of up to 250 HB), such as stainless, carbon and alloy steels. In the case of sintered carbide marked G30, it is a durable hard metal for difficult machining conditions. Its basis is tungsten carbide with 14 % Co binder. This material is very resistant to impacts, fractures and vibrations when machining hard materials and irregular shapes. It is used primarily for applications where an increased risk of chipping or uneven loading of the tool can be expected. Sintered carbide G30 is used in technical practice mainly for the production of tools that must withstand impacts, such as turning knives for roughing, grooving and shaping tools, etc. At the same time, for tools intended for machining hard materials (with a hardness above 300 HB), such as cast iron, tempered steels and steels with very high hardness.

Table 3 presents the chemical composition of the sintered carbides labelled F10 and G30, which were used to produce experimental samples using WEDM technology, including their selected physical and mechanical properties.

Table 3. Chemical composition, selected physical and mechanical properties of sintered carbides labelled F10 and G30 used to make experimental samples

Parameter	Value	
	F10	G30
Contents WC (%)	90.0	86.0
Contents Co (%)	10.0	14.0
Grain size (μm)	0.7	2.5
Density (g.cm^{-3})	14.35	14.10
Thermal conductivity (W/m·K)	70	65
Coefficient of thermal expansion (10^{-6} K^{-1})	5.5	5.5
Hardness (HV30)	1580	1100
Hardness (HRC)	91.8	87.3
Transverse fracture strength (N.mm^{-2})	3800	3200
Tensile strength K_{IC} (MPam$^{1/2}$)	10.7	14.2
Modulus of elasticity (GPa)	550	520

To produce experimental samples from F10 and G30 sintered carbides using WEDM technology, a cutting wire labelled Elecut Super Zinc with ∅0.25 mm was used (Fig. 4). This is a paraffin-free wire electrode with advanced multilayer coatings manufactured by Elero, s.r.o. Povazska Tepla. Its composition consists of brass wire of the CuZn37 type with a content of approximately 37 % Zn and 63 % Cu. The robust base material provides it with good strength and process ability. At the same time, a multiple special coating of the gamma compound γCu_5Zn_8 improves its cutting speed and wear resistance. At the same time, the coated brass core provides higher resistance to oxidation during use in a dielectric liquid [Mascenik 2024]. Compared to other standard brass electrodes, it thus exhibits up to 50 % higher cutting speed.

Figure 4. Cutting wire ∅0.25 mm with the Elecut Super Zinc marking used in WEDM of F10 and G30 sintered carbides

The following Tab. 4 shows the chemical composition and selected properties of the cutting wire labelled Elecut Super Zinc, which was used to produce experimental samples from F10 and G30 sintered carbides using WEDM technology.

Table 4. Chemical composition and properties of cutting wire labelled Elecut Super Zinc

Parameters	Value
Contents Cu (%)	63
Contents Zn (%)	37
Density (g.cm^{-3})	8.45
Electrical conductivity IACS (%)	22
Thermal conductivity (W/m·K)	100
Elongation (%)	1
Modulus of elasticity (GPa)	105
Tensile strength (N.mm^{-2})	980

3 EXPERIMENTAL RESULTS AND DISCUSSION

3.1 *Quality of machined surface in WEDM of sintered carbides F10 and G30 in terms of roughness parameters Ra and Rz*

Experimental samples were made from two blocks of F10 and G30 sintered carbides with dimensions 100 mm x 20 mm and height H = 100.0 mm, which were first divided by a longitudinal roughing cut into dimensions 100 mm x 10 mm and height H = 100.0 mm using WEDM technology using an Elecut Super Zinc cutting wire with ∅0.25 mm (see Fig. 5).

Subsequently, one of the pair of blocks was divided using WEDM technology in the height parameter ratio H = 30 : 70 mm. Experimental cuts were subsequently made on the basic blocks thus made. A total of 6 cutting operations were performed on each sample. The first operation was performed as a roughing cut, while the following 5 operations represented finishing cuts. The number of offset cuts was gradually increased for each finishing operation, with the first finishing cut corresponding to one offset cut, the second to two, the third to three, the fourth to four and the fifth to five offset cuts (see Fig. 6). 18 experimental surfaces were made for each of the sintered carbides, which made up a total of 36 samples.

