QUALITY OF DIMENSIONS ACCURANCY OF COMPONENTS AFTER WEDM DEPENDING ON THE HEAT TREATMENT

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The main purpose of this paper is to examine the gap width of the wire cut after WEDM depending on the heat treatment of machined material - high-alloy steel X210Cr12. This steel is usually used for the production of cutting tools. Cutting gap occurs during the discharge between the tool electrode and the machined material. This discharge causes melting of microscopic particles of the workpiece; the particles are then washed out from the place of the discharge by dielectric, which creates small craters. The size of the cutting gap is a limiting factor for the manufacture of internal radius and also it affects the final dimensions of the machined part. The heat treatment has an effect on the grain size and hardness of the material which results in a huge evaporation of the material and its subsequent leaching from the cutting place. The amount of evaporated and leached material was examined on the groove with width of 3 mm produced by WEDM to 4 differently heat treated steel samples X210Cr12. For cutting of all grooves the same parameters of the machine settings were used. The grooves were cut into four sections in order to achieve the highest possible dimensional accuracy.

KEYWORDS

WEDM, electrical discharge machining, heat treatment, kerf width, steel X210Cr12

1 INTRODUCTION

Nowadays, there are increased demands particular in the technology and design of cutting tools. With the development of new manufacturing processes highly accurate and shapely very ragged and complex cutting tools are required. EDM wire cutting method with a more than 50-year tradition has caused a huge shift in the technology of producing forming and cutting tools. Rapid and steep increase in the use of this technology is slowed down only by a limiting factor, which is a necessity of electrical conductivity of the machined components [Kumar 2012], [Ghodsiyeh 2013].

WEDM technology does not use the mechanical energy, but electric physical phenomena. The substance of electro erosion lies in an electrical discharge that occurs when the tool (wire electrode) is getting closer to the workpiece. This discharge causes melting of microscopic particles of the workpiece, these particles are then washed out from the place of the discharge by dielectric, which causes small craters on the surface of the machined material and on the surface of the tool electrode [Tosun 2003], [Luo 2009], [Okada, 2009]. At the same time it also leads to the evaporation of the eroded material and thus a so-called cutting gap, see Fig. 1. The size of this gap is directly dependent on the setting of machine parameters [Somashekhar 2010], [Tosun 2004], the dielectric used and also on the machined material. A key factor in this case is a kind of heat treatment of the machined material, which modifies its hardness and the grain size [Wu 2009].

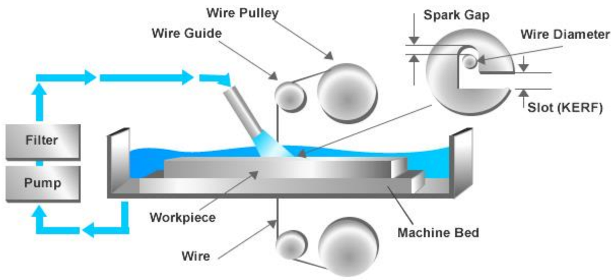


Figure 1. Schematic view of wire electrical discharge machining Process [American Wire EDM 2015]

The size of the cutting gap affects the final dimension of the machined component and has a limiting effect on the production of the smallest radius of the inner radius [Parashar 2010]. The wire-workpiece gap usually ranges from 0.025 to 0.075 mm and is constantly maintained by a computer controlled positioning system. In WEDM operations, material removal rate (MRR) determines the economics of machining and rate of production. In setting the machining parameters, the main goal is the maximum MRR with the minimum Kerf width [Kanlyasiri 2007].

For the commercial exploitation of the EDM wire cutting technology, machine manufacturers provide the database with tables of setting machine parameters depending on the type of material, its thickness and the type of electrode used. These tables with setting parameters are not further divided into possible ways of the heat treatment of the machined material. Therefore the same setting parameters are used for the material which was heat treated and for the material without any heat treatment.

2 EXPERIMENTAL SETUP AND WORK-MATERIAL

The samples for the experiment were made from high-alloy chrome steel X210Cr12 (Czech to European equivalent grades of CSN 41 9436). The chemical composition is in the Tab. 1. This material is mainly used for much stressed tools with high performance and durability for cutting and punching metallic materials of small thicknesses (up to 4 mm). These include the tools for cold forming, which are highly stressed, and shapely simple tools with high wear resistance with lower requirements for toughness, e.g. moulding dies, paper-weights, drawing dies, stamping dies, extrusion dies, compression pins, profiled and threaded cylinders. The material is in 9b class of machinability, it is hardly formable and weldable.

