Study of Machine characteristics during Rotary EDM Machining using Tools made of Die Steel EN24

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Abstract: Electro Discharge Machining (EDM) is an unconventional machining process that uses spark energy to remove material from the work piece. EDM process is extensively being used in die/mould making industries, automobile industry, aerospace industry etc. for generating complex and intricate shape on hard material. Numbers of research works have been carried out using EDM process in order to improve the performance. Further, different variant of EDM process like dry EDM, orbital EDM, and powder mixed EDM, ultrasonic assisted EDM and rotary EDM etc. have also been studied. Rotary EDM process is very promising process that helps to improve surface finish, overcut as well as tool wear rate. In the present paper, a extensive review has been presented on rotary EDM process. Significance of several input parameters has been observed on output characteristics like material removal rate, tool wear rate, overcut and out of roundness.

Key words: EDM, Rotary, MRR, Overcut, Out of roundness

1 Introduction

Electrical-discharge machining (EDM) is an unconventional, non-contact machining process where metal removal is based on thermo-electric principles. In this process, the material removal mechanism uses the electrical energy and turns it into thermal energy through a series of discrete electrical discharges occurring between the electrode and work piece immersed in an insulating dielectric fluid. Electrical Discharge Machining (EDM) uses an electrical discharge (spark) that is accurately controlled by way of a small gap (approximately 10 to 50 microns) to remove metal from work piece. The gap between the electrode and a work piece is filled with dielectric fluid. The process is unaffected by hardness of the work piece. The work piece has to be electrically conductive and its material is removed by erosion controlled through a series of electric sparks of short duration and high current density between the electrode and the work piece. Both the work piece and tool are submerged in a dielectric bath, which may consist of kerosene or demineralized (pure) water. During this rotary EDM process thousands of sparks are generated in each second. A tiny crater is created in the material by each spark along the cutting path by melting and vaporization. The aim of the work presented in this paper is to find suitable process parameters that minimize the tool wear rate using die steel EN24 as a work piece steel and square copper, copper tungsten electrodes as a tool and dielectric flushing during rotary electric discharge machining. The machining parameter selected are discharge current, and tool Rpm, remaining all constant voltage pulse duration, fluid pressure of the tool analysing the responses of over cut and out of roundness. The EDM cavity has to be always larger than the electrode in machining it. The difference between the size of the cavity (or hole) and the size of the electrode is called the overcut. The overcuts are of two types – the total overcut, overcut per side or diametral overcut. Diametral overcut is most commonly used & the same is being implemented in this project.
There are evidences in many studies which show the rotation of the electrode affects EDM

performance. Wang and Yan [10] used rotary electrical discharge machining (REDM) with different flushing techniques on Al2O3/6061Al composite material and studied their effect on MRR, electrode wear rate (EWR), and surface roughness (SR). They also used tubular, solid and electrode with eccentric hole for experiments. Rozenek et al. [9] used a metal matrix composite as work piece material and investigated the variation of machining feed rate and surface roughness with machining parameters. Guu and Hocheng [3] reported that the rotary motion of the work piece helps in better circulation of dielectric fluid through the sparking gap and improves the MRR. Mohan et al. [5, 6] used a REDM with a hollow tube electrode for drilling of the SiCp/6025 composite. They reported that the rotary electrode improved the MRR, and also, the EDM drilling with the tube electrode has a higher MRR and lower EWR and SR with respect to injection flushing. Mahapatra and Patnaik [7] studied the machining factors of wire EDM process using the Taguchi method for maximizations of MRR and minimization of surface roughness. The analysis showed that factors like discharge current, pulse duration, and dielectric flow rate have been found to play a significant role in cutting operations. Chattopadhyay [8] proposed a new analysis for improvement of the machine output during electrical discharge machining by introducing an induced magnetic field on the work piece during REDM of EN-8 steel with a rotary copper electrode. Patel et al. [9] investigated the feasibility of fabricating micro holes in SiCp–Al composites using micro-electro-discharge machining with a rotary tube electrode. The experimental results show that servo-speed significantly affects the MRR and EWR, while pulse on duration affected the taper. Kuppan et al. [10] reported the experimental investigation of small deep hole drilling of Inconel 718 using the REDM with a tubular electrode. The results revealed that MRR is more influenced by peak current, duty factor, and electrode rotation. In a similar work, Dev et al. [9] investigated the effects of machining parameters in micro EDM with a rotary tubular electrode on the SiCp–Al composites. Kozak and Gulbinowicz [10] presented two mathematical models of REDM; the first one considered machining with the face of the end tool electrode, and the second one considered EDM with the lateral side of the electrode. The experimental results confirmed the validity of the proposed mathematical models and the simulation software. Iqbal and Khan [10] reported the experimental investigations of REDM milling of stainless steel AISI 304. They established empirical relations regarding machining parameters and the responses in analyzing the machinability of the stainless steel. Then response surface methodology was used to investigate the relationships and parametric interactions between the input variables and MRR, EWR, and SR shown in Figures 1 to 7.