On individual cut surfaces of the samples, the values of the surface roughness parameters Ra and Rz were recorded using a contact roughness tester Mitutoyo SJ 400. The graphs in the following Fig. 7 and 8 show the course of changes in the roughness parameters Ra and Rz depending on the number of offset cuts.

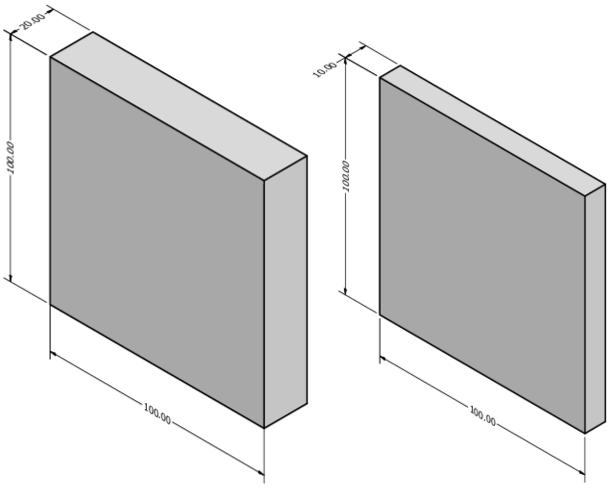

Figure 5. Experimental samples made from blocks of F10 and G30 sintered carbide with dimensions 100 mm x 20mm (10 mm) and height *H* = 100.0 mm

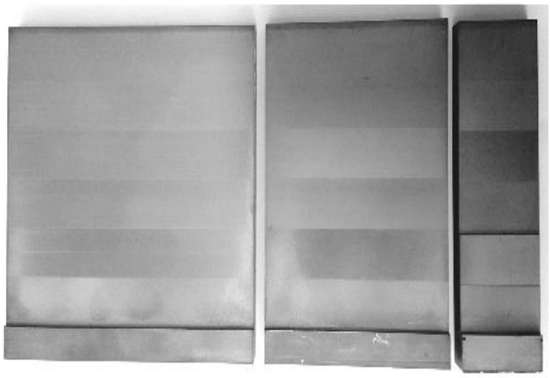

Figure 6. Experimental samples of F10 sintered carbide with dimensions 100 mm x 10 mm and heights *H* = 100.0 mm, 70.0 mm and 30.0 mm

From the graphical dependences in Fig. 7 and 8, it can be observed that the lowest value of the surface roughness parameters Ra = 0.29 µm and Rz = 1.80 µm was recorded during WEDM of sintered carbide with the designation F10 and the cutting height *H* = 30.0 mm with the application of five offset cuts. On the contrary, the highest value of the surface roughness parameters Ra = 3.44 µm and Rz = 22.35 µm was recorded during WEDM of sintered carbide with the designation G30 and the cutting height *H* = 100.0 mm with the application of a roughing cut. At the same time, it can be observed that with identical settings of the main technological parameters during WEDM, lower values of the roughness parameters Ra and Rz were recorded during machining of sintered carbide F10.

