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Experimental Study On Electro-Discharge Machining Of Oxygen Free Copper Cu102 For The Application Of Beam Dump

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Abstract- *An experimental study on the effects of electro-discharge machining (EDM) parameters on the surface finish and material removal rate (MRR) by machining copper work piece with copper electrode is presented. The varying significant parameters are discharge current, pulse on-time and pulse off-time and other parameters such as gap voltage, duty cycle, polarity, flushing pressure etc. are kept constant for the proposed machining. In this all factorial combinations were used for getting the optimum parameters for the required average surface roughnessRa of less than 1µm for the application of finishing a copper beam dump.*
Keywords- *ANOVA, Copper, EDM, Regression, Surface roughness*

I. Introduction

Non-conventional machining such as Electro-discharge machining (EDM) is gaining popularity among various industries. There is no bar for the hardness of material to be machined until the material is a conductor. The shape of the required machining on the work piece has to be a negative replica on the tool.EDM is the process by which metal is removed with the help of spark generation between the work piece and the tool. A spark is produced at gap between electrode and work piece when a DC supply with appropriate voltage and current is given. So, the dielectric breaks down and electrons are emitted from cathode, the gap is ionized and thousands of sparks/sec occurs at the gap. The gap is maintained with the help of servo control mechanism. Due to the high temperature and high pressure produced by the spark, metal is eroded and flushed away by the dielectric fluid. Hence it also known as Spark Erosion Machining .When the voltage drops, the dielectric fluid gets deionized.The process creates small craters on the material surface of their size and shape dependent on the discharge energy, electrode material thermal properties and heat conduction pattern [1].

Several efforts have been made for improving the material removal rate and surface finish of variety of materials with variety of electrodes and variety of parameters selection. Y.S. Wong et al. [2] performed machining various types of steel with combinations of powder suspensions in dielectric to produce mirror finish. A similar work of improving the surface condition by mixing of micro and nano powder in the dielectric of EDM was obtained by Amitkumar et al.[3]. While optimizing the process parameters of powder mixed electrical discharge machining (PMEDM) by using response surface methodology was done by H.K.Kansal et al. [4]. Combination of EDM with ball burnish machining by using taguchi method and optimal combination level of machining parameters for Al-Zn-Mg alloy were achieved by Y.C.Lin et al. [5]. Similar study for machining 6061Al composite using rotary EDM with ZrO_2 balls offering immediate ball burnishing, analysis by ANOVA and F test and optimization of values was obtained by BiinHwa Yan et al. [6].

A. Curodeau et al. [7] proposed a Hybrid Electro discharge polishing (HEDP) process which demonstrated a variant of standard die sinking EDM process, where a thermoplastic composite electrode instead of solid graphite is used to perform fine EDM finishing using air as a dielectric medium.Many modifications in the process and tools for the analysis have been developed. Sameh S. Habib [8] correlated the interactive and higher order influences of various EDM parameters through Response Surface Methodology (RSM) by utilizing the experimental data. Ozlem Salma et al. [9] suggested a mathematical relationship between Genetic Expression Programming (GEP) model and parameters affecting surface roughness.

Generally hard materials which are difficult to machine are being processed by EDM. Numerous study and experiments for machining of various hard materials have already being done. Several modifications, attachments and combinations havebeen obtained by various researchers. But unfortunately little work on Electro Discharge Machining of soft material such as pure copper is available. J.C.Rebelo et al presented experimental study for analysis of rough, finishing and micro finishing of copper beryllium alloys with Die sinking EDM [10]. They compared the results for MRR and surface quality with the past studies of steel [11]. The machinability of EDMon a copper alloy grade HR750 with a copper tungsten electrode in terms of the material removal rate and electrode wear ratio was evaluated by MuttamaraApiwat et al. [12].

In this study, the influence of EDM parameters on machining the pure copper material Cu102 or ETP copper Cu110 is presented. Although number of data is available for rough EDM regime, very less is available about optimal parameters setting for finishing operation. The results of the current study have to be used for the finishing of a copper beam dump [13] which was difficult by the conventional machining techniques and hence it has led to perform this experimental study.