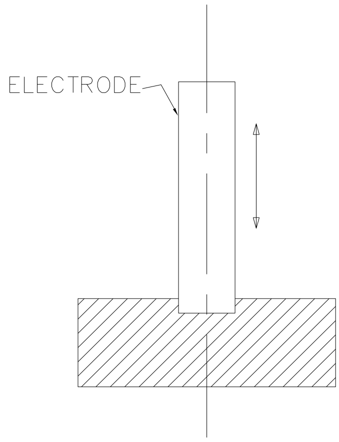


Figure 1: Electro- discharge machining with stationary electrode

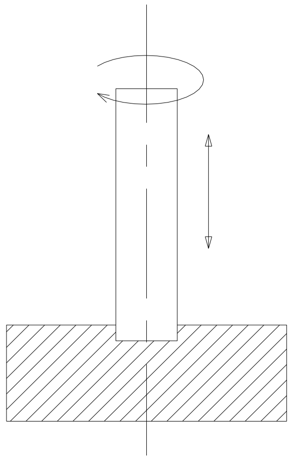


Figure 2: Electro- discharge machining with rotating electrode

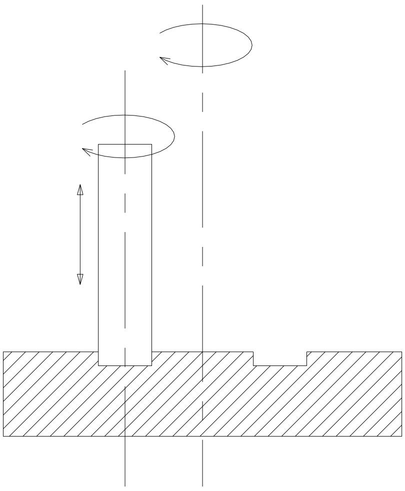
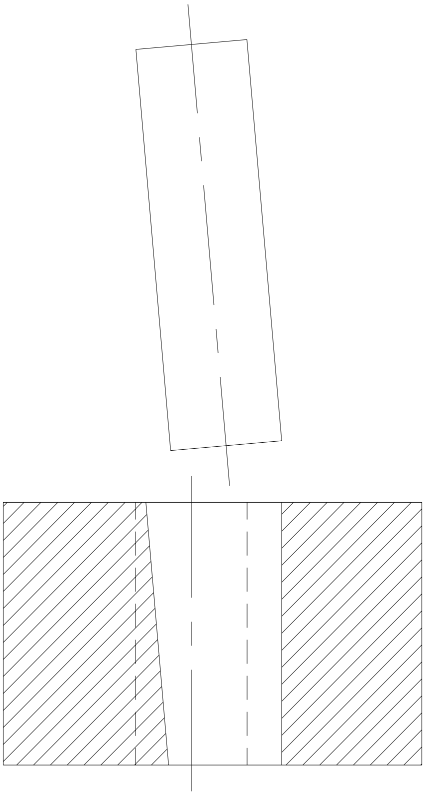


Figure 3: Electro-discharge machining with rotating electrode with orbital motion



