INVESTIGATIONAL STUDY OF WIRE ELECTRICAL DISCHARGE MACHINING OF AISI D5 TOOL STEEL

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Abstract: This paper displays an exploratory examination of the machining qualities of AISI D5 instrument steel in wire electrical release machining process. During tests, parameters, for example, open circuit voltage, beat span, wire speed and dielectric liquid weight were changed to investigate their impact superficially harshness and metallurgical structure. Optical and checking electron microscopy, surface unpleasantness and microhardness tests were utilized to contemplate the qualities of the machined examples. Thinking about the test results, it is discovered that the power of the procedure vitality affects the measure of recast and surface harshness just as microcracking, the wire speed and dielectric liquid weight not appearing to have quite a bit of an impact.

Keywords: WEDM process; Surface integrity; AISI D5 tool steel

I.INTRODUCTION

The quality of a machined surface is becoming more andmore important to satisfy the increasing demands of sophisticated component performance, longevity and reliability. When machining any component, it is necessary to satisfy the surface integrity requirements. Surface integrity has two important parts. The first is surface texture, which governs principally surface roughness. The second is surface metallurgy, which concerns to the nature of the surface layer produced in machining. Surface integrity of a surface produced by a metal removal operation includes the nature of both surface topography as well as surface metallurgy on the mechanical and physical properties of a material in its chosen environment. Electrical discharge machining removes electrically conductive material by means of rapid, repetitive spark discharges from a pulsating direct-current power supply with dielectric flow between the workpiece and the tool [1]. Each discharge melts or vaporizes a small area of the workpiece surface. This molten metal is then cooled in the dielectric fluid and solidifies into a small spherical particle which is flushed away by sweep action of the dielectric. Considering the challenges brought on by advanced technology, the EDM process is one of the best alternatives for machining an ever increasing number of high-strength, non-corrosion and wear resistant materials. Wire-EDM is a special form of electrical discharge machining wherein the electrode is a continuously moving conductive wire. Material removal is effected as a result of spark erosion as the wire electrode is fed through the workpiece. Thermal nature of this process always produces a recast and underlying heat-affected zone on the surface being machined and develops a residual tensile stress that often causes microcracks [2,3]. However, the thermal sensitivity or chemical complexity of the material can also affect the surface integrity. Optimum utilization of the capability of the WEDM process requires the selection of an appropriate set of machining parameters. Hence, the machining parameters, including pulse-on time, pulse-off time, table feed rate, flushing pressure, wire tension, wire velocity, etc. should be chosen properly according to workpiece properties so that better performance can be obtained. However, the selection of appropriate machining parameters is difficult and relies heavily on the operators' experience and machining parameters tables provided by the machine-tool builder [4]. But, these alternatives completely do not satisfy the requirements of both high efficiency and good quality. In order to optimize machining conditions for materials with different thermal properties or advanced materials, experimental investigations are still required [5]. Several studies have been carried out in order to determine appropriate workmaterial/machining parameters combination from aspect surface integrity. These studies show that the surface roughness of the process is closely dependent on the machining parameters [6–10]. The structural changes of EDMed surfaces of steels have been studied and found that the top-most surface layer is non-etchable layer, namely the white layer. Immediately beneath this layer, there is a heat-affected zone, where heat caused microstructural transformations [11,12]. Relationship between EDM parameters and surface crack formation for D2 and H13 tool steels was studied [13]. It was shown that crack formation and white layer thickness is related to the EDM parameters. An increased pulse-on duration will increase both the white layer thickness and the induced stress. Two conditions tend to promote crack formation. The purpose of this paper is to determine effect of machining parameters namely, open circuit voltage, pulse duration, wire speed and dielectric fluid pressure on surface integrity of AISI D5 tool steel used in manufacturing die and mold components by wire-EDM process.

II. EXPERIMENT

The composition of AISI D5 steel used in experiments is given in Table 1. One series of specimens were quenched and tempered. Another series were annealed (Table 2). Specimens were prepared that cutting area is 8mm ×8mm square shaped. The experiments were performed on a Sodick A320D/EX21 WEDM machine. In experiments, different settings of pulse duration, wire feed rate, dielectric flushing pressure and open circuit voltage were used (Table 3). Different combinations of these machining parameters were tested using factorial experimental design method. Pulse interval time (16 _s), table feed rate (7.6 mm/min) and wire tension (1800 g) were fixed. CuZn37 master brass wire with 0.25mm diameter was used in experiments. De-ionized water was used as the dielectric fluid. After machining, fol-lowing experimental techniques were employed for assessing the surface integrity of the specimens. Average surface roughness (Ra) was obtained using Mitutoyo Surftest SJ-201 portable device. Specimens were sectioned transversely and prepared under standard procedure for metallographic observation. Etching was performed by immersing the specimen in 5% Nital reagent. Microhardness from cross-section of machined surface was measured to determine hardness variation of heat-affected zone of specimens.

