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Study the Effect of Process Variables on Cutting Velocity during WEDM of Al/ZrO_2-MMC

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Abstract **- This paper presents an experimental investigation of the machining characteristic (cutting velocity) and the effect of process parameters of Al /$ZrO_{2(p)}$ metal matrix composite (MMC) in wire electrical discharge machining process (WEDM). Experiments have been carried out using one factor at a time approach to investigate the effects of input parameters such as pulse width, time between pulses, servo control mean reference voltage, short pulse time, and wire mechanical tension on cutting velocity. Result indicates that cutting velocity increases with the increase of pulse width and short pulse time and decreases with the increase of time between pulses and servo control reference mean voltage. Moreover it remains constant with the increase of wire tension.**

Key words **- WEDM, Metal Matrix Composites, Cutting velocity.**

I. Introduction

Metal Matrix Composites (MMC) are a new class of advanced materials whose properties can be tailored to satisfy the design needs by varying the reinforcements, matrices and microstructure. It is composed of a metallic matrix such as Aluminium, Magnesium, Iron, Copper and a dispersed ceramic (oxide, carbides) or metallic phase such as lead, molybdenum, and tungsten. MMC are used for space shuttle, commercial airliners, electronic substrates, bicycles, automobiles, golf clubs and a variety of other applications. MMC are better than polymer matrix composites as they are able to retain their strength and stiffness at elevated temperature, does not allow absorption of moisture, non-inflammable, possess good abrasion and creep resistance properties [1]. However MMCs have high cost of fabrication and machining, and it has placed limitations on their applications. Al /$ZrO_{2(p)}$ MMC is prepared using Stir Casting technique. Many researchers have tried modern machining methods to machine the MMC and out of which wire electrical discharge machining (WEDM) emerged as an effective machining method [2]. In the present work, WEDM is used to machine the $ZrO_{2(p)}$/Al MMC and study the effect of process parameters such as pulse width (PW), time between pulses(TBP), servo control mean reference voltage(SCMRV), short pulse time(SPT) and wire mechanical tension(WMT) on cutting velocity(CV). The Author studied on WEDM and optimized the cutting parameters, which are effective for material removal rate and surface finish [3]. Author carried out an experimental investigation to determine the material removal rate for varying machining parameters [4]. Taguchi method was used to determine the significance of the machining parameters on the material removal rate [5]. Author made an attempt to understand the effect of machining parameters on the cutting rates and cutting width for machining a precision workpiece [6]. Author developed the high performance coated wire electrodes for high speed cutting and accurate machining [7]. The Author studied and optimized the machining parameters of WEDM based on Grey relational and statistical analysis. It was found that the table feed rate had a significant influence on the metal removal rate, while the gap width and surface roughness were mainly influenced by pulse on time [8]. Investigated a study on kerf and material removal rate in wire EDM based on Taguchi method. The experimental studies were conducted under varying pulse duration, open circuit voltage, wire speed and dielectric flushing pressure. Based on ANOVA method, the highly effective parameters on both the kerf and MRR were found as open circuit voltage and pulse duration, whereas wire speed and dielectric flushing pressure were less affective factors [9]. Optimized the WEDM process by non-dominated sorting genetic algorithm and found that there was no single optimal combination of cutting parameters, as their influences on the cutting velocity and the surface finish are quite opposite. It was found that cutting velocity and surface finish are most important output parameters which decide the cutting performance [10]. Modelled the machining parameters of Inconel 601, a nickel based super alloy with high content of iron, chromium and niobium, strengthened mainly with Ni_3Nb using response surface methodology. The volumetric metal removal rate increased with the increase of the peak current value and water pressure. The wear ratio increased with the increase of peak current. The surface roughness increased with the increase of peak current and decreased with the increase of duty factor and wire tension [11]. Ramakrishnan and Karunamoorthy used multi response optimization method using Taguchi's robust design approach for WEDM. Each experiment had been performed under different cutting conditions of pulse on time, wire tension, delay time, wire feed speed and