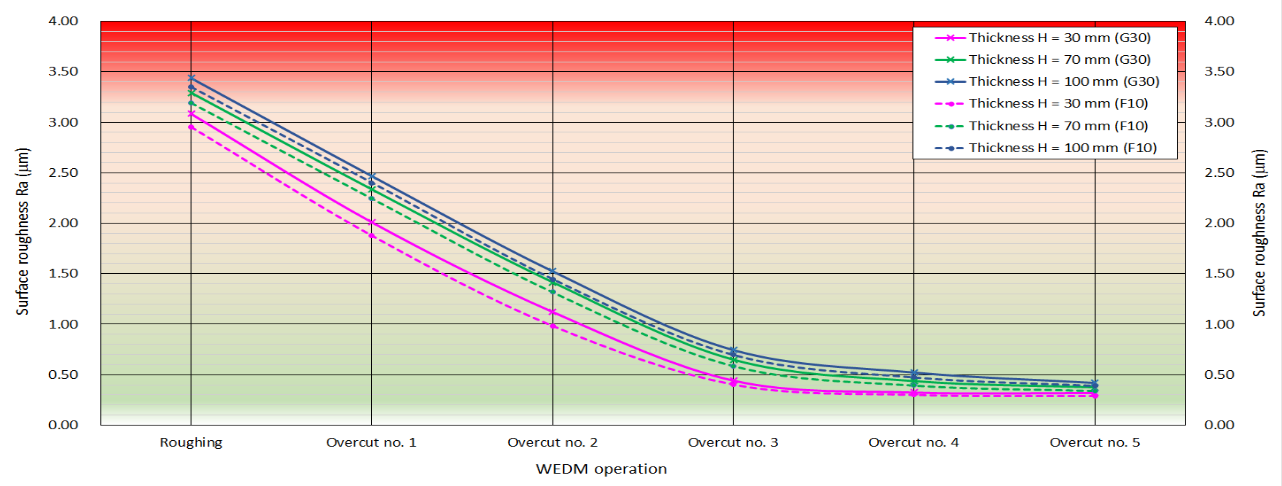

Figure 7. Dependence of the surface roughness parameter Ra on the number of offset cuts during WEDM of F10 and G30 type sintered carbides

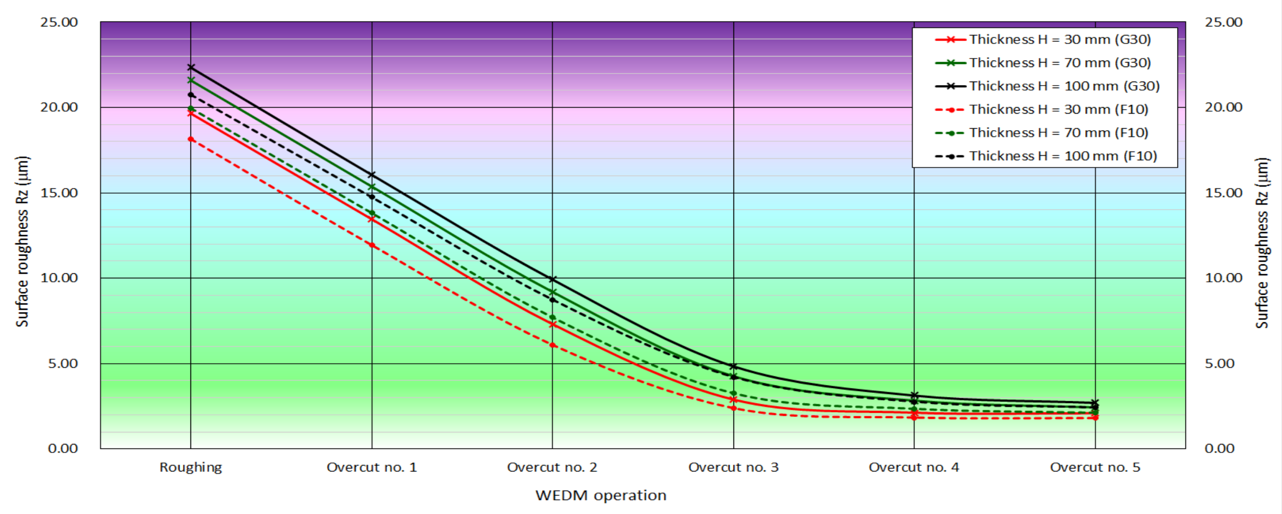

Figure 8. Dependence of surface roughness parameters Rz on the number of offset cuts in WEDM of sintered carbides of type F10 and G30

3.2 Material removal rate in WEDM of F10 and G30 type sintered carbides

WEDM is a technology for machining electrically conductive materials, in which material is removed by repeated electrical discharges between a moving wire and a workpiece immersed in a dielectric liquid. Unlike conventional chip machining methods, the process is independent of the mechanical hardness of the material, which is why it is also particularly suitable for machining sintered carbides, which are characterized by extreme hardness and high wear resistance. Since the F10 and G30 sintered carbides used in the experiment belong to cemented sintered based on tungsten carbide (WC) with different percentages of the metal binder Co, there are certain differences in the intensity of material removal during their machining. The F10 sintered carbide contains a lower proportion of cobalt and is characterized by a fine-grained structure and higher hardness. On the contrary, the G30 sintered carbide contains a higher proportion of the metal binder Co, which leads to higher toughness and better electrical and thermal conductivity. The graph in Fig. 9 shows the course of the change in the material removal rate during WEDM of sintered carbides of type F10 and G30 during a full cut and individual offset cuts.