_____ _ __ Obtain ed hole

- - - - - - Expected hole

Figure 4: Overcut without rotating electrode

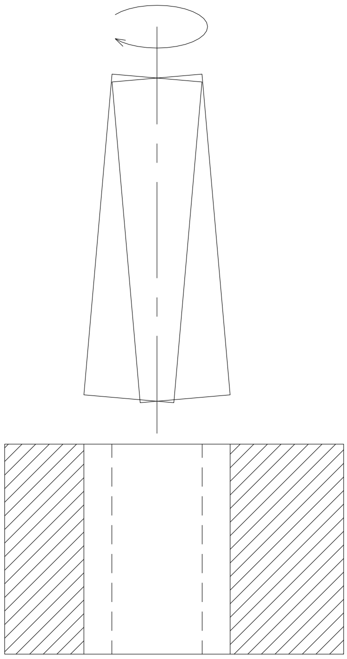


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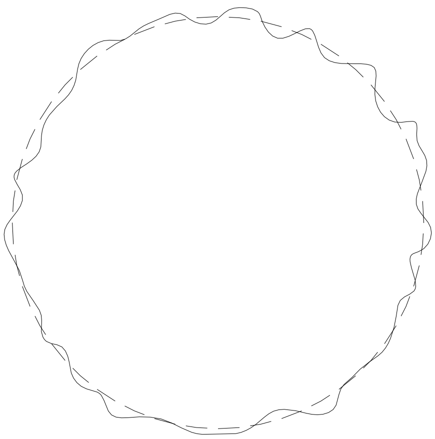
Figure 5: Overcut with rotating electrode



_____ _ __ Obtain ed hole

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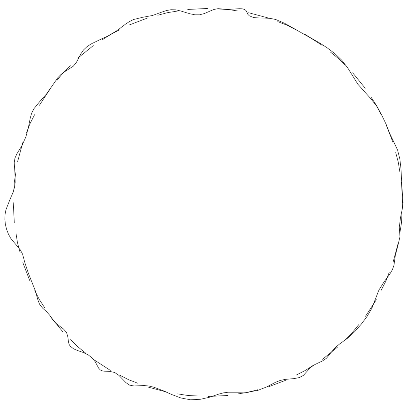
Figure 6: Out of roundness without rotating electrode



_____ _ __ Obtain ed hole

- - - - - - Expected hole

Figure 7: Out of roundness with rotating electrode

2 Methodology

Work & Tool material properties shown in Table 1:

TABLE 1
WORK & TOOL MATERIAL PROPERTIES

Work materials	**Die Steel EN24**
Work shape & size	50x50x10mm
Density	
Hardness	22-30Hrc
Tool materials	Copper& Copper Tungsten
Tool shape & size	Cylindrical shape of dia3mm
Density	14700Kg/m3
Hardness	170 BHN
Process Parameters	
Dielectric	Demineralised Water
Voltage	90 V
Current	60A, 70A & 80A
On pulse duration	35
Electrode rotating speed	0rpm, 500rpm, 750rpm & 1000rpm
Type of machining	Through hole machining

2.1 Experimental Details

3D micro EDM milling Sx 200 HPM high precision & high capacity work table 700x300mm xyz travelling 350x200x200mm solid & tube electrode 45 microns to 3mm high precision & accuracy upto ±1 micron.

The micro EDM with servo control & rotating aids with variable speeds for electrode was used to conduct the experiments. Table 1 gives the properties of the materials used & their process parameters.

2.2 Measurements

Eroded hole diameter was measured using optical microscope. The electrode diameter was measured with micrometer which had a least count of 0.001mm.

The magnification used for the photographs of the holes was (x16) on a metallurgical microscope. TalyRond was used to measure out of roundness at a magnification of (x500).

2.3 Design of experiments (DoE):

The experiment work was planned on the basis of statistical design of experiments. Hence a complete 32 factorial experimental model was randomly formulated with the help of random number table. The data was simplified by setting the levels at equal intervals. This resulted in orthogonal contrasts which facilitated easy computation of the regression coefficients. The scheme of experiment plan, along with the factors & their coded levels are as given in the Table 2 & 3.

The total number of regression coefficients is represented as N & is given by the expression shown in equation 1:

$$N = n(n+3)/2 + 1 \text{ ---------(1)}$$

Where n is the number of factors.