ignition current intensity. Three responses namely material removal rate, surface roughness and wire wear ratio had been considered for each approach. It was identified that the pulse on time and ignition current had influenced more than the other parameters. The research showed that multiple performance characteristics such as material removal rate, surface roughness and wire wear ratio can be improved concurrently [12]. Manna and Bhattacharyya used Taguchi and Gauss elimination method for the parametric optimization of Aluminium reinforced silicon carbide metal matrix composite. Effect of machining parameters such as pulse on-time, pulse off-time, peak current, pulse peak voltage, wire feed rate, wire tension and spark gap voltage on machining performance criteria such as metal removal rate, surface roughness, gap current, and spark gap were studied. Open gap voltage and pulse on period were most significant and significant influencing machining parameters respectively for controlling the material removal rate. Wire tension and wire feed rate were most significant and significant influencing machining parameters respectively for controlling the surface roughness. Wire tension and spark gap voltage setting were most significant and significant influencing machining parameters respectively for controlling the spark gap [13]. Mahapatra and Patnaik used a 0.25 mm diameter zinc coated copper wire for a block of D2 tool steel workpiece in their experimental work and took Discharge current, Pulse duration, Pulse frequency, Wire speed, Wire tension, Dielectric flow rate as a process parameters. Minimum wire tension gives maximum MRR but maximum wire tension gives maximum surface finish and minimum kerf. Factors like discharge current, pulse duration and dielectric flow rate and their interactions have been found to play a significant role in rough cutting operations for maximization of mrr, minimization of surface roughness and cutting width. The future scope includes using different work material and hybrid optimization techniques [14]. Modeled and optimized the wire electrical discharge machining of γ-TiAl (trim cutting). A second-order mathematical model, in terms of machining parameters, was developed for surface roughness, dimensional shift and cutting speed using response surface methodology (RSM). The experimental plan was based on the face centered, central composite design (CCD) result [15]. Study discussed the development of reliable multi-objective optimization based on Gaussian process regression (GPR) to optimize the high speed WEDM process considering mean current, on-time and off- time as input features and material removal rate (MRR) and surface roughness (SR) as output responses [16]. Manna and Lautre (2009) discussed the effects of the cutting parameters on the wire deflection during machining of T160G12 alloy steel. Author utilised finite difference and new marks method to develop mathematical model for wire deflection in WEDM. A second order multi-variable regression model and a feed-forward back-propagation neural network model have been developed to correlate the input process parameters, such as pulse-on time, pulse-off time, peak current and capacitance with the process performance namely cutting speed and surface roughness. Singh and Garg studied the effects of process parameters on material removal rate in WEDM. the effects of various parameters of WEDM like pulse on time, pulse off time, gap voltage, peak current, wire feed & wire tension have been investigated to reveal their impact on MRR of hot die steel. It was concluded that MRR directly increases with increase in pulse on time & peak current while decreases with increase in pulse off time & servo voltage [17]. Patil and Brahmankar presented a semi-empirical model for material removal rate in WEDM based on thermo-physical properties of the workpiece and machining parameters such as pulse-on time and average gap voltage. The model was developed by using dimensional analysis and quasi-Newton and simplex non-linear estimation techniques. An empirical model based on response surface method was also developed and the comparison of models showed significant agreement in the predictions [18]. Such as open voltage, servo voltage, pulse on-time, pulse off-time, wire feed speed, wire tension, dielectric pressure and also thickness of tungsten carbide material on machining characteristics such as material removal rate, surface roughness and kerf .The workpiece thickness was expected to have a major effect on the material removal rate but showed to be significant in the case of surface roughness only. It can be concluded that the material thickness has little effect on the material removal rate and kerf but is significant factor in terms of surface roughness. For thinner work pieces, in order to obtain a fine surface finish, the spark energy will have to be reduced, which also reduces the material removal rate.

