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Effect of EDM Process Parameters on Deep Cryogenic Heat Treatment of Cold Work Tool Steel AISI D2

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Abstract:

In this study ,The effect of input parameters of EDM machining process such as pulse current and pulse on time on the output parameters like metal removal rate(MRR) and surface roughness (Ra) of machining of AISI D2 tool steel were investigated. The deep cryogenic treatment (DCHT)and conventional heat treatment (CHT)were applied on AISI D2 tool steel .The objective of this research is to found out the effect of these treatments on output parameters of EDM process .The results have shown that the discharge current and pulse on time are the major parameters influencing the (MRR) and (Ra) for both the treatments, However the cryogenic treatment has significant effect on (MRR)& (Ra).

Keywords: EDM, Cryogenic, Surface Roughness ,Metal Removal Rate.

1-Introduction:

Electrical discharge machining (EDM) is one of the most successful and widely used processes for production of complicated shapes and tiny apertures with high accuracy. This method is commonly used for profile tarring of metal bond diamond wheel, micro nozzle fabrication, drilling of composites and manufacturing of moulds and dies in hardened steels. These hard and brittle materials fabricated by conventional machining operation cause excessive tool wear and expense. The mechanical properties of tool steels have been studied extensively for many years. During EDM, the tool and the work piece are separated by a small gap, and submerged in dielectric fluid. The discharge energy produces very high temperatures on the surface of the work piece at the point of the spark. The specimen is subject to a temperature rise of up to 40 000 K causing a minute part of the work piece to be melted and vaporized[1].

The Electrical Discharge Machining process is employed widely for making tools, dies and other precision parts. It is capable of machining geometrically complex or hard material components, that are precise and difficult to machine such as heat treated tool steels, composites, super alloys, ceramics, carbides, heat resistant steels etc. being widely used in die and mold making industries, aerospace, aeronautics and nuclear industries. So it is one of the well-liked non-traditional machining processes being used today. Electric Discharge Machining has also made its presence felt in the new fields such as sports, medical and surgical, instruments, optical, as well as automotive areas. EDM can be used to machine difficult geometries in small batches or even on job-shop basis. Tool and Work material to be machined by EDM has to be electrically conductive **[2].**

Cryogenic hardening is a cryogenic treatment process where the material is cooled to approximately −185 °C (−301 °F), usually using liquid nitrogen. It can have a profound effect on the mechanical properties of certain steels, provided their composition and prior heat treatment are such that they retain some austenite at room temperature. It is designed to increase the amount of martensite in the steel's crystal microstructure, increasing its strength and hardness, sometimes at the cost of toughness. Presently this treatment is being practiced over tool steels, high-carbon, and high-chromium steels to obtain excellent wear resistance**[3]**.

2- LITERATURE REVIEW

P. I. Patil et.al.[4] investigated the Comparison of Effects of Cryogenic Treatment(CT) on different types of Steels, the comprehensive analysis of strategies followed in CTs and their effects on properties of different types of steels by application of appropriate types of CT's from cryogenic conditioning of the process.

A.D.Wale, et.al. [5] investigated the effect of cryogenic treatment on mechanical properties of cold work tool steels at various combination of heat treatment cycle (process sequence). The material selected for these processes were AISI D2 and D3. It was seen that for D2and D3 tool steel conventional heat treated (CHT) specimen has less hardness than cryotreated specimen. But for D2 tool steel there is gradual decrease in hardness observed from Austenizing Quenching Cryogenic (AQC) to Austenizing Quenching Tempering Cryogenic Tempering (AQTCT) specimens. For D3 tool steel there is gradual increase in hardness observed from Austenizing Quenching Cryogenic Tempering(AQCT) to AQTCT and AQC specimen has highest hardness. The multiple tempering decreases hardness in D2 tool steel whereas increases hardness in D3 tool steel. For D2 and D3 tool steel in process sequence AQC massive carbides were not seen and 95% unstable austenitic structure was seen. But both tool steels have maximum hardness value for this process sequence. In D3 tool steel the micro cracks were observed on the untempered samples. The general shape of carbides observed was Globular, Nodular or elliptical. In D2 tool steel retained austenite is not totally converted to martensite whereas in D3 tool steel retained austenite is totally converted to martensite**.**

Shivnandan, **et.al. [6]** investigated the effect of cryogenic tempering of AISI D2 steel (work piece) and copper electrode (tool) on material removal rate (MRR) in Electrical discharge drilling(EDD) based on design of experiments approach. The discharge current, pulse-on-time and electrode-workpiece combination (cryogenically tempered or untempered) are the parameters selected for this study. The orthogonal array, signal-to-noise ratio (S/N) and analysis of variance(ANOVA) are used to find out the effect of cryogenic tempering on MRR. The results demonstrate Cryogenic tempering that have significant effect (nearly 10%) on MRR. It is recommended to cryogenically temper both the electrode and work piece to maximize the MRR.