II. Experimental Procedure

The material used for machining is oxygen free copper Cu102 with typical composition of .05 % oxygen and 99.95% copper having melting point of 1085°C and thermal conductivity of 388 W/mK. The machine used for experimentation was Electronica 500x300 ZNC Die sinking EDM with industrial grade EDM fluid. The electrode of ETP copper of 10mm diameter was used. Experiments were performed in 2 stages of Roughing and Finishing with the combinations of parameters shown in Table 1 while keeping other parameters fixed which are shown in Table2.

Table 1: Varyingsignificant parameters

	Current Intensity I (A)	Pulse On-Time T_{on} (μs)	Pulse Off-Time T_{off}(μs)
Roughing	30,15,5	15,28,58,126,206	9,17,35,74,122
Finishing	4,2,1	5,11,23,58,106	2,5,11,27,52

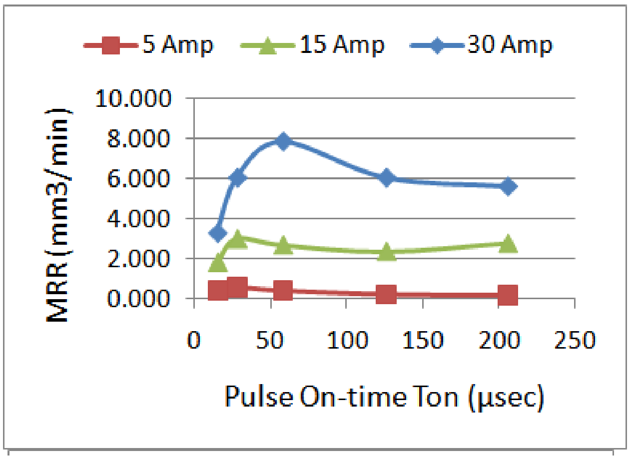
Table 2: Fixed Parameters

	Gap Voltage(V)	Duty cycle (%)	Machining Depth (mm)	Polarity (+/-)	Spark time (sec)	Flushing pressure (bar)
Roughing	50	62-66	1,2	+	1	0.25-0.5
Finishing	40	68-71	0.5	+	1	0.25-0.5

The EDM machine was set at positive polarity and other non-significant parameters were also fixed shown in Table2. The depth of machining was fixed to 1mm and 2mm (in some cases) during roughing operation while it was 0.5mm for the finishing operation with their respective combinations of current and pulse on time made from the Table1. Machining time for each combination of operation was noted down and material removal rate is calculated by using the machining depth, cross section area of electrode and machining time. Surface roughness of each operation is then measured with help of Mitutoyo SV514 surface roughness tester.

III. Results And Discussion

The results obtained for the MRR for roughing operation are plotted in Fig 1 as a function of Pulse on time (T_{on}).It can be seen that the highest value of MRR is obtained at pulse on time of 58μs for discharge current of 30A while it is obtained at 28μs for both 15A and 5A. MRR value obtained for finishing operation is highest at pulse on time of 11μs for all discharge currents. The decrease in MRR after a certain pulse on time is seen unlike steels or other materials. MRR decreases due to the high thermal conductivity of copper which results in quick resolidification beginning in the deepest part of the crater. Theseresults showclose similarity to those obtained by J.C.Rebelo et al [10].



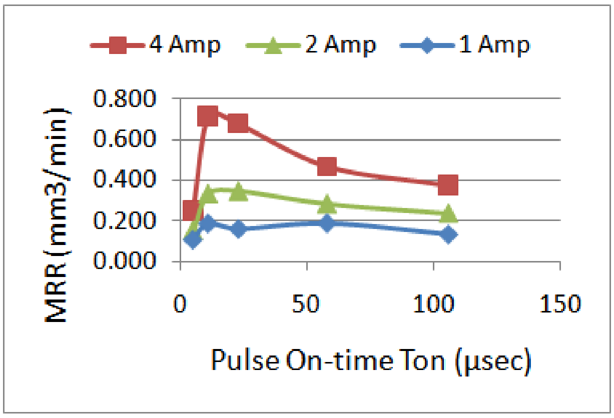


Fig 1: MRRvs T_{on} plot for roughing (left) and finishing (right) operations.

