Effect of Casting Process Parameters of Al6061-Cu- SiCp metal matrix Composite on Material Removal Rate by Electrical Discharge Machining

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Abstract
Instead of lots of developments in ceramic metal matrix composites field still its uses are restricted due to the high cost of production and difficult to machine with traditional machining processes. In present experimentation an attempt is made to find the parameters which affect the material removal rate of metal matrix composite casting through Electric Discharge Machining (EDM). The effect of stirring speed and pouring temperature on mechanical, microstructure and machining properties of Al6061-Cu reinforced SiC MMC by stir casting technique were under investigation. The input parameters are five level of stirring speed viz. 50 rpm, 200rpm, 400 rpm, 600 rpm and 800rpm and five level of pouring temperature are 675^{o}C, 700 ^{o}C, 725^{o}C, 750 ^{o}C and 775 ^{o}C. The dependent variables are hardness, impact strength and metal removal rate of MMC by electro-discharge machining while the independent parameters are five level of stirring speed and five level of pouring temperature. It is observed from experimentation that with increase in stirring speed increases- the impact strength and hardness of MMC up to a certain limit after that these properties decrease drastically. The optimal value of hardness and impact strength for MMC is obtained at pouring temperature of 725˚C and 400 rpm and impact strength of MMC are least at 800 rpm and 775˚C and followed by 50 rpm and 675˚C. It is observed from an SEM study that at stirring speed 400 rpm better homogeneity can be obtained compared to 200 and 600 rpm.

Keywords: *EDM; Ceramic Metal Matrix composite; Stir casting; Scanning electron micrograph of composites.*

1. Introduction:

The ceramic metal matrix composites are material that contains ceramic in discrete phases which provide it additional strength [1]. The previous researches advocated that ceramic metal matrix composites have better mechanical properties compared with its base alloy of metal especially hardness [2,3] which make it difficult to machine through conventional machining processes. Ultrasonic machining destroys the finish of edge of work piece through repetitive generation of micro cracks [4]. Laser machining has high cost of production also it may cause thermal stresses and heat effected zone on work piece [5].

Electric Discharge Machining (EDM) commercially utilized to machine complex geometrical shape and difficult material which are unfeasible to machine through conventional machining process while negligible machining force and low cost of machining [6-9] make it most suitable among unconventional machining processes. Casting parameters of ceramic metal matrix composites effect on metal removal rate through EDM is not sufficiently argued in literature, so in present research it is tried to find out the optimal casting process parameter at which best machining through EDM is achieved.

2. Design of Experiment:

2.1 Process Parameters

It is postulated in null hypothesis that “input casting parameter stirring speed and pouring temperature has no significant effect on metal removal rate through EDM”. Five levels of stirring speed: 50rpm, 200rpm, 400 rpm, 600rpm and 800rpm and five levels of pouring temperature: 675^0C, 700^0C, 725^0C , 750^0C and 775^0C at constant pouring rate 2.5cm/s were under consideration for experiments.

Basic principle of Electric Discharge Machining is shown in figure 1. A series of experiments were conducted using die-sinking EDM machine as shown in Figure2. A tool made of copper with diameter 10 mm was used as an electrode. The Work piece was Al6061 +4% Cu composites reinforced with 5wt. %SiC particles. The dimension of work piece 20X20X10 mm3, weight 250 grams.

Commercial grade EDM oil (density = 0.86, flash point= 132°C) was used as dielectric fluid and the side injection of dielectric fluid was adopted. A jet flushing system was employed to assure adequate flushing of the debris from the gap zone. The process parameters (current 9A, pulse on time 300µs and 50 V) were being set in the EDM machine and the experiments were conducted as per the design matrix. After each experiment the weights of specimen is measured with an electronic weighing machine.

2.2 Production of Metal Matrix Composites:

A stirring system has been developed by the motor with regulator and a cast stirrer (Figure 3). To ensure the pro- per mixing of melts, all the melting was carried out in a graphite crucible in an open hearth furnace. Billet of aluminum and copper were preheated at 450˚C for 40 minutes before melting and the SiC particles were pre-heated at 1100˚C for 2 hours to make their surfaces oxidized. The furnace temperature was first raised above the liquidus to melt the feed stock completely and was then cooled down just below the liquidus to keep the slurry in a semisolid state. At this stage the preheated SiC particles were added and mixed manually.

Manual mixing was done because difficulty in mixing by using an automatic device when the alloy was in a semi-solid state. After sufficient manual mixing, the composite slurry was reheated to a fully liquid state and then automatic mechanical mixing was carried out for about 10 minutes at a normal stirring rate of 600 rpm. In the final mixing process, the furnace temperature was within 760˚C and the composite slurry was poured in a sand mould de-signed to get standard specimens.

