

INVESTIGATION OF THE SURFACE QUALITY OF THE EDM ELECTRODE AND THE MACHINED SURFACE

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INTRODUCTION

The electric discharge machining (EDM) is an often used production technology for free form surfaces machining, especially in the mould and die industry.

The chip removal is done by the electric sparks, which evolve between the electrode and the machined part in the dielectric fluid. The temperature of the spark is about 8000-20000 C°, which is suitable for evaporating the material. The material removal rate generally is 2 to 400 mm³/min. The advantages of the EDM technology are the next: every electrically conductive material is suitable for machining; the hardness of the material doesn't have effect on the machining; no mechanical load to the machined part. The material of the electrode is most often copper or graphite, but other material can be used like tungsten, silver, graphite-copper etc [1, 2].

During the EDM process the geometry of the electrode is copied to the workpiece. The nature of the machine surface is different from the cutted surfaces. In case of cutting technologies the tool motions create geometric patterns, while in case of EDM technology the surface consists of random pattern of caters (Figure 1).

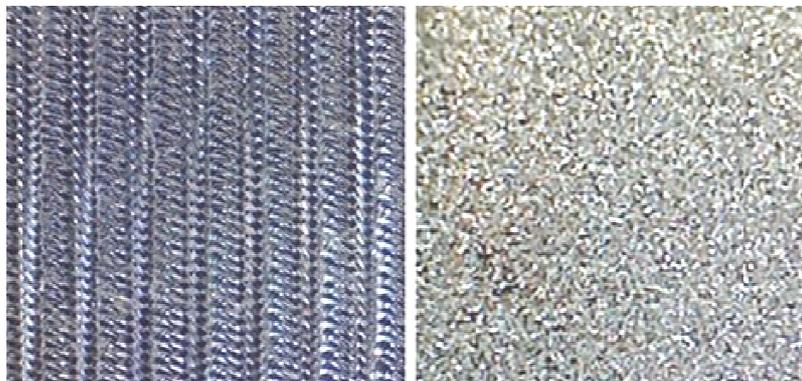


Figure 1

Surface structure in case of milling and EDM technology

The surface quality depends on the process parameters (current intensity, voltage, frequency etc. [3]), the grade of the electrode material, the distance between the electrode and the workpiece (spark gap), and the surface quality of the electrode.

DESIGN OF EXPERIENCE

The aim of the current research is to study the effect of the electrode's surface quality to the time, the accuracy, surface quality and the electrode wear. The

electrode wear based on the previous tests and literature was defined by weight lossing [4].

The investigation process can be seen in the Figure 2.

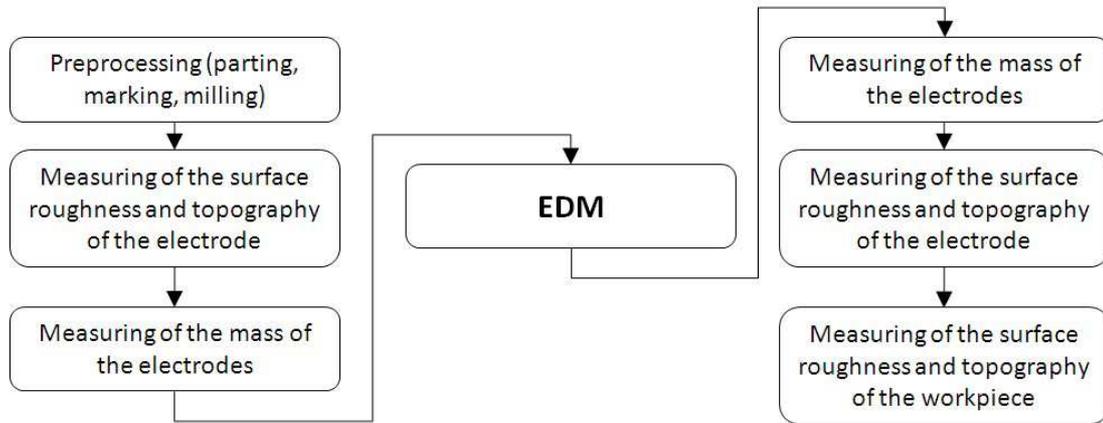


Figure 2
The investigation process

During the EDM machining three parameters were varied:

- The surface roughness of the electrode,
- The planned surface roughness of the workpiece,
- The spark gap.