A similar plot for surface roughness measured by the parameter Ra as function of pulse on time is shown in Fig.2.The best surface finish obtained during rough machining is Ra value of 1.35µm for 5A whereas during finishing operation the Ra value obtained was 0.5µm for all the three discharge currents of 1A,2A and 4A at the same pulse on time of 5µsec. The roughness value increases with the increase in pulse on time which is also similar to steels and to the results obtained by J.C. Rebelo et al [10].

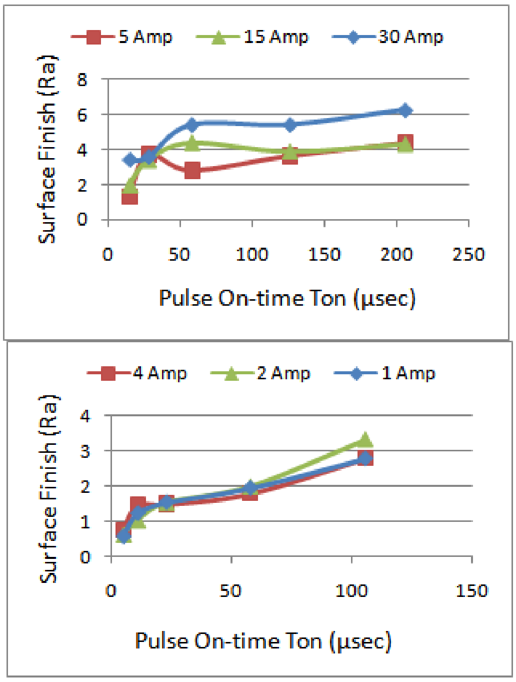


Fig 2: Surface Finish vs T_{on} plot for roughning (left) and finishing (right)

IV. Statistical Analysis

Statistical analysis were performed in Minitab 18 software such as ANOVA for the surface finish which gives the R^2 value of 92% and a regression equation for the Surface finish in terms of I and T_{on} is obtained. A surface plot and contour plot are also obtained for the surface finish shown in Fig.3 and Fig.4 respectively.

4.1Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	5	8.61701	1.72340	19.91	0.000
Linear	2	8.22614	4.11307	47.51	0.000
Current Intensity I (A)	1	0.00008	0.00008	0.00	0.976
Pulse On-time Ton (µsec)	1	8.20453	8.20453	94.77	0.002
Square	2	0.04648	0.02324	0.27	0.770
Current Intensity I (A)*Current Intensity I (A)	1	0.02638	0.02638	0.30	0.594
Pulse On-time Ton (µsec)*Pulse On-time Ton (µsec)	1	0.02010	0.02010	0.23	0.641
2-Way Interaction	1	0.04594	0.04594	0.53	0.485
Current Intensity I (A)*Pulse On-time Ton (µsec)	1	0.04594	0.04594	0.53	0.485
Error	9	0.77919	0.08658		
Total	14	9.39621			

Model Summary

S	R^2	R^2(adj)	R^2(pred)
0.294240	91.71%	87.10%	75.43%

4.2Regression Equation in Uncoded Units

Surface Finish (Ra) = $0.437 + 0.290I + 0.02701\ Ton - 0.0453\ I^2 - 0.000037Ton^2 - 0.00118\ I{*}Ton$