T M Sonar, et.al. [7] investigated the effect of deep cryogenic treatment on surface integrity and dimensional stability of the D2 tool steel. The results have shown improvement in surface roughness. The improvement in surface roughness is attributed to the release of tensile residual stresses and more precipitation and uniform distribution of fine secondary carbides. GILL SS et.al.[8] investigated the metallurgical changes that occurred during the cryogenic treatment of tool steels to benefit the cutting tools industry. The prominent reasons found to be responsible for improving the mechanical properties of tool steels are transformation of retained austenite to martensite and precipitation of fine carbides. It is observed that cryogenic treatment can significantly enhance the mechanical properties of the tool steels. The improvement in mechanical properties by cryogenic processing is attributed to the combined effect of conversion of retained austenite to martensite and precipitation of fine carbides. Also, every tool steel reacts differently to the cryogenic treatment depending upon the steel's conventional heat treatment history and constituent elements. Cryogenic treatment, if properly employed, can provide a significant improvement in both productivity and product quality and hence overall machining economy even after covering the additional cost of cryogenic treatment. **CHORNG-JYH TZENG.et.al. [9]** studied and analyzed the material removal rate, electrode wear ratio and work piece surface finish on process parameters during the manufacture of SKD61(**hot work alloy tool steel**) by electrical discharge machining (EDM).In addition, analysis of variance (ANOVA) was implemented to identify significant factors for the EDM process parameters. The results show that the ANOVA indicated that the cutting parameter of discharge current is the most significant factor, and the cutting parameter of pulse-on time is the most significant factors for Ra. Namely, the higher discharge energy with the increase of discharge current and pulse on time leads to a more powerful spark energy, and thus increased MRR. **P. Balasubramaniana.et.al. [10]** In this research work two different materials have been used as work pieces. These EN8 and D3 steel materials have been machined in an Electrical discharge machine which has wide application in Industry fields. The important process parameters that have been selected are peak current, pulse on time, die electric pressure and tool diameter. The outputs responses are material removal rate (MRR), tool wear rate (TWR) and surface roughness (SR). The Cast Copper and Sintered Powder Metallurgy Copper (P/M Copper) have been considered as tool electrodes to machine the fore said work pieces. Response surface methodology(RSM) has been used to analyze the parameters and analysis of variance (ANOVA) has been applied to identify the significant process parameters. It is noticed that, for EN-8 material mean value of MRR is high (72.4 mm3 /min) and low TWR value (12.73mm3 /min) for Cast electrode compared with Sintered electrode. Furthermore the SR value is marginally less for Sintered electrode compared with Cast electrode. Considering die steel (D3) which has been machined by the Cast electrode, the mean value of MRR is high and TWR is low compared with Sintered electrode. The mean value for SR is marginally lower for Sintered electrode than that of Cast electrode[10].**I. K. et.al.[11]** studied the effects of process parameters of electrical discharge machining, peak current and pulse-on time duration on surface integrity. During spark electrical discharge machining of AISI D2 cold work tool steel, surface finish and the microstructure changes like the depth of white layer, heat affected zone and crack depth were examined. The results shows that the increase in current and pulse duration tends to increase the surface roughness as well as an increase in the white layer and heat affected layer thickness, also crack length showed influenced by variation in process parameters.

Hence, this study has been planned to investigate the effect of deep cryogenic heat treatment compared with conventional heat treatment of cold work tool steel AISI D2 during EDM process.

3-EXPERIMENTAL DETAILS:

This study was carried out on spark discharge machine charmless 2l, for studying, the machining parameters on cryogenic& heat conventional treatment samples (9 samples for each treatment) of cold work tool steel AISI D2 and The chemical composition in weight per cent shown in Table 1.

Table 1: the Chemical composition (wt. %) of AISI D2 tool steel

C	CR	MO	Cu	MN
1.54	12.4	0.69	0.13 2	0.375
P	S	Ni	FE	
0.0218	0.003	0.24	84.2	

The nine conventional treatment specimen was cut (20mm*10mm*10mm) as shown in figure (1), and hardening to 1050°C then quenching in oil bath then tempered to temperatures 100°C, the average hardness obtained was 55 HRC .The procedure of heat treatment is shown in table 2 and the nine cryogenic treatment specimen that have same dimensions heated to 1050°C then cryogenic treatment (-195) for 20 h ,then tempered to100 °C (2 h) the average hardness obtained was 60 HRC.