The tests were performed by 15x15 mm sized copper electrodes (grade Meusburger 2.0060), a 7.5 mm wide 1 mm depth steps were machined (Figure 3) in an Ingersol Gantry 400 die sink EDM machine. The process parameters were defined by the machine's controller. The test part made of 1.2343 (x38CrMoV5-1) hardened (52-54 HRC) high alloyed tool steel.

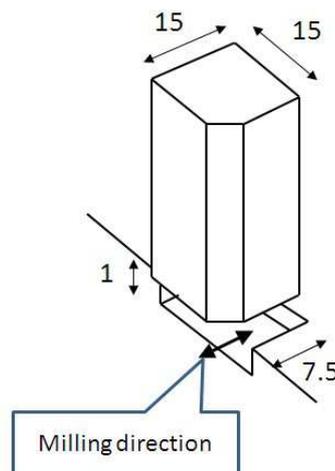


Figure 3
The test part geometry

The different electrode surface qualities were produced by ball end surface milling, which were controlled by the step over parameter (ProEngineer WF4 CAM system).

The working surfaces of the electrode were manufactured by milling with a Mazak A410-II CNC machining centre. The surface roughness and the 3D topology were measured by Mahr-Perten Concept device. The geometric dimensions were measured by Mitutoyo PJ-H3000F optical projector, the mass of the electrodes were measured by a Kern ALJ 220-4NM digital scale, and the statistical analysis was performed by MiniTab v14.

The planned surface quality of the workpieces was defined based on the VDI 3400 standard and the industrial requirements of mould manufacturing.

The levels of the parameters are the next:

- Stepper of the electrode surface milling: $a_e = 0,1 - 0,2 - 0,3$ mm.
- Planned surface quality of the workpiece (VDI 3400): VDI = 18 (Ra 0.79) – 21 (Ra 1.12) – 24 (Ra 1.58).
- Spark gap: SD = 0,20 – 0,25 - 0,30 mm.

In order to optimize the number of test sets, Taguchi DOE method was applied, thus 10 sets were performed instead of 27 sets. The 9+1 sets can be seen in Figure 4.

Taguchi DOE

	ae	VDI	SD
1	0,1	18	0,2
2	0,1	21	0,25
3	0,1	24	0,3
4	0,2	18	0,25
5	0,2	21	0,3
6	0,2	24	0,2
7	0,3	18	0,3
8	0,3	21	0,2
9	0,3	24	0,25
10	0,2	21	0,25