TABLE 2
THE SCHEME OF EXPERIMENT PLAN, ALONG WITH THE FACTORS & THEIR CODED LEVELS

Response	**Factors**	**Code levels**			**Remarks**
		-1	**0**	**+1**	
Overcut (mm)	X1 Current (amp)	60	70	80	Pulse duration constant
Out of roundness (µm)	X2 Electrode rotation (rpm)	500	750	1000	

TABLE 3
DIE STEEL EN-24 COMPOSITION

Component	weight %	Component	weight %
C	0.36-0.44	S	0.40max
S_i	0.10-0.35	p	0.035max
M_n	0.45-0.70	C_r	1.00-1.40
M_o	0.20-0.30	N_i	1.30-1.7

3 Results and Discussions

Variation of overcut with rotation speed and current while using copper electrode shown in Figure 8. The graph is fairly consistent for all the values of current. There's a hump at 500rpm which means any current would yield maximum overcut at 500rpm. However the average values for 60A are a trifle more than the others for every speed under consideration.

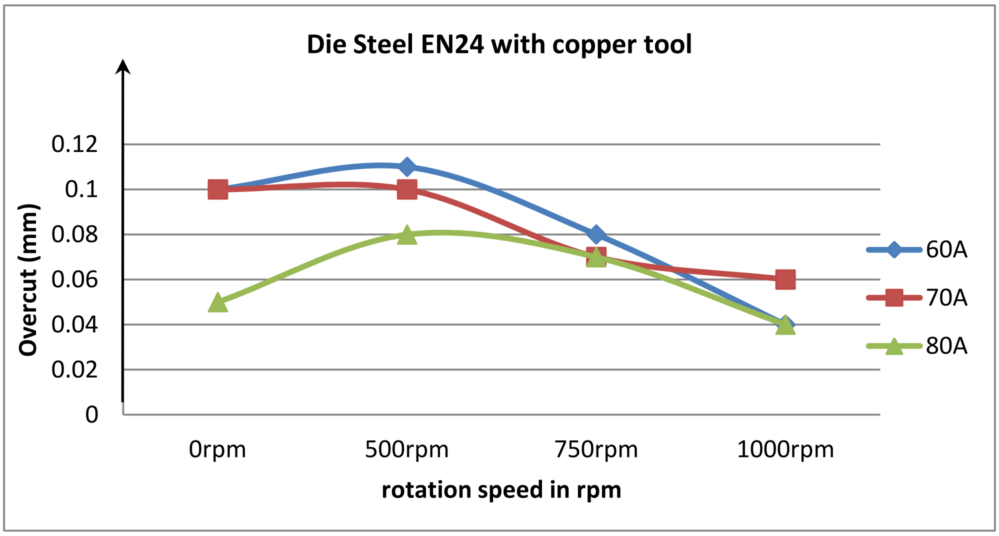


Figure 8: Die Steel EN24 with copper tool with rotation speed

Variation of overcut with current and electrode rotation while using copper electrode shown in Figure 9.

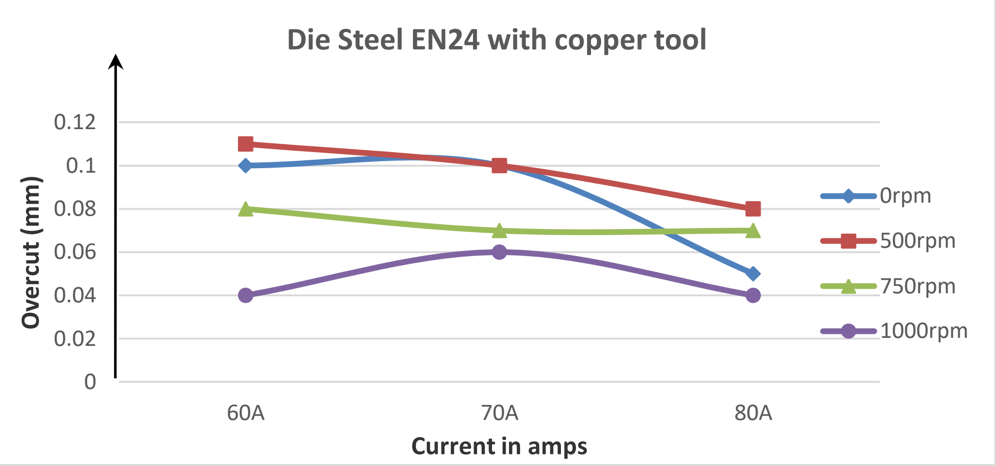


Figure 9: Die Steel EN24 with copper tool with current

The out of roundness value varies to the extremes over the speed range in which the values were collected. While the 70 & 60 A currents give a fairly consistent variation in out of roundness. A stationary electrode seems to be giving best overall out of roundness value in this case.