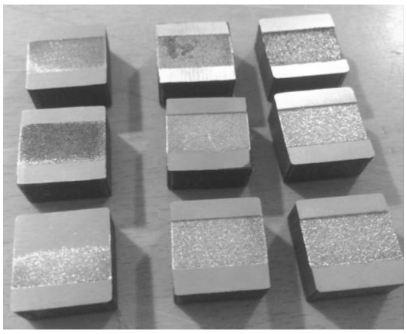


Fig 1: Shows the nine samples

Table 2: the Heat treatment cycle

W/P	Hardening	Hardness
conventional heat treatment (CHT)	Heating 1050 °C+Tempering 100°C	55 HRC
Cryogenic deep heat treatment (DCHT)	Heating 1050 °C+Deep Cryogenic at (-185 °C) for 20 hrs+ Tempering 100°C	60 HRC

A full factorial design of experiment was used two parameters and three levels, nine sample machining on RoboForm 2lc spark EDM manufactured by charmless technologies (Fig 2) with spark current 5, 10 and 20A and pulse on time duration was 100,400 and 1600 µs other machine parameters are fixed as indicated in table(3).Each machining test was performed for 25 min .

Figure 2: RoboForm 2lc spark EDM Machine

Table 3: the experimental test conditions

Machine type	Roboform 2-LC
Pulse current (A)	5,10,20
Pulse on time (µs)	100,400,1600
Pulse off time (µs)	50
Voltage (v)	120
Tool material	copper
Dielectric	Kerosene
Polarity	Positive

4- RESULTS AND DISCUSSIONS:

4-1 Effect of Pulse Current& Pulse-on- time on surface roughness:

The surface finish is an indicator of process performance in EDM work-piece and its main output characteristic. In this present research, the influence of main process parameters current and pulse on time on surface roughness during spark electrical discharge machining on (DCHT) and (CHT) D2 tool steel samples with copper electrode is summarized at different experimental conditions as shown in table (4).

Table 4: the variation of surface roughness between (DCHT) and (CHT).

W/ P. No	CURRENT (A)	TIME ON (µsec)	Ra (CHT) (µm)	Ra (DCHT) (µm)
1	5	100	4.44	6.4667
2	5	400	7.87	6.78
3	5	1600	8.03	7.32
4	10	100	6.41	7.8667
5	10	400	11.99	8.2833
6	10	1600	12.79	9.41
7	20	100	8.55	10.1567
8	20	400	9.24	10.1067
9	20	1600	10.24	10.7767

As shown in figures (3&4) , the surface roughness value increases as the pulse current and the pulse–on time increase. The maximum increase was observed at a pulse current of 10 A ,pulse on time of 1600 µsec with the CHT process.

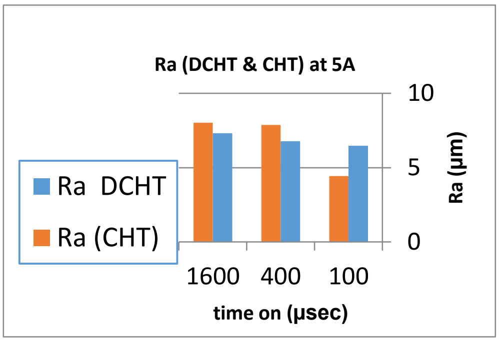
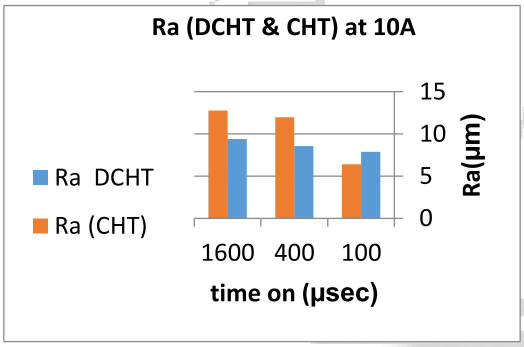
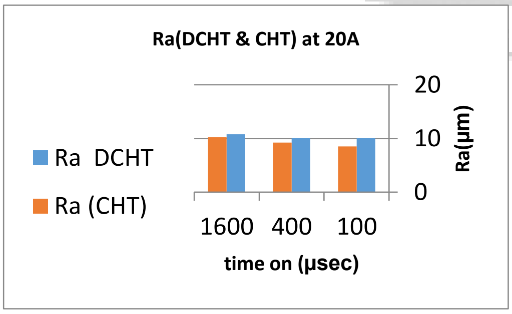


Fig (3a) the variation of surface roughness in CHT process compared with DCHT at 5A.



