Effect of WEDM parameters on MRR of CADI sample Austempered for 06 hours

P.L.Pandit, Y.S.Sable

Abstract—Researchers and scientist are in continuous search of a material having properties like high strength, high wear resistance and durability to satisfy the need of industries. CADI can be a option in future for satisfying this need. Carbidic Austemperd Ductile Iron can be used for manufacturing piston rings, dies, drill bits etc. Machining CADI with conventional method is tedious and complicated, so non conventional method is used. Among the non conventional machining operations Wire Electrical Discharge machining is the one which is used for machining hard materials with intricate shapes. In this study, experiments were conducted using Taguchi's L9 orthogonal array. Using S/N ratio analysis, optimum levels of process parameters were identified and by using Analysis of Variance (ANOVA), relatively significant parameters were determined. The variation of output responses with process parameters were mathematically modeled by using linear regression analysis method and the models were checked for their adequacy.

Keywords: —Carbidic Austemperd Ductile Iron (CADI), WEDM, MRR., Taguchi and ANOVA.

1 Introduction

Industry demands high strength, high wear resistance and durable material. So, scientists and researchers are developing new material having the above mentioned properties. CADI is new material in development process which can be used for different industrial applications like drill bits, dies, piston rings etc. Austempered ductile iron (ADI) is well known for its high tensile strength over 1600 Mpa (as per ASTM A-834-95 for grades 5 and 1), toughness and high abrasion wear resistance.Due to these properties forged steel in many applications is replaced by ADI. To further increase the abrasion wear resistance performance of ADI, carbide are introduced in it which is known as CADI.

CADI is anew class of ADI containing carbides in the ausferrite matrix. CADI is produced by austempering the carbide ductile iron at different temperatures and time. ADI is a economical substitute for wrought or forged steel and has been used in many automobile applications. minning, railways and agricultural machinery sectors. Due to its high wear abrasion resistance it can be used in piston rings in IC engines, dies, gears, rollers etc.[1][2]

Hardness of CDI austempered for 06 hours is observed in the range of 51 to 55 HRc, hence machining in conventional way is difficult and complicated. So, non conventional machining process is preffered while machinng CADI.

Among the several non conventional machining processes

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WEDM is one which can be used for machining hard materials with dimensional accuracy. While machining on WEDM it is necessary to set correct paramenters to achive maximum MRR with lower surface roughness value. This process is highly dependent on the experience of the operator and practically it is very difficult to achive optimal conditions for machining. So, to achive optimal machining conditions, a simple but reliable method based on statistically designed experiments is suggested for investigating the effects of various process parameters on MRR.

Noor Zaman Khan, Zahid A. Khan, Arshad Noor Siddiquee & Arindam K.Chanda [4] investigated the effect of pulse-on-time, pulse-off-time and current in machining of ASTM A572 grade 50 HSLA steel using NC wire cut EDm process with Grey Relation Analysis. Results show that increase in pulse-on-time and pulse current increases the value of surface roughness. Also, result state that, pulse-off-time is most significant for surface roughness.

S S Mahapatra and Amar Patnaik [5] used genetic algorithm to find optimal values of parameters viz. discharge current, pulse duration, pulse frequency, wire speed, wire tension and dielectric flow rate for maximization of MRR and minimization of surface roughness.

Lokeswara Rao T. and N.Selvaraj [6], evaluated the effects of machining parameters viz. pulse-on-time, pulse-off-time, peak current, servo voltage and servo feed, on volume material removal rate and surface roughness. Taguchi Analysis approach was used to determine the factors which have significant impact onvolume material removal rate and the optimal setting is found by S/Nratio analysis. Equations which correlate machining parameters with material removal rate is found by regression analysis. Results reveal that, pulse-on-time and peak current are the most significant factors for the performance measures. Wire tension, servo voltage and servo feed settings are less significant on-

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performance measure.

2 Experimental Setup

The reference material used for experimentation is Darbide Ductile Iron (CDI) developed by incorporating the carbides in the typical matrix of ductile iron which is heat treated involves austenitizing in the temperature range of 900° C to 920° C in the muffle furnace for one hour. After that austempring in salt bath of 325° C for time period of 06 hours is carried out. Table 1 shows the chemical composition of As-cast CADI.[7]

TABLE 1
Chemical Composition of CADI Material

Alloying Element	Percent
C%	3.6
Si%	1,9
Mn%	0.64
S%	0.0122
P%	0.0294
Cr%	4.3
Cu%	0.61
Ni%	0.431
Ti%	0.016
Mg%	0.044
CE	4.23

As Experiments were conducted on a 4-axis WEDM, model: Elektra-Sprintcut 743 f, manufactured by Electronica Machine Tools Ltd., India. De-ionized water was used as a dielectric fluid and a brass wire electrode of 0.25 mm dimeter was employed as tool electrode. Fig 1 shows the shematic diagram of WEDM.

