Effects of Work Piece Characteristics on Wire Electrical Discharge Machining Process

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Abstract— Extensive experiments were carried out to correlate cutting speed in WEDM process with wire diameter and work piece characteristics. It is evident that higher melting point and latent heat of fusion of materials reduces cutting speed. Powder compact materials like graphite and WC show very low cutting speed due to presence of pores.

Keywords: Wire electrical discharge machining (WEDM)

I. Introduction

Wire electrical discharge machining (WEDM) is defined as the process of material removal of electrically conductive materials by use of thermo – electric source of energy. The WEDM process has a unique advantage of machining of precision and complicated geometry with high degree of accuracy and surface finish. The process does not introduce significant mechanical stresses. Hence, the machined surface is almost stress free with very less or no micro-cracks. The surface quality is very high and can be controlled by proper selection of machining parameters.

The process of WEDM involves a continuous travelling wire electrode which is controlled by the computer to follow a predefined path to cut a slot through the work piece to produce the required shape [1]. High frequency alternating current is discharged from the wire to the work piece with very small gap through an insulated dielectric fluid. The heat of each electrical spark erodes away the material. These particles are flushed away from the spark zone with a stream of dielectric fluid forced with the help of nozzle. This dielectric also prevents the heat buildup in wire and the work piece.

The constraints of WEDM process in production is cutting speed. Any attempt to increase of cutting speed by WEDM parameters would increase frequency of wire rupture. The major cause of wire rupture is excessive thermal load which the wire is unable to withstand. Several studies have been carried out to predict the thermal load by analyzing temperature distribution in the spark zone [1-3]. Some other studies [4-6] reveal that WEDM involves large number of input parameters affecting the quality characteristics and investigates the relative importance between the input and output parameters. It has been noticed that very few data are available to correlate cutting speed with material properties and input parameters of WEDM. In this paper, an attempt is made to correlate input parameters with cutting speed or surface removal rate and its dependence on material properties.

II. Experimental

Work pieces of different materials were taken for WEDM operation in ELECTRONICA SPRINTCUT 734 machine and details are given in the Table I. Complete test pieces of 10 mm x 10 mm were cut based on the manufacturers optimized parameters recommendation for that particular test piece so that maximum cutting speed can be achieved without wire rupture. The wire used was Brass (CuZn37) with tensile strength of 500 N/mm^2.The cutting speed was calculated as follows:

Cutting speed = (Total contour length of test piece) / (Total time taken to cut the test piece)

Material	Job height range in MM
HCHCr	10 to 80
Copper	10
Aluminum	10
Zinc	10
Tin	10
Graphite	10 to 50
WC	10 to 40

Table 1: Details of Samples

III. Results & discussion

A. *Effect of Job Height and Wire Diameter:*

Figure 1 illustrates that the cutting speed reduces with increase of job height. It is observed that there is a sharp decrease of cutting speed with increase of job height from 10 to 20 mm. It may be pointed out that WEDM operation is most efficient in the height range of 30 to 50 mm. Calculations of surface removal rate (SRR) show that SRR of 0.25 mm becomes 72.8 mm^2/min at job height of 40 mm, whereas, it becomes 47.2 mm^2/min on job height 20 mm and 64.4 mm^2/min on job height of 60 mm. Figure 2 displays the SRR of all diameters of wire with job height of 40 mm.

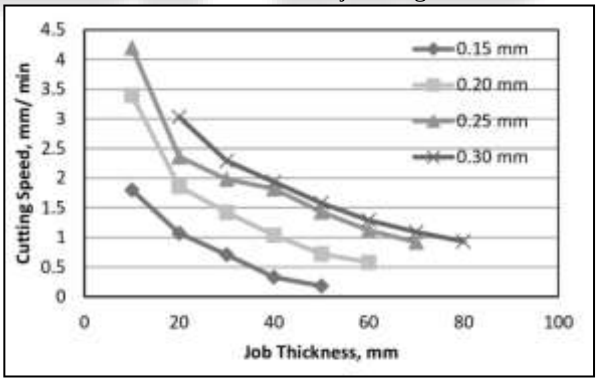

Fig. 1: Variation of cutting speed with job thickness and various diameter of wire (Job - HCHCr).

It is evident from figure 2 that there is a substantial enhancement of SRR when diameter of wire is increased from 0.15 mm to 0.20 mm and from 0.20 mm to 0.25 mm. However, the increase of SRR due to increase of wire diameter from 0.25 mm to 0.30 mm is marginal. Higher the cutting speed, higher would be debris of eroded job particles. At this stage, the rate of removal of debris from the plasma zone by flushing may not be adequate and can result accumulation of worn out particles in the sparking zone which hinders further enhancement of material removal.

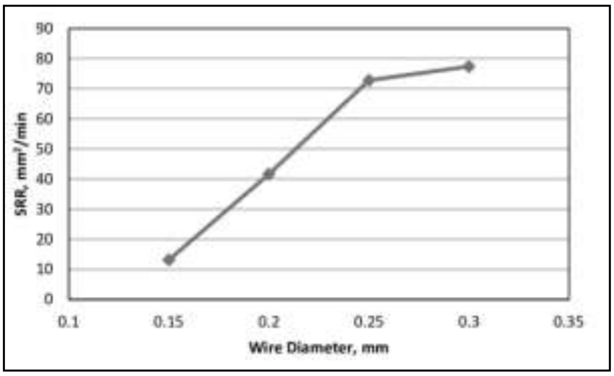

Fig. 2: Dependence of SRR with wire diameter (Job – HCHCr, Job height – 40 mm).