Contents	C	Si	Mn	P	S	Cr
Min [wt%]	1.9	0.1	0.2			11
Max [wt%]	2.2	0.6	0.6	0.03	0.03	13

Table 1. Chemical composition of steel X210Cr12 prescribed by the norm

The material for the production of each sample was heat treated differently according to Tab. 2. The heat treatment was carried out mainly in order to change the grain size and the hardness of the material. Types of the conducted heat treatment were chosen so that the samples had a low hardness as well as a higher one, which is used primarily for the cutting punches and punch tools for cold cutting.

For the production of samples the EDM wire cutting machine Makino EU64 was used. The basic parts of the WEDM machine consists of a wire, a worktable, a servo control system, a power supply and an electric supply system. The brass wire PENTA CUT E with the diameter of 0.25 mm was used for cutting (the chemical composition is 60 % of Cu and 40 % of Zn). The workpiece was immersed in the deionised water with high pressure waterjets flushing to remove debris in the gap between the wire electrode and workpiece.

Sample n.	Heat treatment
1	780 °C/ 20 hours / cooling down in the furnace
2	Quenched and tempered 960 °C / 1 hour / oil 200 °C / 2 hours / air
3	Quenched 1100 °C / 1 hour / oil
4	Soft annealed 760 °C / 2 hours / furnace

Table 2. Type of heat treatment of individual samples

Each sample was machined with the same setting cutting parameters. These parameters were determined according to the manufacturer's recommendations for the given material of a given thickness. In order to achieve the highest possible dimensional accuracy and the quality of machined surface, each sample was cut by 4 cuts. Setting the cutting parameters of pulse on time, pulse off time, gap voltage, wire speed and discharge current for each of the cuts is shown in Tab. 3. The height of the workpiece material was 15 mm.

parameter	Gap voltage	Pulse on time	Pulse off time	Wire speed	Discharge current
unit	[V]	[µs]	[µs]	[m/min]	[A]
Cut 1	40	9	44	15	29
Cut 2	30	2	40	10	13
Cut 3	30	2	42	10	11
Cut 4	80	1	3	10	1

Table 3. Machining parameters used in the experiments

On each sample of the material with a different heat treatment, a groove with width of 3 mm was made as shown in Fig. 2. The exact width dimension of the groove was the subject of this experiment.

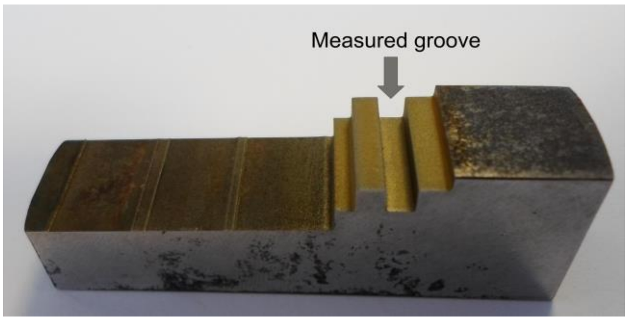


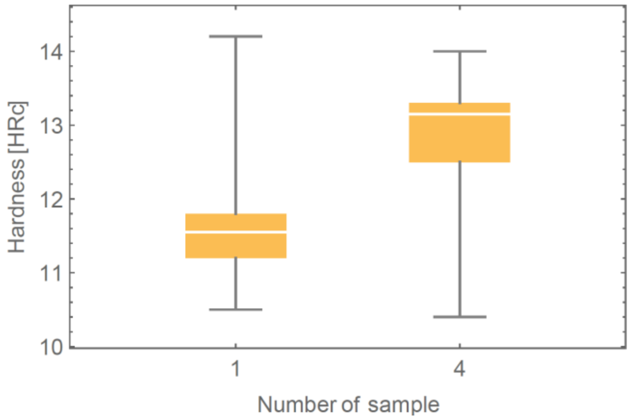
Figure 2. X210Cr12 samples with measured groove

3 EVALUATION OF THE EXPERIMENT

3.1 Hardness measurement

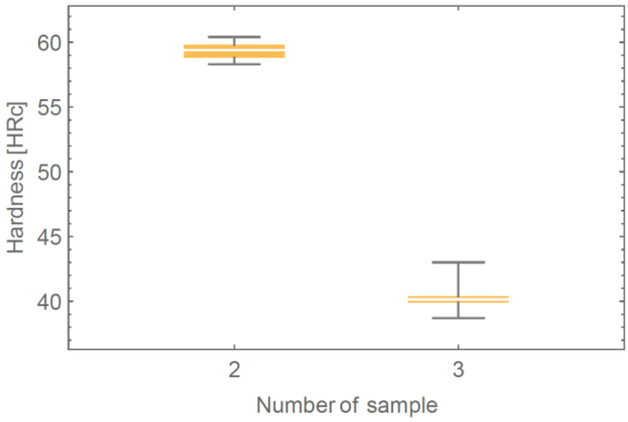
For hardness measurement a hardness tester ZHR 4150AK from Zwick Roell Company, of Rockwell production was used. 10 measurements were done on each sample. Depending on the heat treatment of the individual samples, values of degrees of hardness according to Rockwell were obtained.