II. Experimental Setup

Robofil-290 CNC wire EDM as shown in figure 1 with brass coated wire having 250 μm diameter is used for experimentation. Performance of WEDM is evaluated on the basis of cutting velocity. The cutting velocity is calculated by the following relation: Cutting velocity= length of travel/ machining time. Machining time is obtained from the computer, which is attached to the machine tool.

Fig. 1 Robofil-290 CNC wire EDM

Experiments have been performed by varying the process parameters shown in table 1considering one factor at a time approach.

Table 1. Parameters and their Range/Values

Sr. No	Parameter	Unit	Range/Values
1.	Pulse width	μs	0.2 to 3
2	Time between pulses	μs	1.6 to 25
3	Short pulse time	μs	0.2 to 0.8
4	Servo control reference mean voltage	.01 volts	1-200
5	Wire tension	Deca Newton	0-3
6	Wire diameter		250 μm
7	Thickness of workpiece		10.1 mm
8	Maximum feed rate		8
9	Ignition pulse current		8(0.5A)

III. Results and Discussions

A. *Effect of Pulse width on Cutting Velocity*

In first set of experiment, pulse width was varied in the increment of 0.2 μs by keeping other parameters constant which are shown in Table 1. Cutting velocity increases with the increase of pulse width as shown in fig. 2. Cutting velocity increases with the increase of pulse width because spark energy produced during spark increases with the increase of pulse width.

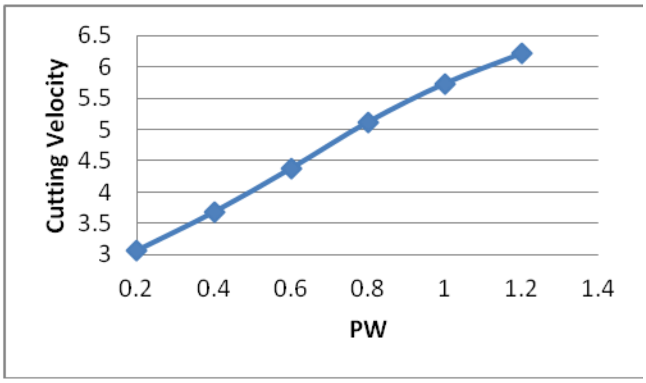

Fig. 2: Pulse Width vs Cutting Velocity

B. Effect of Time Between Pulses on Cutting Velocity

In the second set of experiment, Time between Pulses was varied in the increment of 3 µs by keeping the other parameters constant which are shown in table 1. Cutting velocity decreases with the increase of Time between Pulses as shown in fig. 3. This is because spark energy produced during spark decreases with the increase of time between pulses.

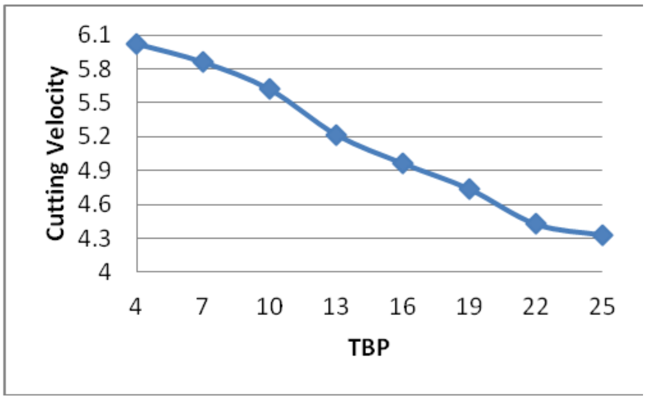

Fig. 3: Time between Pulses vs Cutting Velocity

C. Effect of Short Pulse Time on Cutting Velocity

In the third set of experiment, short pulse time was varied in the increment of 0.1 µs by keeping the other parameters constant which are shown in table 1. Cutting velocity increases with the increase of short pulse time as shown in fig. 4 and the rise is more when the short pulse time is between 0.5 to 0.6 µs. Cutting velocity increases with the increase of short pulse time because spark energy produced during spark increases with the increase of short pulse time.