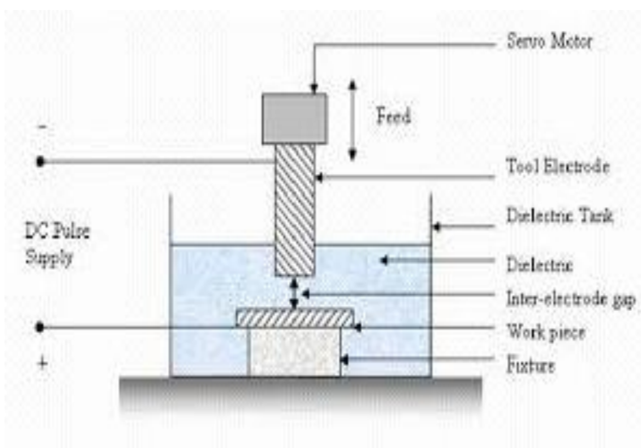

Figure 1 *Basic Principle of EDM*

Figure *2 EDM machine***.**

Figure 3 *Stirrer system with speed controller.*

3. Results and Discussions:

3.1 ANOVA and Graphs:

The data were analyzed by one way ANOVA (ANalysis Of VAriants) technique using SPSS software as shown in table 1. The independent variable stirring speed is highly significant means influential factor for material removal rate through electrical discharge machining (As P=0.000<< 0.05 for 95% confidence interval). The R squared value is 85.1 % it indicate the strong relationship between material removal rate through electrical discharge machining and stirring speed of stir casting of the metal matrix composites.

It is clearly shown through graph of figure 4 that at low [i.e., 50 rpm] and high [i.e., 800 rpm] stirring speeds the material removal rates of metal matrix composites are inferior compared to other stirring speeds. Also superior values of material removal rate of electric discharge machining are observed at 400 rpm.

Table 1. Tests Between-Subjects Effects- Dependent Variable; Material Removal Rate

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.145[a]	4	.036	99.996	.000
StirringSpeed	.145	4	.036	99.996	.000
Error	.025	70	.000		

a. R Squared = .851 (Adjusted R Squared = .843)

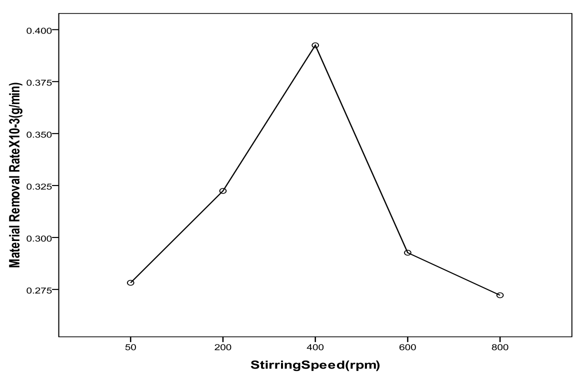

Figure 4 *Material Removal Rate Vs Stirring Speed graph*

The graph of figure 5 revert the effect of pouring temperature on material removal rate of metal matrix composite. The pouring temperature 725^{0}C have best result in terms of material removal rate. It is clear from table 2 that the effect of pouring temperature on material removal rate through EDM is not statistically significant. R square value is 8.1% means weak relationship between pouring temperature and material removal through EDM machining.

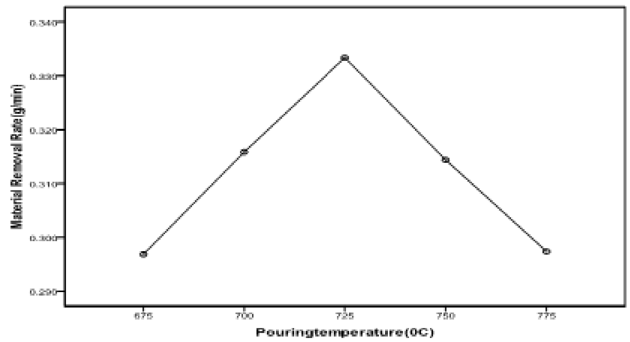

Figure 5 *Material Removal Rate Vs Pouring Temperature graph*

3.2 Regression Analysis:

From multiple linear regression analysis as shown in table 3, the value of R square for predictors (constant, stirring speed and pouring temperature) is 2.2 %, it states there is a very weak relationship between constant, stirring speed and pouring temperature for material removal rate. So some other variables also required to develop appropriate mathematical model.

Table 2. Tests Between-Subjects Effects- Dependent Variable; Material Removal Rate.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	.014[b]	4	.003	1.540	.200
Pouring Temperature	.014	4	.003	1.540	.200
Error	.157	70	.002		

R Squared = .081 (Adjusted R Squared = .028)

Equation (1) represents the relationship between Material removal rate through EDM and Stir speed and Pouring Temperature for Al6061-Cu-SiC_p MMC.