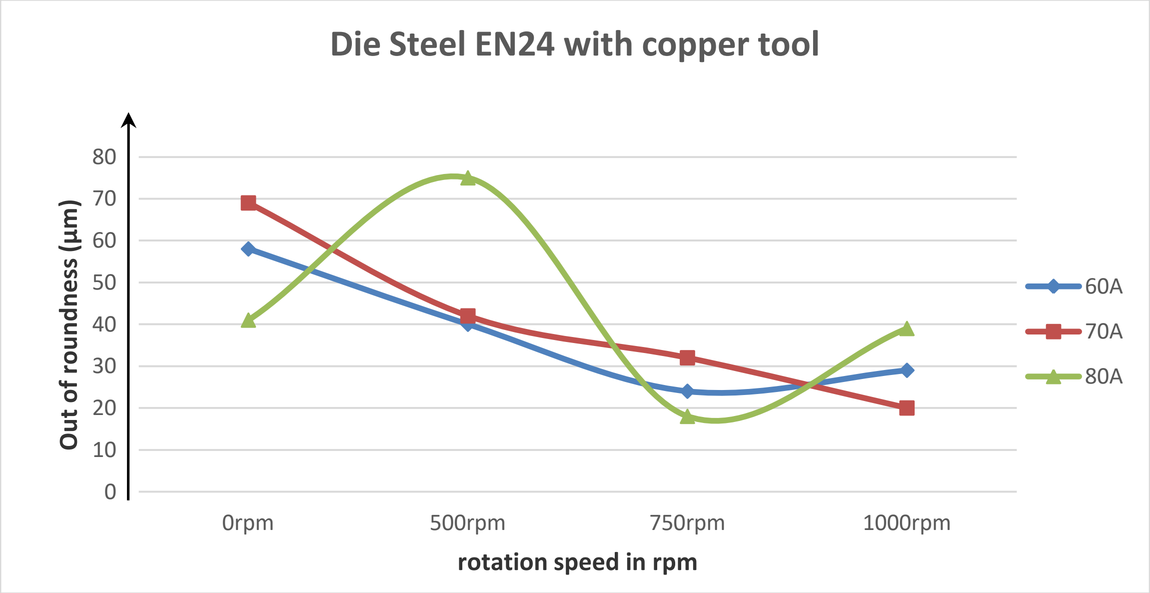


Figure 10: Die Steel EN24 with copper tool with rotation speed

Variation of out of roundness with current and rotational speed while using copper electrode.