Table 1
Chemical composition of specimens tested (wt.%)

C	1.53
Si	0.89
Mn	0.46
Cr	12
Mo	1.00
Ni	0.384
Fe	Balance

Table 2
Initial state of specimens

Heat treatment	Microhardness (HV)	Notation
Annealed	380	A
Quenched and tempered	750	B

Table 3
Parameters of the setting

Input parameters	Level 1	Level 2	Level 3
Pulse duration (ns)	300	500	700
Open circuit voltage (V)	100	270	–
Wire speed (m/min)	5	10	–
Dielectric flushing pressure (MPa)	0.6	1.2	–

III. EXPERIMENTAL RESULTS AND DISCUSSION

The surface texture is composed of a random array of overlapping craters or cusps, as shown in Fig. 1, after machining. During each electrical discharge, intense heat is generated, causing local melting or even evaporation of the workpiece material. With each discharge a crater is formed on the workpiece. Some of the molten material produced by the discharge is carried away by the dielectric circulation. The remaining melt resolidifies to form an undulating terrain. Figs. 2–4 show typical cross-sectional view of A and B specimens, respectively. Four zones were identified considering microhardnesses and micrographs in all specimens after machining. Outermost surface is debris or recast layer which cooled too quickly to escape the gap and were recast to the material. Next layer commonly called the white

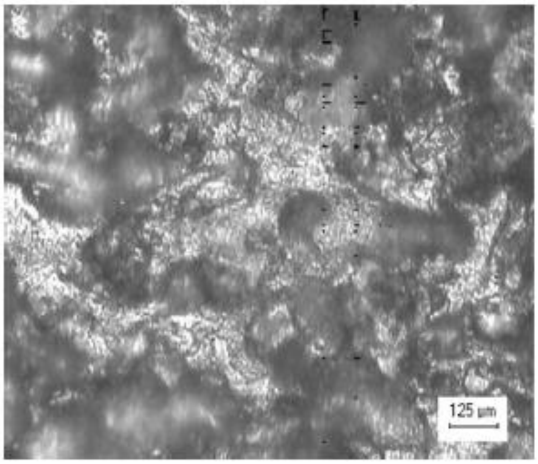

Fig. 1. A typical surface after wire-EDM.

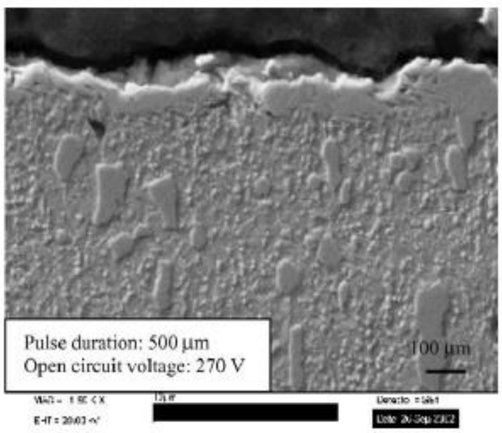

Fig. 2. Cross-sectional view of A specimen (dielectric fluid pressure0.6MPa, wire speed 5 m/min).

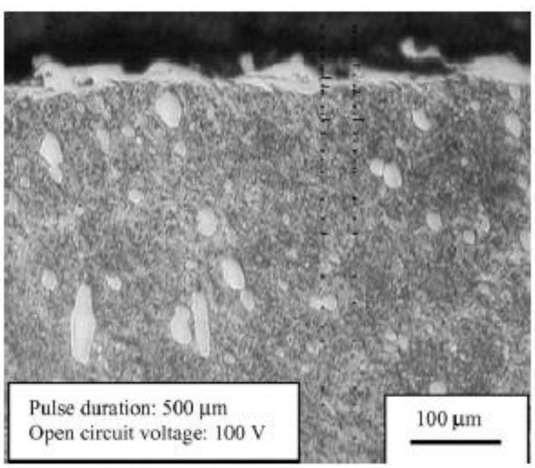

Fig. 3. Cross-sectional view of A specimen (dielectric fluid pressure 1.2MPa, wire speed 5 m/min).

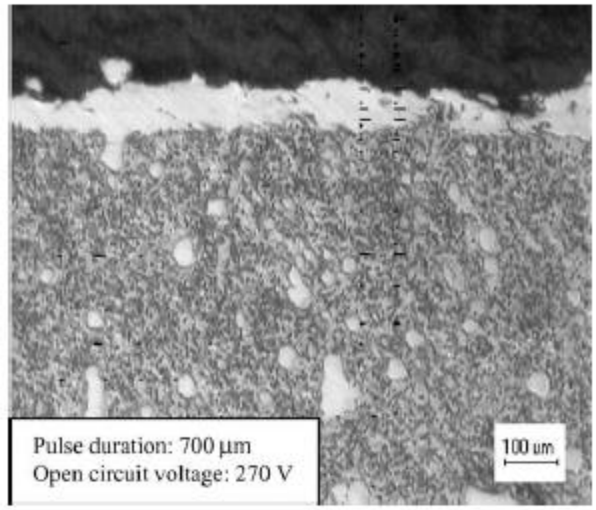

Fig. 4. Cross-sectional view of B specimen (dielectric fluid pressure 0.6MPa, wire speed 5 m/min).