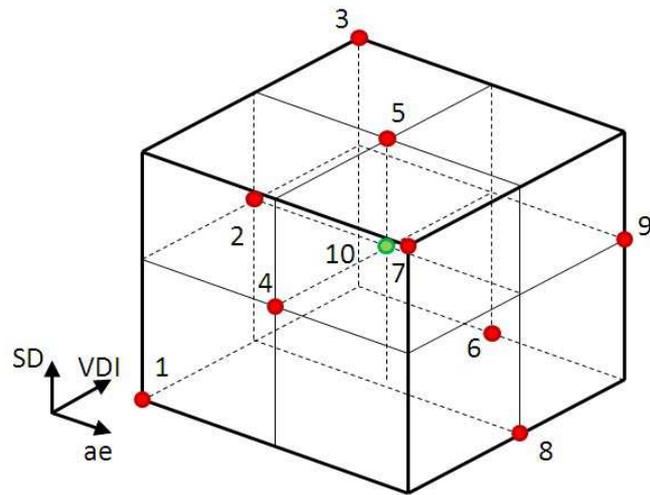


Figure 4
Taguchi DOE sets

PREPROCESSING OF THE ELECTRODES

The working area of the electrodes is a horizontal plane surface, the different surface roughness was generated by ball-end surface milling ($D_c = 10$ mm). The tool path was parallel with the x axis of the milling machine, and zig-zag strategy was used. The cutting parameters were the next: cutting speed (v_c) 250 m/min, revolution (n) 8.000 1/min, feed speed (v_f) 2.000 mm/min. The three different surface roughness was set by the density of tool path, the stepover were 0.1 – 0.2 – 0.3 mm. The generated cusps result the surface roughness (Figure 5).

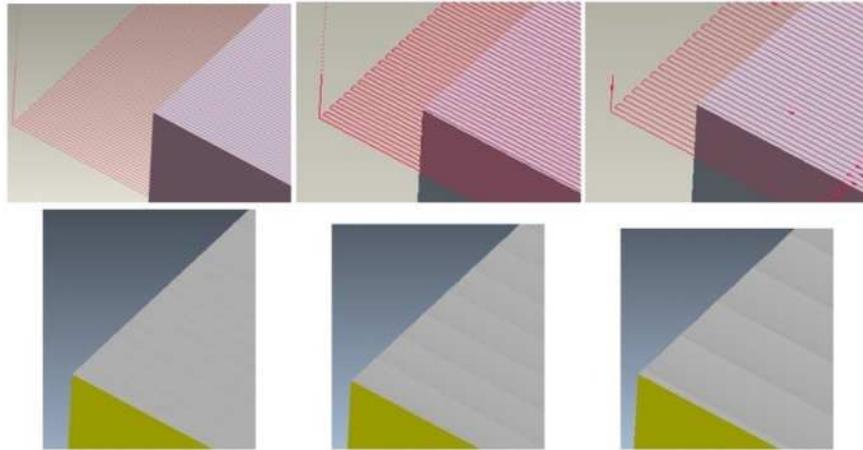


Figure 5

The tool paths and the cusps in the CAM simulation

The pictures of the 3D topology (Figure 6) show a 1x1 mm surface patch. The cusps and the marks of the feed can be identified, but the pattern is not as clear then the geometric model. The distance of the cusps is the twice than the stepover parameter which is against the geometric model. But in the top views the marks of the up cut and down cut are shown, the every second cusps are eliminated.

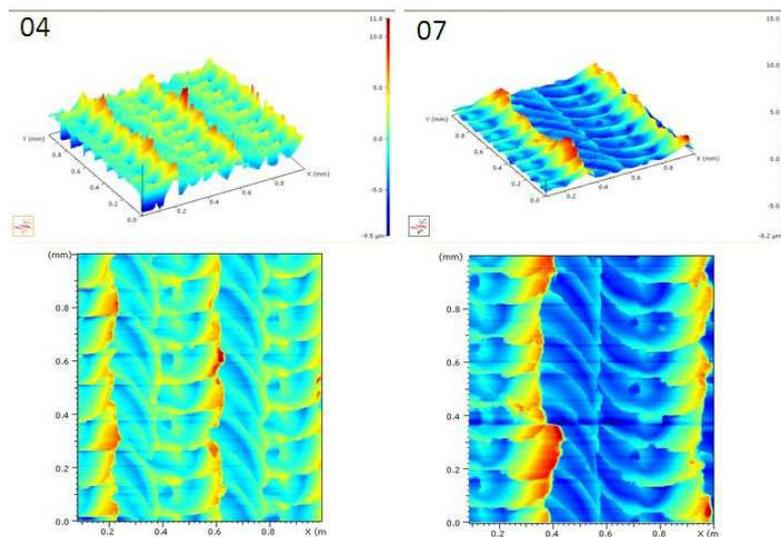


Figure 6

The 3D topology of the milled electrode surfaces (No. 4 and 7)

The surface roughness of the electrodes are the same, which were milled with same parameters, but the equal change in the stepover results larger change in the surface roughness. The Table 1 shows the Ra and Rz values of the electrodes.