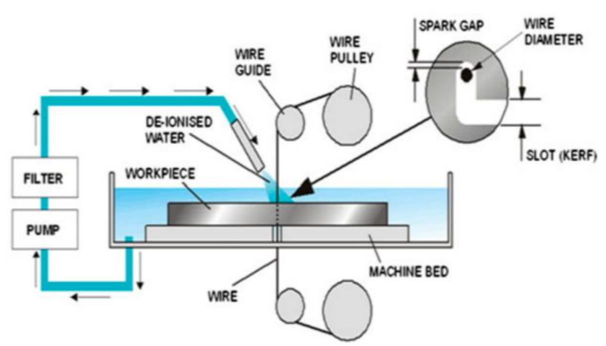

Fig. 1. Schematic representation of WEDM

In this study, three important WEDM parameters, namely pulse-on-time (TON), pulse-off-time (TOFF) and peak current (IP) have been considered with three different levels each as shown in TABLE 2. Based on pilot experiments and literature survey the parameter range was selected. Other parameters are kept constant at their default settings. The response variable selected for this study is Material removal rate (MRR) this can be calculated using the following expression:

$$MRR = \frac{\text{Initial weight} - \text{Final weight}}{\text{Machining Time}} \quad \text{..........(1)}$$

3 Mathematical Modelling

Using orthogonal L_9 array, experiments were designed. Table

TABLE 2
Process Parameters and Their Levels

Sr. No	Parameters	Levels		
		-1	0	1
1	Pulse on Time (TON)	116	122	128
2	Pulse off Time (TOFF)	30	38	46
3	Peak Current (IP)	210	220	230

No 03 given below shows the valu of MRR for each experiment. Analysis of variance is used for data analysis and to check good fit of model.

Equation obtained for MRR is given below:

$$MRR=-0.187+0.00155*T_{ON}-0.00026*T_{OFF}+0.000380*I_{P} \quad (2)$$

TABLE 3
DoE with Experimintal Reslts

Sr. No	T_{ON} µS	T_{OFF} µS	T_{IP} (AMPS)	MRR (gm/min)
1	116	30	210	0.069877243
2	116	38	220	0.064242424
3	116	46	230	0.071342201
4	122	30	220	0.075197889
5	122	38	230	0.0799508
6	122	46	210	0.069489685
7	128	30	230	0.093516209
8	128	38	210	0.082634731
9	128	46	220	0.085290482

ANOVA of the model for MRR is shown below in Table 4. The value Of R^2 is 98.4% and R^2(adj) is 93.5%, which means that the regression model provides an excellent explanation of the relationship between the independent variables (factors) and the response (MRR). The associated P-value for the model is 0.03 which is lower than 0.05 (i.e. α=0.05 or 95% confidence level), indicating that the model isconsidered to be statistically significant. [8]

Normal probability plot of the residuals for MRR is shown

TABLE 4
ANOVA OF MODEL

Source	DF	SS	MS	F	P
Regression	3	0.000635	0.00021	20.35	0.003
Residual Error	5	0.000052	0.00001		
Total	8	0.000687			

in Figure 2 below.From the figure it is clear that the residuals are falling on a straight line, which means that the errors are normally distributed and the regression model fairly agrees with the obtained values.

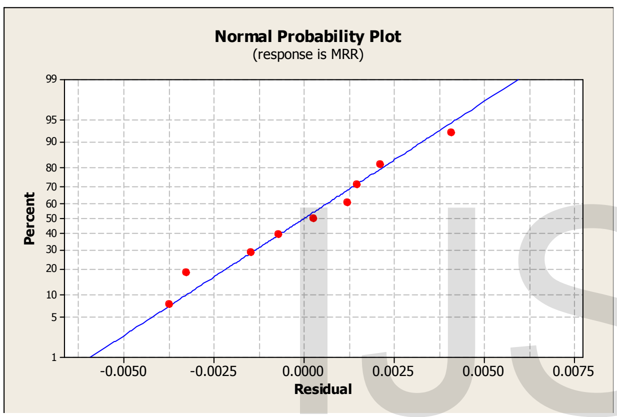

Fig. 2. Normal Probability Plot

4 RESULT AND DISCUSSION

4.1 S/N Ratio Analysis

The term "signal" in Taguchi method represents the desirable value (mean) for the output characteristic and the term "noise" represents the undesirable value for the output characteristic. Taguchi uses the S/N ratio to measure the quality characteristic deviating from the desired value. There are several S/N ratios available depending on type of characteristic: lower isbetter (LB), nominal isbest (NB), or larger isbetter (LB). Larger is better S/N ratio isused here. Larger-the-better quality characteristic was implemented and introduced in this study. [1]