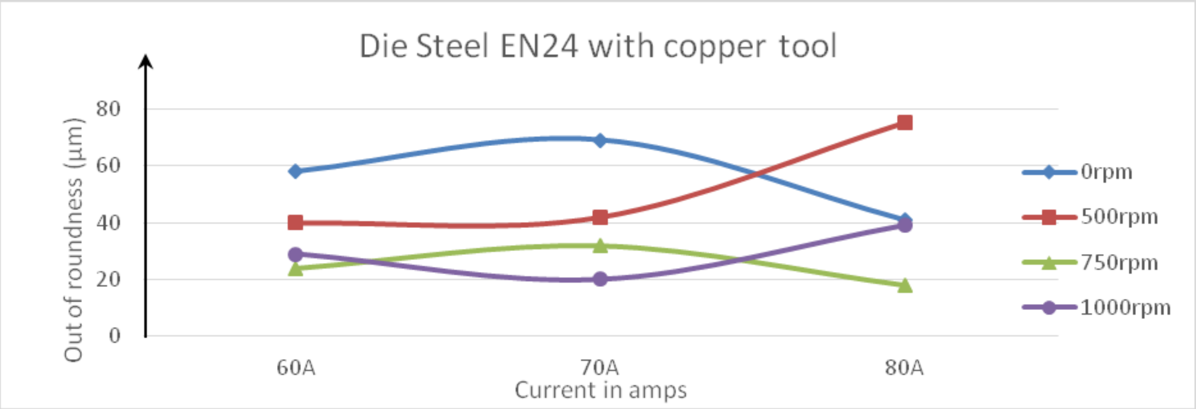


Figure 11: Die Steel EN24 with copper tool with current

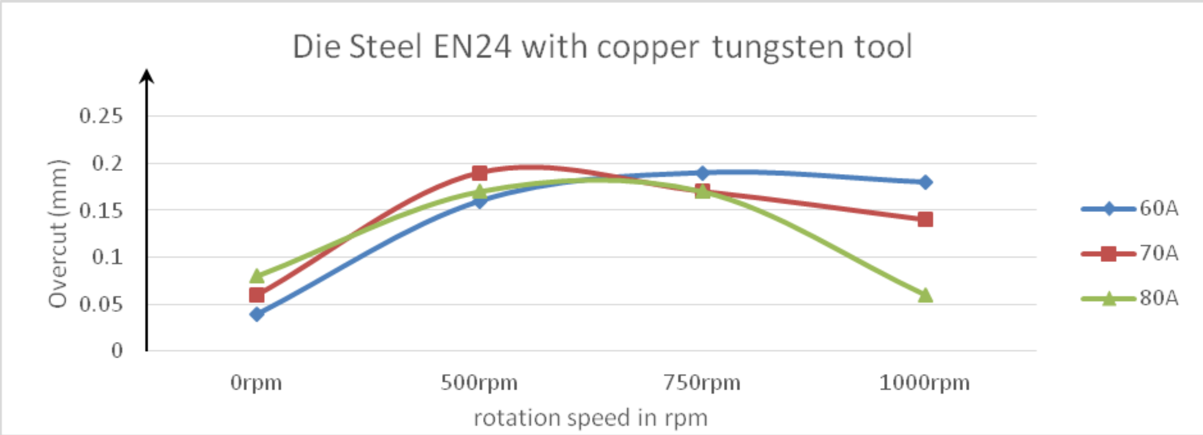


Figure 12: Die Steel EN24 with copper tool with rotation speed

Overcut for die steel with copper tungsten tool as shown in the above graph provides better overcut values at speeds of 500rpm to 750rpm for all the current values. However when speeds are taken as a reference as seen below, the stationary electrode has least overall overcut while 500rpm & 750 rpm give fairly high values of overcut.

Variation of overcut with current and rotational speed while using copper- tungsten electrode.