Fig(3b)the variation of surface roughness in CHT process compared with DCHT at 10A.



Fig(3c)the variation of surface roughness in CHT process compared with DCHT at 20A

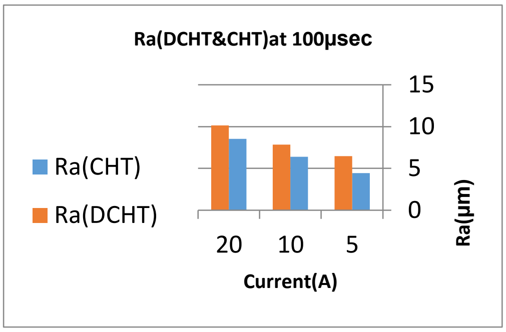


Fig.(4a) the variation of surface roughness in CHT process compared with DCHT at 100 µsec

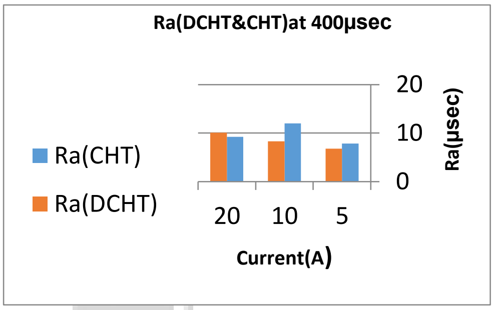


Fig. (4b) the variation of surface roughness in CHT process compared with DCHT at 400 µsec.

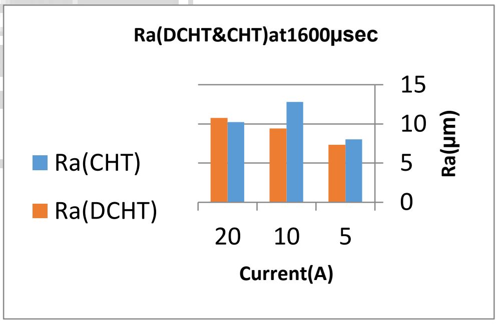


Fig. (4c) the variation of surface roughness in CHT process compared with DCHT at 1600 µsec

4-2 Effect of Pulse Current &Pulse-on time on material removal rate(MRR):

Material removal rate was obtained by calculating the difference between the final weight (after machining) of the sample and initial weight (before machining) of the sample. Material removal rates obtained under different experimental conditions are shown in table (5).

Table 5: Shows the variation of Material Removal Rate between (DCHT) and (CHT) .

W/P. No	CURRENT (A)	TIME ON (µsec)	MRR (CHT) (mm3/min)	MRR (DCHT) (mm3/min)
1	5	100	0.00468	0.019
2	5	400	0.00184	0.0656
3	5	1600	0.00768	0.0879
4	10	100	0.04644	0.1897
5	10	400	0.0298	0.2155
6	10	1600	0.10192	0.2435
7	20	100	0.0226	0.5702
8	20	400	0.02456	0.4717
9	20	1600	0.05	1.0091

As shown in figures (5&6) , in order to enhance the MRR , the current and pulse-on time should be increased . It can be concluded that cryogenically tempered work piece has their respective role to play in improving the MRR .

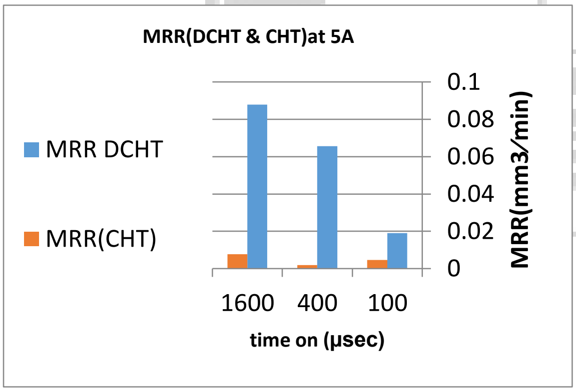


Fig. (5a) the variation of Material removal Rate in CHT process compared with DCHT at 5A.