The values for samples 1 and 4 were measured as very low, as seen in Graph 1. Sample 1 has a hardness of 11.7 HRc and Sample 4 has a hardness of 12.9 HRc. This was caused by the heat treatment type; where Sample 1 was heated in a furnace at 780 °C with a holding time at this temperature of 20 hours and then cooled down in the furnace. Sample 4 was soft annealed.



Graph 1. Box plot of hardness for samples 1 and 4

Samples 2 and 3 show a higher hardness than Samples 1 and 4, namely 59.4 and 40.3 HRc, as shown in Graph 2. Both samples were heat treated by quenching and sample 2 was subsequently tempered at 200 °C for 2 hours with cooling in a furnace.



Graph 2. Box plot of hardness for samples 2 and 3

3.2 Measuring dimensions of the groove

The width of the groove machined using the wire electric discharge cut machining was measured on each of 4 samples using a contact measuring instrument Vision Systems - Venture touch VI-3030 from BATY Company. For the measuring, the probe with a bead's diameter of 2 mm was used.

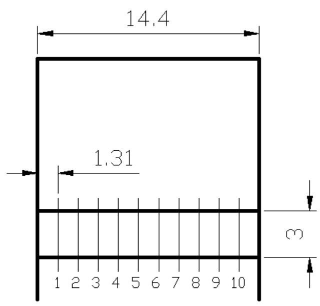
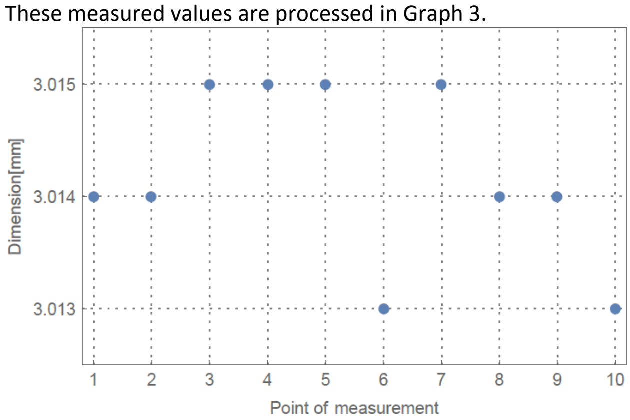


Figure 3. The points on the sample, where the measurement of groove width was carried out

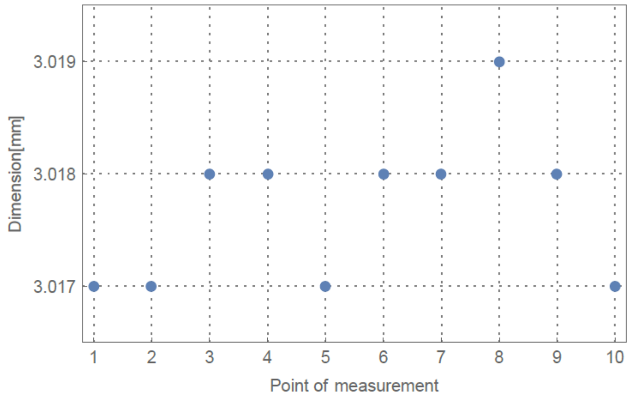
Points 1 to 10, see Fig. 3, at which the individual measurements were carried out, are always spaced by 1.31 mm on the total length of the groove, which is 14.40 mm.

The measured values of the groove width on Sample 1 at various points are in the range from 3.013 up to 3.015 mm. These measured values are processed in Graph 3.