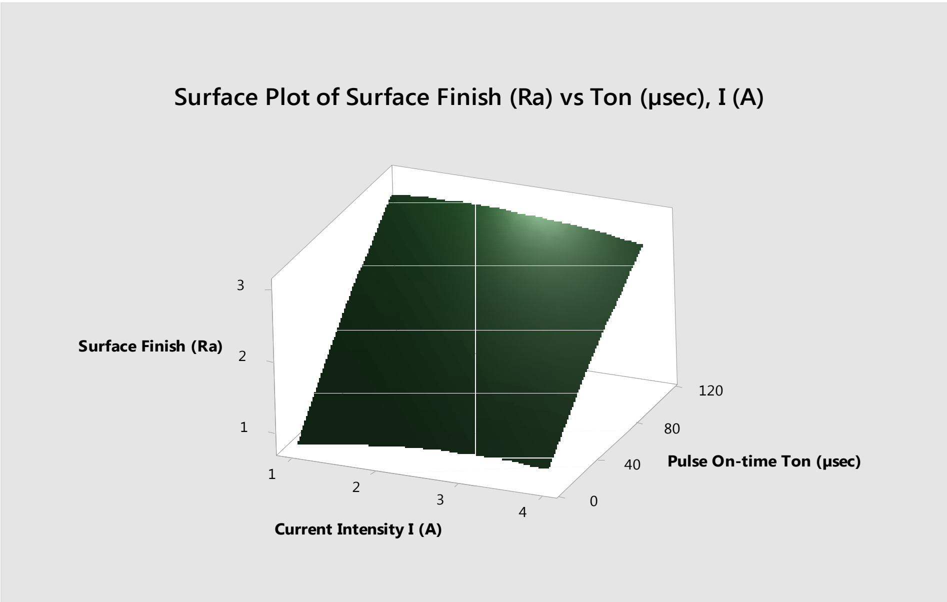


Fig 3 : surface plot of surface finish vs pulse on-time and current intensity

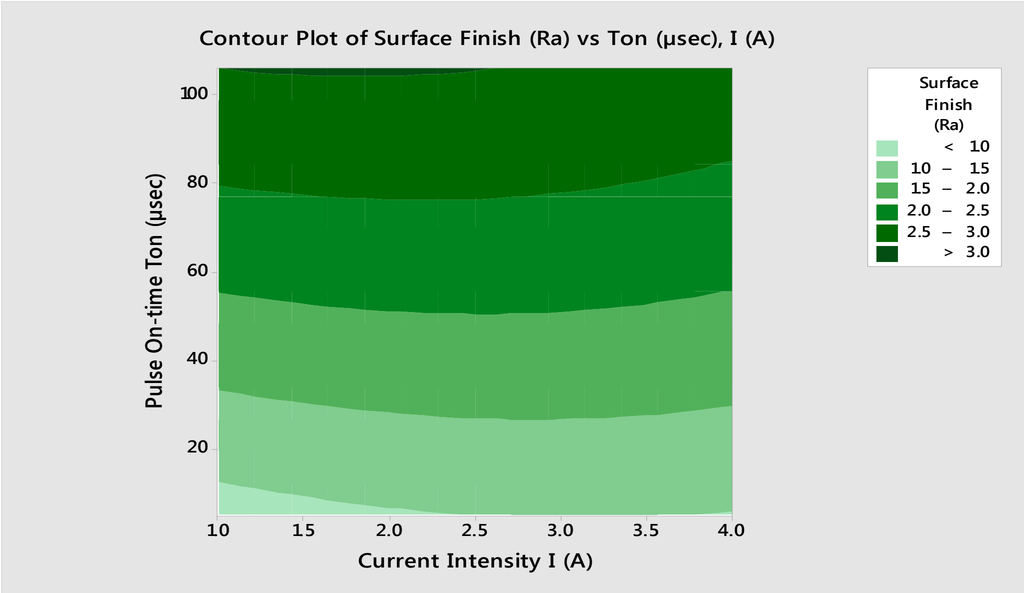


Fig. 4 : contour plot of surface finish vs pulse on-time and current intesity

V. Conclusion

In this experimental study, the optimization of EDM parameters for machning of copper Cu102 is performed. The effects of current intensity and pulse on-time on the MRR and Surface roughness is presented.The maximum of the MRR curve is shifted towards lower on-time and can be explained by higher thermal conductivity of copper compared to steels or other materials. With the help of statistical tool of ANOVA a regression equation for surface finish is obtained interms of I and T_{on}andhence a surface plot and a contour plot is also obtained. The best surface roughness Ra value obtained is 0.5µm at lower currents of 1A and 2A with pulse on-time of 5µsec corresponds to pulse off-time of 2µsec at gap voltage of 40V with the positive polarity.Experimental findings shows that pulse on time has most significant effect upon surface roughness. Though EDM of copper is more time consuming comapred to steels, high quality of surface finish is possible which can improve lifetime and efficiency of the applications. The achieved optimum parameters has to be used for finishing a copper beam dump.

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