From the graphical dependences in Fig. 9, it can be observed that the highest value of the material removal rate MRR = 65.08 mm.min^{-1} was recorded for WEDM of sintered carbide with the designation G30 and the cutting height *H* = 100.0 mm with the application of the roughing cut. On the contrary, the lowest value of the material removal rate MRR = 5.67 mm.min^{-1} was recorded for WEDM of sintered carbide with the designation F10 and the cutting height *H* = 30.0 mm with the application of the fifth offset cut. At the same time, it can be observed that with identical settings of the main technological parameters, lower values of the material removal rate MRR were recorded for WEDM of sintered carbide F10 in comparison with the machining of sintered carbide G30.

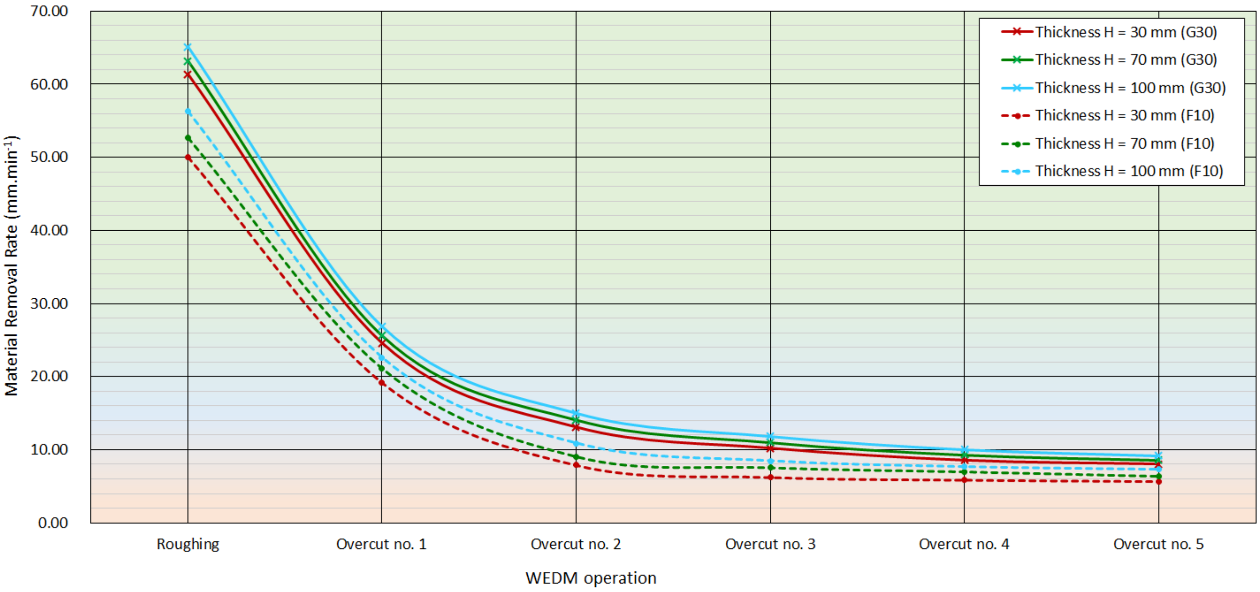

Figure 9. Material removal rate during WEDM of F10 and G30 type sintered carbides during full cut and subsequent offset cuts

3.3 Regression mathematical model for predicting surface quality and material removal rate during WEDM of sintered carbides

Both the quality of the eroded surface and the material removal rate during the machining of sintered carbides using WEDM technology are significantly influenced by the setting of the main technological parameters. These are mainly parameters such as discharge current, discharge voltage, but also the duration of the discharge and the pause time between discharges. For this reason, it is obvious that in order to achieve a favourable value of the roughness of the eroded surface and the material removal rate, their precise control is indispensable. Therefore, in the next step, based on the achieved results of experimental measurements, regression mathematical models were designed, the task of which is to predict the achieved quality of the eroded surface and the material removal rate depending on the setting of the main technological parameters of the WEDM process during the machining of sintered carbides based on tungsten carbide with Co binder.