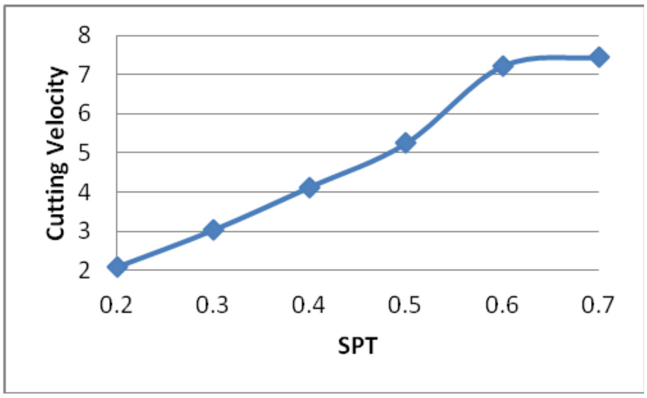

Fig. 4: Short Pulse Time vs Cutting Velocity

D. Effect of Servo Control Mean Reference Voltage on Cutting Velocity

In the fourth set of experiment, servo control reference mean voltage was varied in the increment of 10 volts by keeping the other parameters constant which are shown in table 1. Cutting velocity decreases with the increase of servo control reference mean voltage as shown in fig. 5. This is because spark energy produced during spark decreases with the increase of servo control reference mean voltage.

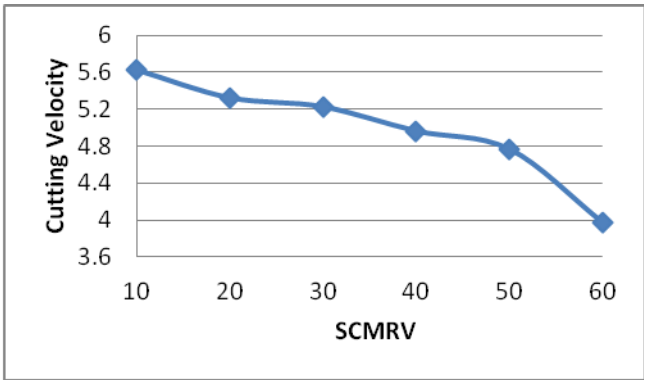

Fig. 5 : Servo Control Ref Mean Voltage vs. Cutting Velocity

E. Effect of Wire Mechanical Tension on Cutting Velocity

In the fifth set of experiment, wire tension was varied in the increment of 0.4 daN by keeping the other parameters constant which are shown in table

1. Cutting velocity almost remains constant with the increase of wire tension as shown in fig. 6. This is because wire tension has no effect on spark energy produced and cutting velocity was mainly depending upon the spark energy produced during the sparks.

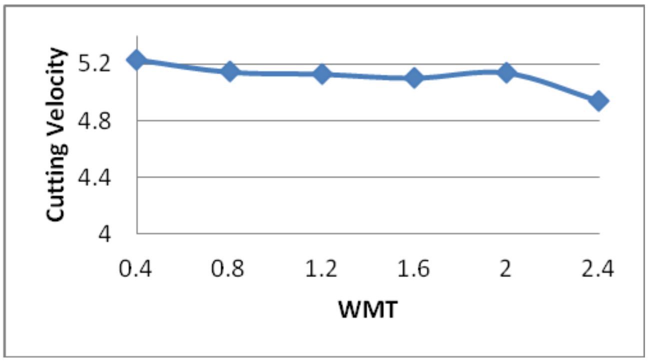

Fig. 6: Wire Tension vs Cutting Velocity

IV. CONCLUSIONS

Cutting velocity increases with the increase of pulse width and short pulse time and decreases with the increase of time between pulses and servo control reference mean voltage. Cutting velocity remains constant with the increase of wire tension. In case of roughing cut, high value of pulse width, short pulse time, and lower value of time between pulses and servo control reference mean voltage should be selected in order to increase the cutting velocity.

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