Table 1

The average values of the surface roughness of the electrodes

No	a_e	Ra_E1	Rz_E1
1-3	0.1	1.4	7.2
4-6, 10	0.2	1.6	8.8
7-9	0.3	2.3	12.5

SURFACE ROUGHNESS OF THE TEST PART

The Table 2 shows test parameters and the average values and deviations of the surface roughness. The surface roughness was defined based on ten measures in each surface.

Table 2
The test parameters and results

No.	VDI	Ra _{VDI}	SD	Ra_P	Dev	Rz_P	Dev
	-	μm	mm	μm	μm	μm	μm
1	18	0.79	0.2	0.92	0.07	6.42	0.40
2	21	1.12	0.25	1.11	0.04	7.58	0.33
3	24	1.58	0.3	1.52	0.13	9.52	0.84
4	18	0.79	0.25	0.92	0.04	6.41	0.36
5	21	1.12	0.3	1.10	0.05	7.26	0.39
6	24	1.58	0.2	1.41	0.06	8.95	0.59
7	18	0.79	0.3	1.16	0.04	7.52	0.42
8	21	1.12	0.2	1.48	0.07	8.92	0.37
9	24	1.58	0.25	1.71	0.11	10.87	0.93
10	21	1.12	0.25	1.14	0.07	7.97	0.27

The natures of the EDM and milled surface are very different, and this difference is reflected in the ratio of Ra and Rz roughness parameters. The same Ra means 20% larger Rz in case of EDM.

$$Rz_{electrode_milling} = 5.380 \cdot Ra_{electrode_milling} \quad (1)$$

$$Rz_{test_part_EDM} = 6.477 \cdot Ra_{test_part_EDM} \quad (2)$$

The next question is, how accurate the technology, what is the difference between the planned and the realized surface roughness. In the Figure 7 the red dash line shows the ideal state, when the planned and the real values are equal, namely:

$$R_{Ra} = \frac{Ra_{planned}}{Ra_{realized}} = 1 \quad (3)$$

If this ratio is larger than 1, smaller surface roughness will be produced than the planned, in that case the measured point is under the dash line. If the ratio is less than 1 – the measured point there is above the line – the produced surface roughness is worse than the planned.

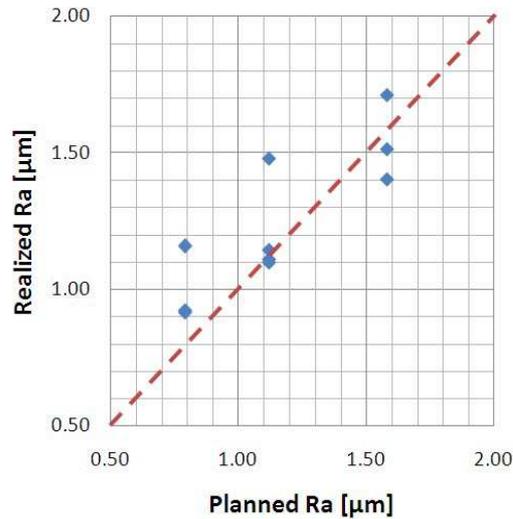


Figure 7
The planned and the realized surface roughness (Ra)