Larger isthe better characteristic isgiven by,

$$S/N= -10\log10\ (MSD) \quad (3)$$

Where MSD= MeanSquared Division

$$MSD= (1/Y_1^2+ 1/Y_2^2+ 1/Y_3^2+\ldots\ldots)/n \quad (4)$$

Where Y_1, Y_2, Y_3 arethe responses and n is the number of tests

TABLE 5
RESPONSE TABLE FOR SIGNAL TO NOISE RATIO- LARGER IS BETTER

Level	T_{ON}	T_{OFF}	I_P
1	-23.30	-22.06	-22.64
2	-22.53	-22.48	-22.57
3	-21.21	-22.49	-21.82
Delta	2.09	0.44	0.82
Rank	1	3	2

in a trial and MSD is the target value of the result. The level of a factor with the highest S/Nratio was the optimum level for responses measured. The higher the signal to noise ratio, the more favorable is the effect of the input variable on the output. Table 5 shows the optimized level of input parameters for MRR are T_{ON} -128, T_{OFF} -30 and I_P-230 which is having higher S/N ratio values.

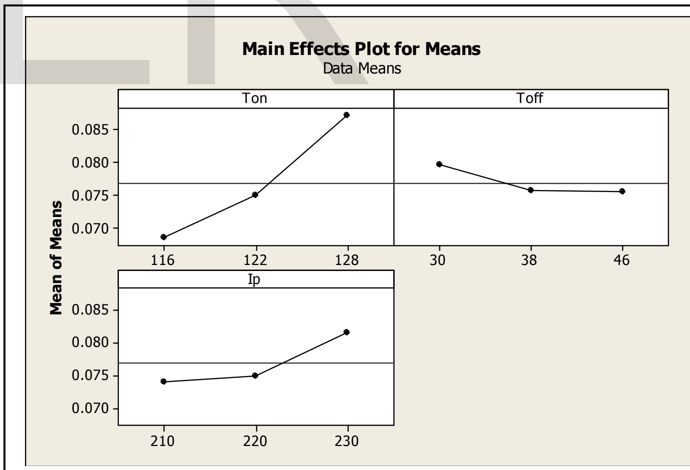

Fig. 3. Effect Plot of Process Parameters For S/N Ratio

Fig. 3 above shows Mean Effective Plot for S/N ratios, which Clearly shows that input parameter level viz. T_{ON} -128, T_{OFF} -30 and I_P-230 is having higher S/Nratio values.
Relative influence of multiple variables and their significance can be studied using Analysis of variance. Analysis of variance is a standard statistical technique to interpret experimental results. It is widely used to discover the differences in average performance of groups of items under investigation. It breaks down the variation in the experimental result into

accountable sources and thus finds the parameters whose contribution to total variation is significant.

TABLE 6
ANOVA OF MRR

Source	DF	Seq SS	Adj SS	Adj MS	F	P
T_{ON}	2	6.7013	6.7013	0.3507	30.39	0.032
T_{OFF}	2	0.3693	0.3693	0.1847	1.67	0.374
I_P	2	1.2441	1.2441	0.6220	5.64	0.151
Residual Error	2	0.2205	0.2205	0.1102		
Total	8	8.5352				

4.2 ANOVA Analysis

ANOVA helps to investigate and find which process parameters affect significantly the quality characteristic. ANOVA of MMR shown in Table 6, shows that most significant factor is T_{ON} having P value less than 0.05 followed by I_P and T_{OFF}.

5 CONCLUSION

In the present study CADI material was machined by wire EDM process. The specimens were machined i.e. sliced by varying the machining parameters like pulse on time, pulse off time and peak current. Performance measure (MRR) was measered by calculating the difference in weight before and after machining and then divided by time requireed for machining the specimen.Taguchi method was used to investigate the effect of input parameters, L9 orthogonal array was employed to perform the experimentation and to develop the coorelation between the WEDM parameters and MRR. ANOVA of model and parameters has been done for analysis. From the results obtained the following conclusions can be drawn:

a) Material removal rate increases with increase in pulse on time T_{ON} and peak current I_P and with decrease in pulse off time T_{OFF}

b) ANOVA on experimental data shows that the mathematiccal model developed is statistically significant.

c) ANOVA shows that T_{ON} and I_P are most significant parameters and T_{OFF} is least significant parameter for MRR.

d) The optimum level of process parameter according to S/N ratio is found to be A3B1C3, which are T_{ON} -128, T_{OFF} -30 and I_P-230

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