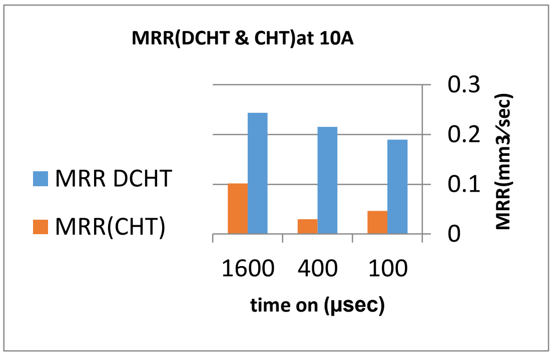


Fig. (5b) the variation of Material removal Rate in CHT process compared with DCHT at 10A.

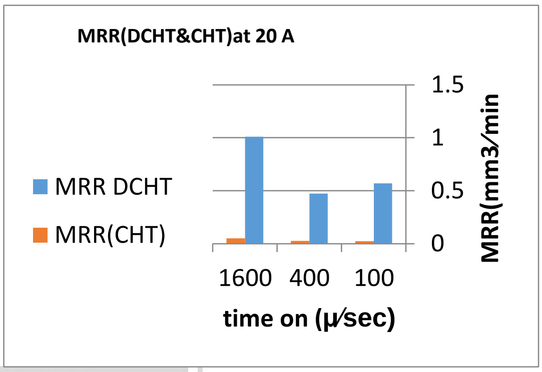


Fig. (5c) the variation of Material removal Rate in CHT process compared with DCHT at 20A.

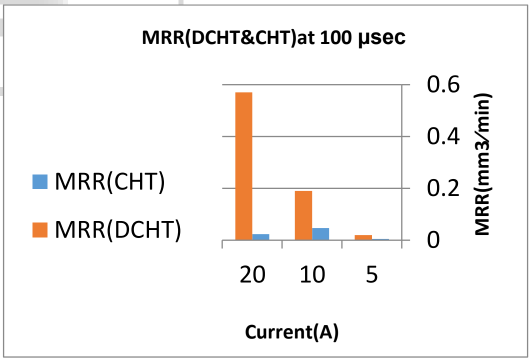


Fig. (6a)the variation of Material removal Rate in CHT process compared with DCHT at 100 µsec.

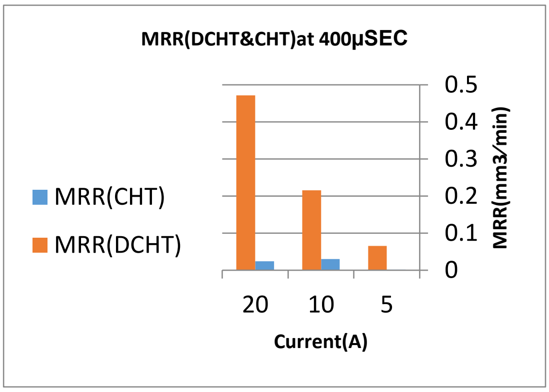


Fig. (6b)the variation of Material removal Rate in CHT process compared with DCHT at 400 µsec.

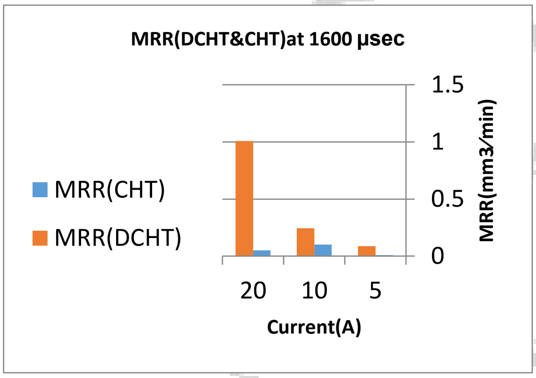


Fig. (6c) the variation of Material removal Rate in CHT process compared with DCHT at1600 µsec.

4-3 Effect of the Cryogenic and Conventional H eat Treatment on Hardness of AISI D2 Tool Steel:

Table 2 shown the hardness values of AISI D2 tool steel metallographic samples after CHT and DCHT process. DCHT specimens have higher hardness value (60 HRC) compared with (55 HRC) CHT specimens. The fact that cryogenic tempering of AISI D2 steel increases its hardness is very well documented in many published papers [6].

The improvement in hardness of cryogenically tempered AISI D2 steel is attributed to the transformation of relatively soft retained austenite into harder martensite [6]

.

5-CONCLUSION:

The hardness of the AISI D2 is markable increased by Cryogenic treatment(about 9 %) in compared with conventional heat treatment Hardening .Due to output parameters of EDM process of the AISI D2 cold work tool steel, the Cryogenic treatment has a positive effect on the Metal Removal Rate compared with conventional treatment ,it can be recommended that cryogenically treated alloy steels can be efficiently machined through EDM .

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