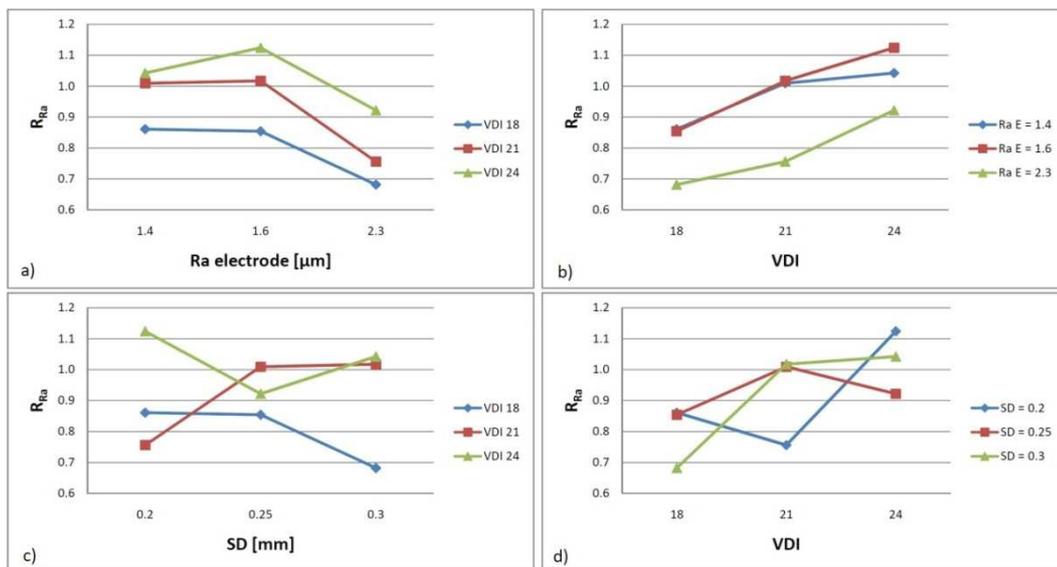


Figure 8
The ratio of the planned and the realized surface roughness (Ra)

The Figure 8 shows the behaviour of this ratio in function of surface roughness of the electrodes, the spark gap (SD) and the planned surface quality.

Based on the diagrams:

- The row electrode surface diminishes the surface quality of the EDM test surface (a and b).
- There is no differences between the two smaller electrode surface roughness from the viewpoint of goodness ratio (a and b).
- The small spark gap (0.2) is only suitable in case of fine (VDI 18) planned surface quality (c).
- The large spark gap (0.3) is advantageous in case of larger (VDI 21, 24) surface roughness (c).
- In case of VDI 18 the next parameters gave the good result:
 - Small electrode surface roughness (Ra 1.4, 1.6) and

- Small or medium spark gap (0.2, 0.25).
- In case of VDI 21 and 24 the next parameters given the good result:
 - Small electrode surface roughness (Ra 1.4, 1.6) and
 - Medium or large spark gap (0.25, 0.3).