Mathematical modelling of the output indicator of the material removal rate MRR as well as the output quality indicators of the machined surface Ra and Rz in connection with the setting of the main input parameters of the process during WEDM of sintered carbides of the F10 and G30 types was performed at a reliability level of approximately 95 %. The reliability value of the proposed mathematical models is described by the determination coefficients (R^2). If the R^2 value approaches 1, this means that the reliability of the model approaches 100 %. The proposed mathematical regression models are applicable for a wide range of settings of the input independent parameters of the electroerosion process such as the discharge current I, the discharge voltage U, the duration of the discharge ton and the pause time between discharges toff with a view to maximizing the output indicator of the process MRR and at the same time minimizing the output indicators of the roughness of the machined surface Ra and Rz.

Equations (1) and (2) represent mathematical regression models that were compiled based on experimental measurement results and serve to predict the output quality parameter of the machined surface Ra depending on the settings of the input process parameters I, U, t_{on} and t_{off} for sintered carbide types F10 and G30. Similarly, equations (3) and (4) represent mathematical regression models that serve to predict the output quality parameter of the machined surface Rz depending on the settings of the input process parameters I, U, t_{on} and t_{off}. The mathematical regression models were compiled with a view to minimizing the surface roughness parameters Ra and Rz.

Equations (5) and (6) represent mathematical regression models that were built based on experimental measurement results and serve to predict the output performance parameter, which is the material removal rate MRR, depending on the settings of the input process parameters *I*, *U*, t_{on} and t_{off} for sintered carbide types F10 and G30. In this case, the mathematical regression models were built with a view to maximizing the material removal rate parameter MRR.

3.4 Surface roughness vs. material removal rate in WEDM sintered carbides

Based on the proposed mathematical regression models (1) to (6), their graphic optimization was performed in the next step in order to define the area in which favourable values of the eroded surface roughness parameter Ra are achieved and at the same time the material removal rate MRR is sufficiently high. Fig. 10 shows the course of the output indicator of the material removal rate MRR as well as the output indicator of the eroded surface roughness Ra during WEDM of sintered carbides with a Co binder using a brass wire of the CuZn37 type with ∅0.25 mm based on the compiled mathematical regression models. From the above graphical dependencies, it can be observed that with an increasing number of offset cuts, the quality of the eroded surface in terms of the surface roughness parameter improves. The range of values for the Ra parameter ranges from 0.34 µm to 3.27 µm. At the same time, from the above graphical dependencies in Fig. 10 it can be observed that with increasing number of offset cuts the material removal rate decreases. The range of values of the material removal rate parameter MRR when machining sintered carbides with Co binder ranges from 6.44 mm·min^{-1} to 63.21 mm·min^{-1}.

Regression mathematical model for predicting the surface roughness parameter Ra for sintered carbide types F10 (1) and G30 (2)

$$Ra_{(F10)} = 2.27 - 0.4231 \cdot I + 0.02322 \cdot t_{on} - 0.02847 \cdot U + 0.03773 \cdot I^2 + 0.0051 \cdot I \cdot U \quad (R^2=0.9948) \quad (1)$$

$$Ra_{(G30)} = 0.562 - 0.0411 \cdot I + 0.019258 \cdot t_{on} - 0.01583 \cdot t_{off} - 0.00409 \cdot I + 0.04194 \cdot I^2 \quad (R^2=0.9963) \quad (2)$$

Regression mathematical model for predicting the surface roughness parameter Rz for sintered carbide types F10 (3) and G30 (4)

$$Rz_{(F10)} = 2.476 - 0.59 \cdot I + 0.11374 \cdot t_{on} - 0.1963 \cdot t_{off} + 0.2609 \cdot I^2 + 0.03019 \cdot I \cdot t_{off} \quad (R^2=0.9961) \quad (3)$$

$$Rz_{(G30)} = 4.06 - 0.388 \cdot I + 0.12683 \cdot t_{on} - 0.1101 \cdot t_{off} - 0.0306 \cdot U + 0.2863 \cdot I^2 \quad (R^2=0.9957) \quad (4)$$