B. *Effect of Job Materials:*

Experimental results of cutting speed on various common materials show that there has been a considerable reduction of cutting speed on graphite and carbide. The cutting speed on graphite and carbide drops about 50% to 60% on job height 40 mm from that of HCHCr steel (cf. Fig.3). It is mostly due to higher melting point of graphite and carbide in comparison with HCHCr which requires more energy to melt work piece. Additionally, it may be pointed out that both graphite and carbide are produced from powder compaction process which instills pores and voids resulting in further lowering of cutting speed [7]. The correlation between cutting speed and melting point of work piece plays very important role and an attempt to relate these factors is made in the next section.

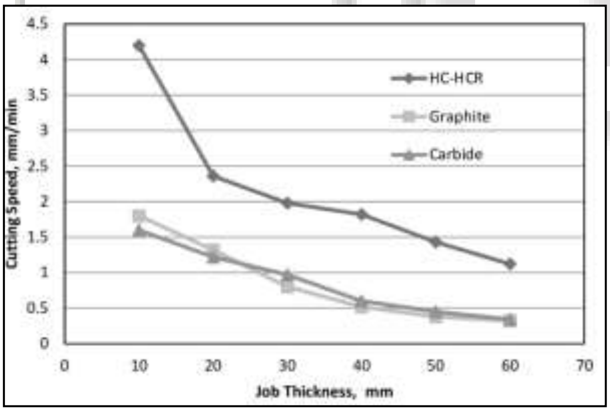

Fig. 3: Effect of cutting speed on job thickness and materials.

C. *Correlation of Cutting Speed with Material Properties:*

The cutting speed of various materials has been shown in figure 4. It is evident that the cutting speed reduces with increase of melting point. The materials are marked in the figure 4 and linear regression has been carried out. It may be pointed out that cutting speed on aluminium is low although the melting point is 660^{0}C. A similar trend has been observed in between cutting speed and latent heat of melting as illustrated in figure 5.

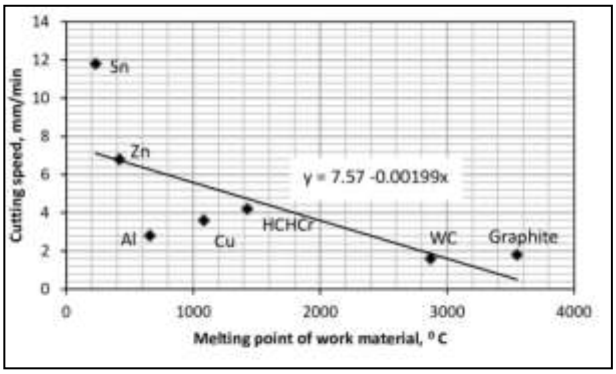

Fig. 4: Variation of cutting speed with melting point of work piece. All the experiments were carried out by cutting 10 mm x 10 mm piece of 10 mm height.

It is well known that WEDM process involves melting of work piece in the sparking zone. The wire has to produce spark with sufficient energy so that the temperature in plasma zone increases to melting point of job and infuse adequate latent heat to the work piece. In other words, it is termed as thermal load of the spark zone and wire has to withstand this thermal load in order to ensure smooth cutting speed. The energy required for material with high melting point requires more energy to melt and hence the progress of wire faces more hindrances. This has resulted lower cutting speed of graphite and WC. In addition to high melting point, higher latent heat of fusion also slows the process of WEDM. Therefore, it is apparent that melting of work piece with high melting point and high latent heat of fusion requires very high energy and leads to lower cutting speed.

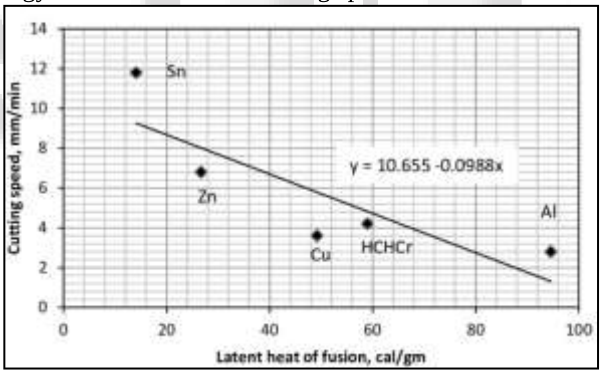

Fig. 5: Variation of cutting speed with latent heat. All the experiments were carried out by cutting 10 mm x 10 mm piece of 10 mm height.

It is observed from the figures 4 and 5 that although the melting point of aluminium is 660^{0}C and the latent heat of fusion is sufficiently high at 94.6 Cal/gm to retard the cutting speed. This means that energy requirement to melt aluminium is low; however, it requires more energy to change physical state of material. This may be attributed for low cutting speed of aluminum. It may be pointed out that cutting speed of WEDM process depends on both melting point and latent heat of melting additively and varies inversely with both of these material properties.

IV. SUMMARY

Extensive experiments have been carried out to correlate several parameters of work material with WEDM process. It is observed that the cutting speed enhances with increase of wire diameter, however, the increase of cutting speed due to increase of wire diameter from 0.25 mm to 0.30 mm is marginal. Cutting speed in graphite and WC is very low in comparison with HCHCr steel which is due to high melting point. Perhaps pores in graphite and WC play important role in reducing cutting speed. Further research work in this area is warranted.

Both melting point and latent heat of fusion influence the cutting speed of WEDM process. It appears that the effects of both of the material properties are additive and reduce the cutting speed. It is possible to explain that although aluminium has low melting point, the cutting speed of it is low because of high latent heat of fusion.

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