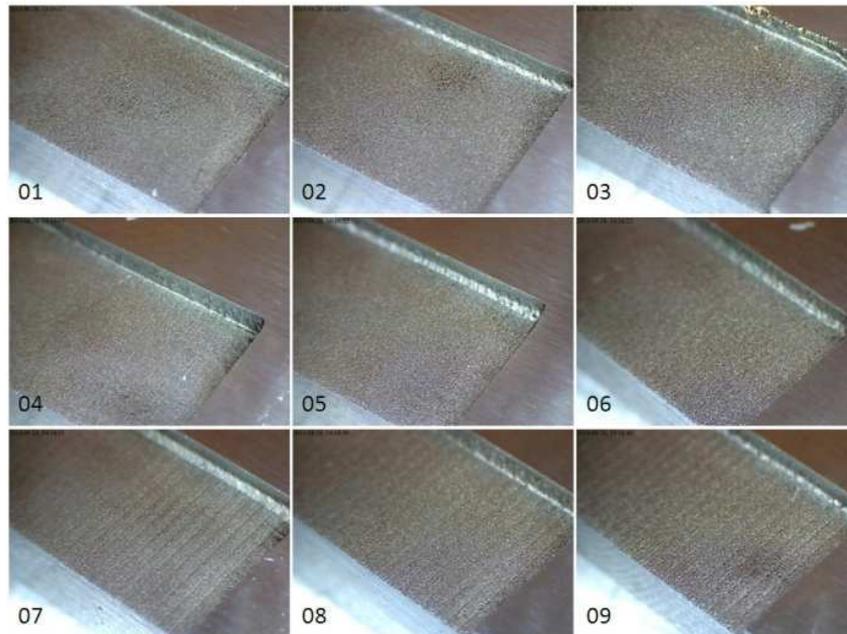


Figure 9
The pictures of the EDM-ed surfaces

Based on the photos of the test surfaces (Figure 9) it can be said that, in case of small electrode surface roughness the test surface is homogeneous, nevertheless in case of large electrode surface roughness the scallops of the electrodes are copied to the test surfaces.

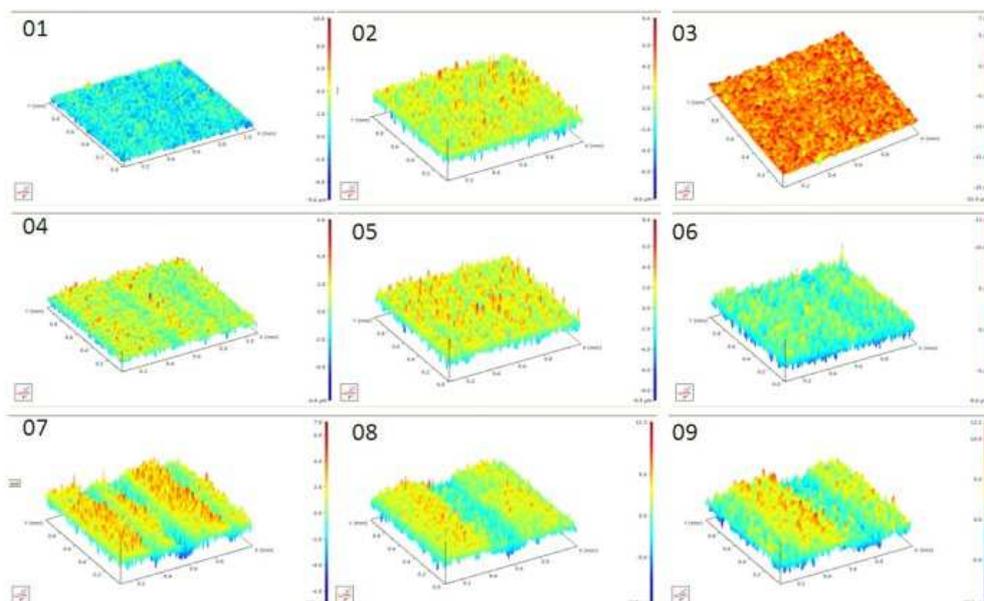


Figure 10
3D topology of the EDM-ed surfaces

Based on the 3D topology (Figure 10) the test surfaces are homogeneous in case of Ra 1.4 μm only, in other cases resulted in structured surfaces, but the increasing of spark gap reduces the inhomogeneity.

SUMMARY

The quality of spark eroded surface depends on many parameters. Based on tests with copper electrodes the importance of the effect of surface roughness of the electrode is presented.

The surface roughness of the electrode modified the results of the default machining parameters, the surface roughness of the test parts differ from the planned quality. The differences are clearly visible to the naked eye. If the electrode surface roughness larger than 1.6 μm , the accuracy of the test part surface roughness decreases. There is no optical difference between the surfaces when machined electrode with Ra 1.4 μm and Ra 1.6 μm , but the 3D topology shows the differences: the Ra 1.4 μm electrode generates more homogeneous surface.

The increasing spark gap increases the inhomogeneity of the surface, and increases the difference between the planned and realized surface quality.

The additional question of the research: what is the effect of the electrode surface roughness and other process parameters to the electrode wear, the productivity and the geometrical accuracy?

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