Regression mathematical model for predicting material removal rate MRR for sintered carbide type F10 (5) and G30 (6)

$$MRR_{(F10)} = 21.68 - 11.22 \cdot I + 0.3026 \cdot t_{on} - 0.549 \cdot t_{off} + 1.789 \cdot I^2 \quad (R^2=0.9800) \quad (5)$$

$$MRR_{(G30)} = 32.58 - 16.71 \cdot I - 0.1131 \cdot t_{on} + 2.2 \cdot I^2 + 0.0892 \cdot I \cdot t_{on} \quad (R^2=0.9869) \quad (6)$$

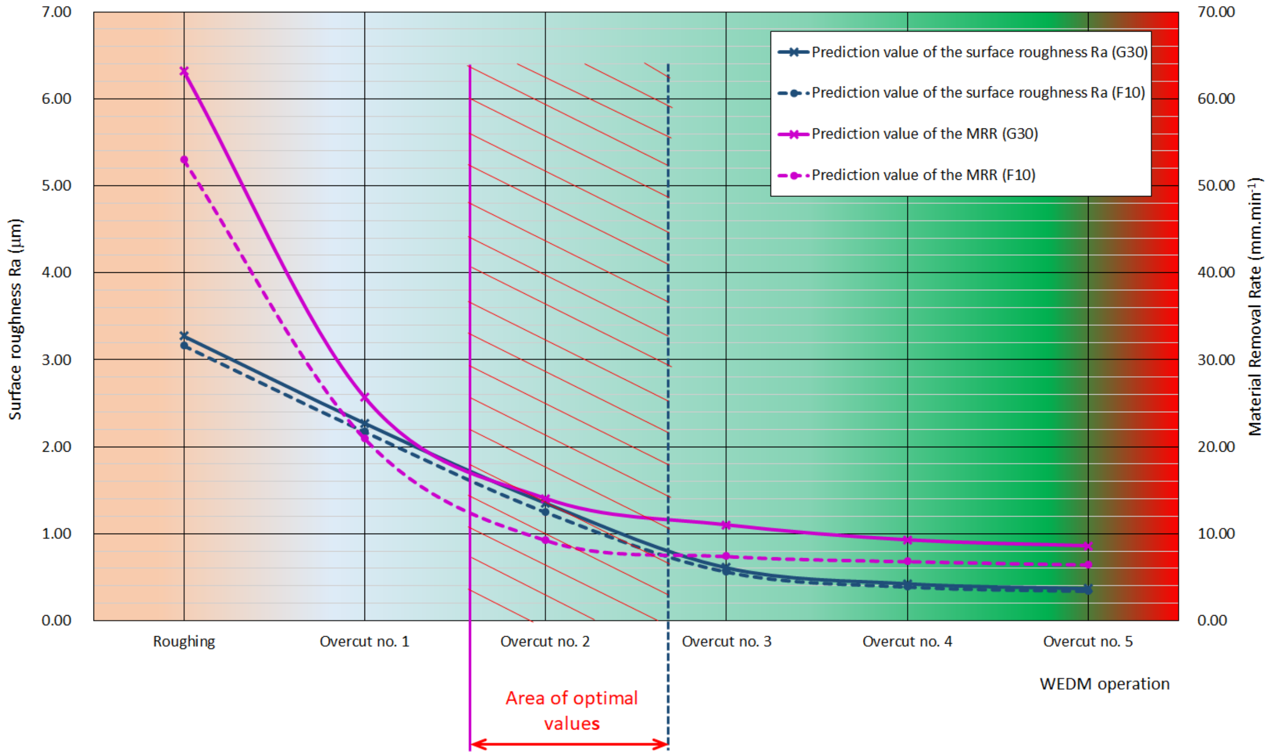

Figure 10. Optimization of surface roughness and material removal rate MRR in WEDM of sintered carbides

At the same time, Fig. 10 shows the performed graphical optimization of the output qualitative indicator of the eroded surface Ra and the material removal rate MRR during WEDM of sintered carbides with Co binder. Based on the performed graphical optimization, the area in which favourable values of the roughness parameters of the eroded surface Ra and at the same time an adequate material removal rate MRR can be achieved during WEDM of sintered carbides using a brass wire of the CuZn37 type with ∅0.25 mm was defined. This area ranges in the case of the parameter Ra in the range of values from 0.8 µm to 1.6 µm. In the specified range of the parameter Ra, the material removal rate is also achieved, which ranges from 8.0 mm min^{-1} to 18.0 mm min^{-1}.