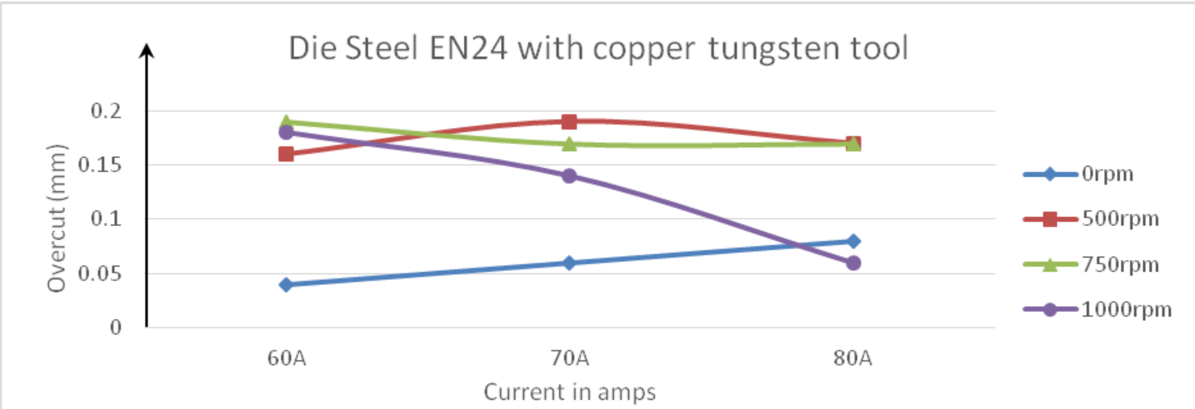


Figure 13: Die Steel EN24 with copper tool with current

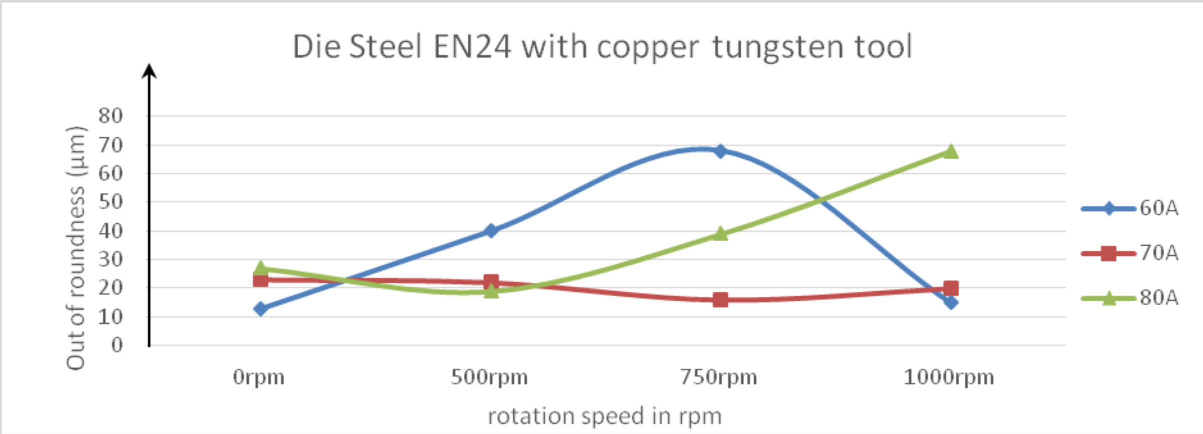


Figure 14: Die Steel EN24 with copper tool with rotation speed

Out of roundness for die steel with copper tungsten tool as shown in the above graph, It is observed that a current of 70A gives fairly constant value for all the rotations speeds but other currents vary the out of roundness to a great extent. The variation of out of roundness for each rotational speed is plotted below:

Variation of out of roundness with current and rotational speed while using copper tungsten electrode.

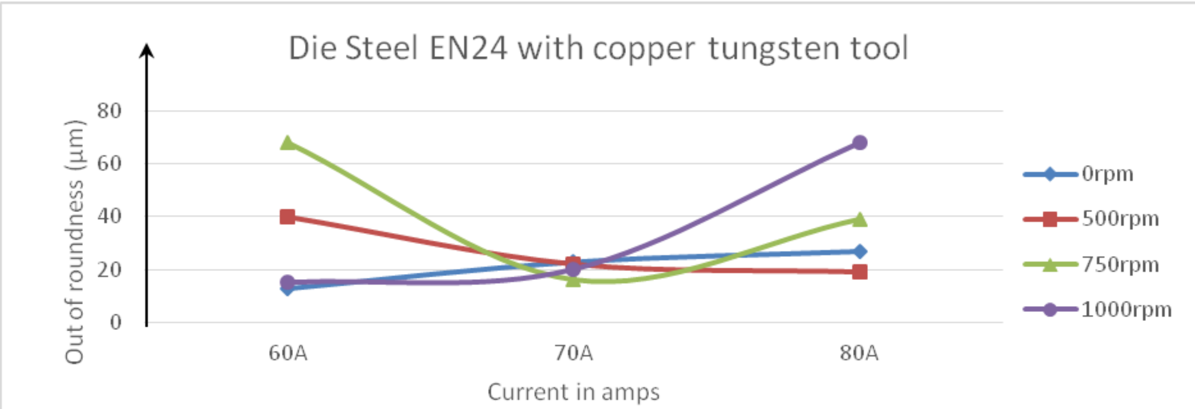


Figure 15: Die Steel EN24 with copper tool with current

4 Conclusion

The research of the present work is summarized experiments were conducted to study the individual effects and optimize the μEDM process parameters. From the experiment the following are the conclusions drawn from the present investigations. Based on the results and discussions the following conclusions are made.

- Rotary EDM improves out-of roundness due to improved flushing.
- The rotary mode of EDM is better than stationary mode of Machining of 3mm hole at 750 rpm is recommended.
- Over-cut and out of roundness increase with increasing current
- It is concluded that rotation of electrode improves out-of-roundness, overcut and out-of-roundness increase with increase of current with both rotating and stationary electrodes. Overcut for die steel with copper tungsten tool as shown in the above graph provides better overcut values at speeds of 500rpm to 750rpm for all the current values.

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