Material Removal Rate =-323.444-0.026*Stir speed -0.002*Pouring Temperature……….(1)

Table3. Summary table of Coefficient of Constants and predictors for material Removal Rate.

Coefficient[a]

Model	Unstandardized Coefficients		Standardized Coefficient		Sig.
	B	Std. Error	Beta	t	
Constant	323.444	114.424		2.827	0.006
Stirring Speed	-0.026	0.020	-0.149	-1.282	0.204
Pouring temperature	-0.002	0.157	-0.001	-0.010	0.992

a. Dependent Variable: Material Removal Rate (MRR) R square=0.22

3.3 Scanning Electron Micrographs (SEM)

The SEM shown in figure 6(a), figure 6(b) and figure 6(c) are taken for specimens of constant pouring temperature of 7250C and variable stirring speed of 200 rpm, 400 rpm and 600 rpm respectively. It is observed from the surface micrographs (SEM) study that with the increase in pouring speed up to certain limit increases the homogeneity in mixing of SiCp ceramic in matrix alloy but after that metal alloy is separated from SiCp. At pouring speed 200 rpm insufficient mixing of alloy metal and SiC ceramic [figure 6 (a)], at pouring speed of 400 rpm having homogenous mixing is achieved [figure 6 (b)] and at pouring rate 600 rpm the clouting of SiC are observed again [figure 6 (c)]. The figure 6(d) , figure 6(e) and figure 6(f) represents the surface micrographs of specimens produced at constant stirring speed of 400rpm and variable pouring temperatures of 7250C, 7500C and 7750C respectively. It is reverted from figure 6(a) more homogeneous mixing of SiCp in base alloy and also size of particles are small compared to figure 6(b) means 7500C and figure6(c) means 7750C.

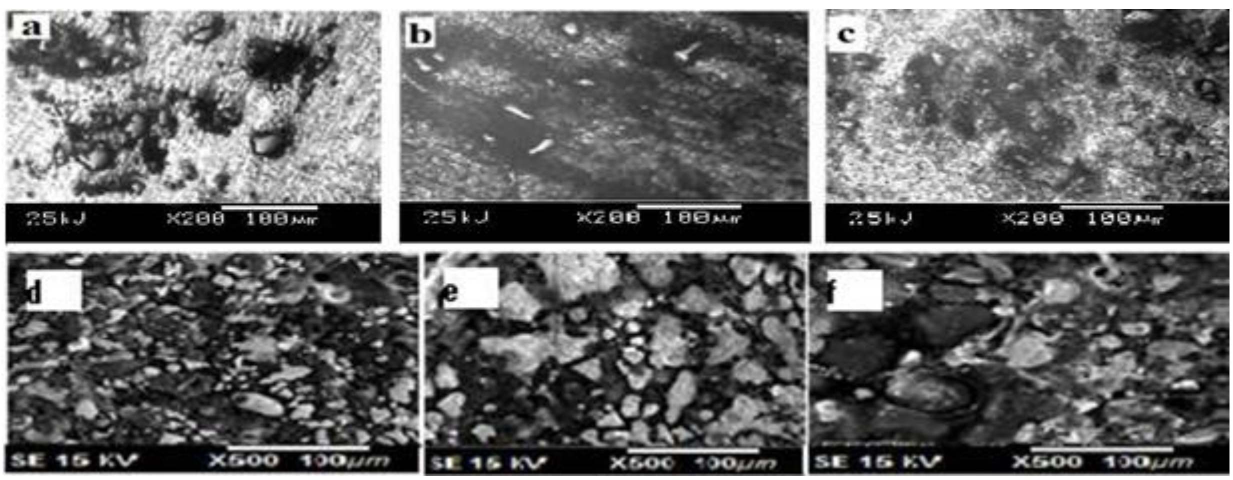

Figure 6 *Micrograph of Al6061+4% Cu and 5% SiCp Composite at different stirring speeds and pouring temperatures.*

4. Conclusions

- The stirring sped is significant factor for material removal rate of the Al6061-Cu-SiC_p composites through EDM.
- At high and low stirring speeds the material removal rate through EDM is inferior compared to medium stirring speed.
- The optimal level of Stirring speed at which maximum material removal obtained is 400 rpm for Al6061-Cu-SiC_p composites.
- The pouring temperature is insignificant factor for material removal rate of composites through EDM.
- The MMC result may be valid for 2000 series of aluminum also as with addition of 4% copper in Al6061 it is more or less comparable to 2000 series of commercial aluminum.

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