3.5 *Evaluation of the experimental research results*

The experimental research was focused on the analysis of the interrelationships between the material removal rate MRR and the quality of the eroded surface in terms of the roughness parameters Ra and Rz during WEDM of tungsten carbide with Co binder using a brass wire with ∅0.25 mm. Several significant facts were found within the framework of the research. It was found that changing the chemical composition and composition of sintered carbides significantly changes the resulting quality of the machined surface and the material removal rate at the same time, with identical settings of the main technological parameters. It was observed that a higher value of the material removal rate was recorded at the same material thickness H for WEDM of sintered carbide with the designation G30 compared to sintered carbide F10. This deviation was on average at the level of 25 %. On the contrary, with identical settings of the main technological parameters and the same material thickness H, better quality of the machined surface was recorded at WEDM of sintered carbide with the designation F10. This deviation was on average 7 % for the Ra parameter and 12 % for the Rz parameter.

This phenomenon can be attributed to the fact that during WEDM machining, a series of electrical discharges are generated between the wire electrode and the workpiece, which cause local melting and evaporation of the material. The stability of the discharge process is then directly dependent on the electrical conductivity of the machined material. In the case of F10 carbide, the lower Co content leads to slightly worse conductivity, which causes less stable sparking and a lower material removal rate per unit of time. The lower material removal rate also has a positive impact on the roughness of the eroded surface. The result is a very high-quality surface with low roughness of the eroded surface. The fine-grained structure also contributes to uniform material removal and minimization of microdefects on the cutting surface.

In contrast, the G30 sintered carbide exhibits higher discharge stability during EDM due to the higher cobalt content, which improves the transport of electrical energy to the discharge site. The energy of the electrical discharge is more efficiently converted into thermal energy, which increases the intensity of material melting and at the same time leads to higher material removal. However, the increased material removal intensity will be reflected in slightly higher surface roughness, as the greater amount of energy released causes the formation of larger craters during individual discharges.

4 CONCLUSIONS

The aim of the paper was to describe the results of experimental research aimed at identifying the relationships between the material removal rate MRR and the quality of the machined surface in terms of surface roughness parameters Ra and Rz during WEDM of tungsten carbide with Co binder.

The research investigated the mechanisms of material removal in relation to the chemical composition of the F10 and G30 sintered carbides. It was found that the hardness of the material does not have a decisive influence on the material removal rate, since material removal in WEDM occurs by a thermal mechanism. However, the key factors are electrical conductivity, metal binder content and the ability of the material to stabilize the discharge channel. Since the F10 sintered carbide contains a lower % of Co binder, its electrical conductivity is also lower in comparison with the electrical conductivity of the G30 sintered carbide. This difference was reflected both in the material removal rate and in the quality of the machined surface. In the case of the material removal rate, this deviation was at the level of 25 %. In the case of the surface roughness parameters Ra and Rz at the level of 7 % to 12 %. The influence of the material removal rate MRR on the quality of the machined surface was also investigated in terms of the roughness parameters Ra and Rz. It was found that a higher value of the material removal rate resulted in an increase in the roughness parameters Ra and Rz of the eroded surface. The mutual relationships between the surface roughness parameters Ra and Rz, the material removal rate MRR and the setting of the main technological parameters of the process were described using established mathematical regression models. The method of graphical optimization also defined a qualitative area in which favourable values of the roughness parameter Ra of the eroded surface and at the same time a sufficiently high material removal rate MRR are achieved in WEDM of sintered carbides. This is an area in the range of the parameter Ra from 0.8 µm to 1.6 µm, while in the given qualitative area the value of the material removal rate MRR ranges from 8.0 mm min^{-1} to 18.0 mm min^{-1}.

In conclusion, based on the facts found, it can be stated that the optimization of the WEDM process parameters should be adapted to a specific class of cemented carbide. At the same time, the correct choice of technological conditions allows for a compromise between the intensity of material removal, process stability and the quality of the machined surface, which is especially crucial in the production of precision tools and shaped parts from sintered carbides using WEDM technology.

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