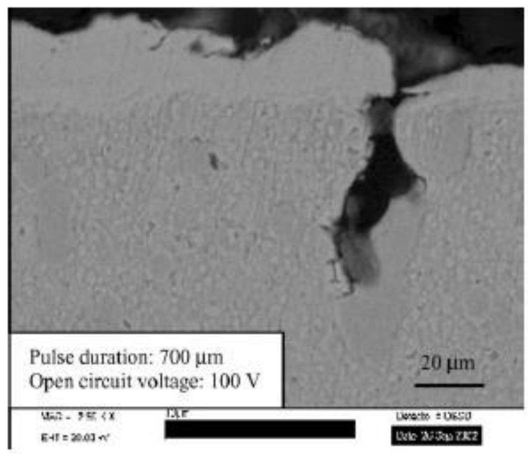

Fig. 5. Showing cross-sections of A specimen (dielectric fluid pressure 0.6MPa, wire speed 5 m/min).

layer, has been heated to very high temperatures, taken to a molten state, and then rapidly cooled. This rapid heating and cooling process causes a very brittle surface, which is highly susceptible to thermal stress cracks. White layers have been suggested to have an untempered martensitic structure [1]. Below the white layer is an area which was heated and cooled more slowly. This created an annealed area, softer than the parent material. Finally, we come to the parent material. As can be seen from figures, the thickness of white layer of WEDMed surfaces increases with the increase pulse duration and open circuit voltage. This layer is always present to some degree. It is found that the wire speed and dielectric flushing pressure have not a significant influence on the microstructure in applied conditions. However, in especially high pulse duration and open circuit voltage value, wire breakage caused of carbides in the workpiece decreases with increase wire speed and dielectric flushing pressure. As seen in Figs. 5 and 6, another primary feature on wire-EDMed surfaces is the existence of microcracks. These cracks are seen to radiate from, and also to circumvent, the craters. Formation of the microcracks in the white layer normally is promoted by the high carbon content in workpiece and excessive electric parameters [14]. The crater sizes increase with pulse energy, as does the density of surface cracks (Fig. 6). Furthermore, the cracks can penetrate into the heat-affected zone depending on pulse energy. the EDM parameters. These microcracks can act as initiation points for failure.

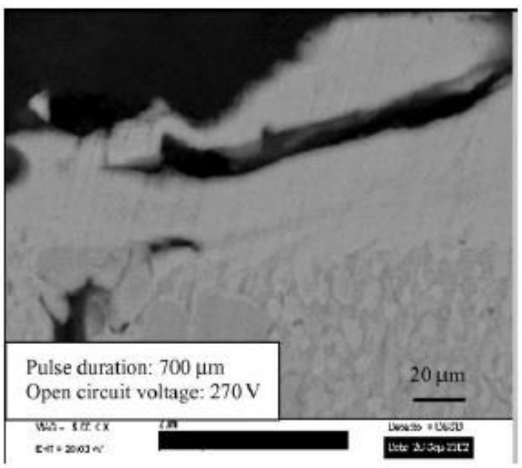

Fig. 6. Showing cross-sections of A specimen (dielectric fluid pressure 1.2MPa, wire speed 5 m/min).

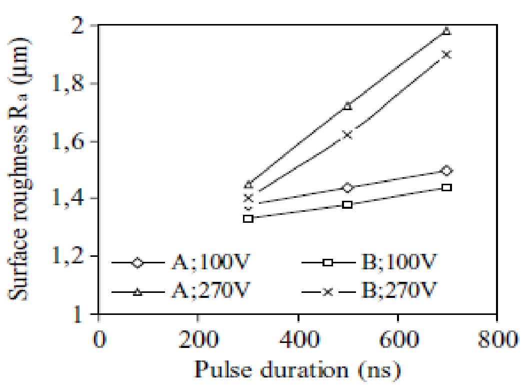

Fig. 7. Surface roughness Ra vs. pulse duration for various open circuitvoltage (dielectric fluid pressure 0.6MPa, wire speed 5 m/min).

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CONCLUSION

In this experimental study, the effect of WEDM parameters such as open circuit voltage, pulse duration, wire speed and dielectric fluid pressure on machining characteristics of AISI D5 steel was investigated. Summarizing the main features of the results, the following conclusions may be drawn:

1. The surface texture is composed of a random array of overlapping craters or cusps, after machining. Four zones were identified considering microhardness and micrographs in all specimens. Outermost surface is debris or recast layer. Next layer is white layer. Below the white layer is an area which was heated and cooled more slowly. This created an annealed area, softer than the parent ma material. Finally, parent material is present. The thickness of the heat-affected zone or white layer on the surface is approximately proportional to the magnitude of the energy impinging on that surface.

2. The density of cracks in white layer increase with increased pulse duration and open circuit voltage. Furthermore, the cracks penetrate into the heat-affected zone depending on pulse energy.

3. The surface roughness increased when the pulse duration and open circuit voltage were increased. It appears that the surface roughness primarily depends on these parameters, dielectric fluid pressure and wire speed not seeming to have much of influence.

4. The cutting surface of all specimens is harder than the bulk material because of white layer, while the heat-affected zone is softer in quenched and tempered specimens because of overtempered martensite.

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