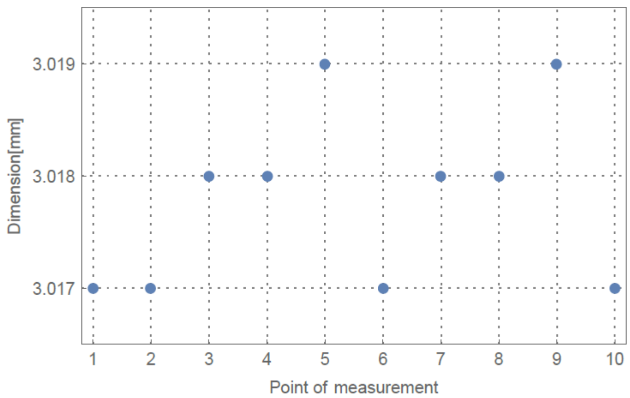
Graph 3. Measured groove width on Sample 1 at points 1 to 10

The width of the groove measured on Sample 2 ranged from 3.017 up to 3.019 mm, which is shown in Graph 4. It is clear from the graph that the width of the groove at points 1 and 10, which are at the edge of the material, is narrower than at the measuring points located nearer towards the centre. The widest dimension of the groove was measured at point 8.



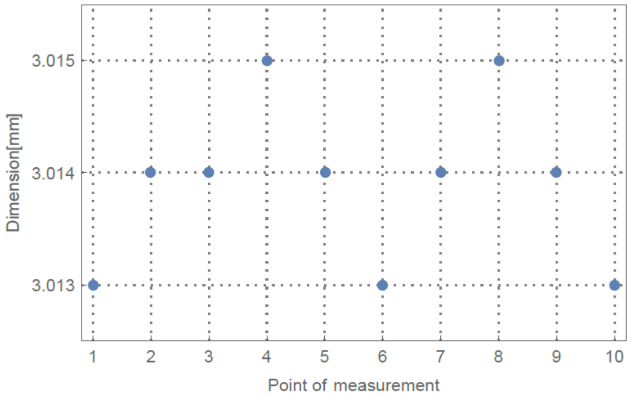
Graph 4. Measured groove width on Sample 2 at points 1 to 10

The dimension of the groove on Sample 3 ranged from 3.017 up to 3.09 mm. The broadest groove was at the measuring points 5 and 9, as shown in Graph 5.



Graph 5. Measured groove width on Sample 3 at points 1 to 10

The width of the groove on Sample 4 was measured at all 10 points in the interval from 3.013 up to 3.015 mm, as shown in Graph 6. The minimum width of the groove was achieved at the measuring points 1, 6 and 10. The maximum width was measured only at points 4 and 8.



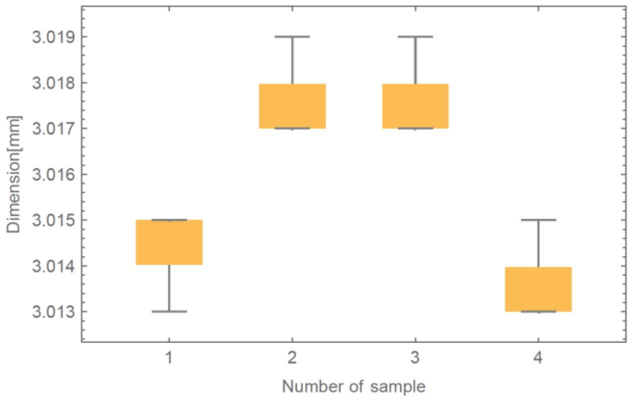
Graph 6. Measured groove width on Sample 4 at points 1 to 10

4 CONCLUSIONS AND DISCUSSION

The hardness of all samples was measured according to Rockwell. Sample 1 and 4 have the lowest measured value of hardness, which is only 11.7 and 12.9 HRc. For Sample 3 hardness of 40.3 HRc was measured, and the highest hardness was measured on Sample 2, which is 59.4 HRc. These measured values of hardness of steel X210Cr12 (after the heat treatment) correspond to the measured values in research [Jirková 2010] and [Brinksmeier 2008].

The final dimension of the machined groove for all samples ranged from 3.013 up to 3.019 mm, as shown in Graph 7. Samples 1 and 4 mostly approached the desired dimension of the groove of 3.000 mm. Sample 1 was heat treated at 780 ° C / 20 hours / cooled down in the furnace and Sample 4 was soft annealed.

Both of these samples had very low hardness (11.7 and 12.9 HRc). Samples 2 and 3, which were heat treated by quenching and by quenching and tempering, had the final dimension of the groove in the interval from 3.017 up to 3.019 mm.



Graph 7. Measured groove width on Samples 1-4

The width of the groove is primarily affected by the cutting gap [Gupta 2012]. The cutting gap width is here dependent on parameter setting machine [Abinash 2012], [Mahapatra 2006], [Ikram 2013], [Matousek 2009] and besides on the heat treatment type of the machined material and its hardness. The lower the hardness of the material, the less likely it is evaporated during electric discharge machining and leached in the form of small beads.

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