Investigation of wire EDM control variables on kerf width for Al6063/SiC/Al2O3 composite by response surface methodology

A Muniappan*, R Prasanna, T Shaafi, V Jayakumar and M Ajithkumar

Department of Mechanical Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Chennai, Tamil Nadu, India.

*Corresponding author: inspire.munish@gmail.com

Abstract. This investigation presents the consequence of Wire EDM process variables over the kerf width (KW) of Al6063/SiC/Al2O3 hybrid composite which is fabricated by stir cast method. 31 experiments were conducted on the basis of response surface methodology central composite design. Kerf width is picked as the quality objective. The important coefficients are gotten by achieving successfully an Analysis of Variance (ANOVA) at the 5% assurance interval. The outcomes discover that KW is much more impacted by Pulse on time, Pulse off time, current and control speed and little of their interactions action or influence. To predict the average kerf width, a mathematical regression model was developed. The forecasted value of optimum kerf width is 0.265 mm for Pulse on time (100), Pulse off time (48), current (200) along with control speed (60%). The Pulse on time is most influential variable for the kerf width. The results have been analyzed using Minitab version 18 software.

1. Introduction

Composite materials had grown rapidly over the past three decades to encompass hybrid matrix composites. Metal matrix composites have pulled in significant consideration for the reason that of their capacity to give an extensive variety of microstructures & properties [1-2]. The underlying thinking of metal composite design is that an continuous metallic matrix, with its ductility and formability, is combined with the stiffness and load withstanding property of a ceramic or refractory reinforcements to produce material with superior properties [3]. Metal Composites have good properties over metals alloys with high specific strengths, better properties of metal composite at elevated high temperatures, minimum thermal expansion, very excellent wear resistance & high structural strength. These properties are predominantly suited to application in an automotive, aerospace as well as electronic sectors [4-5].

Fabrication, shaping and joining with good surface eminence can be done easily [6-7]. The reinforced particles in composites provide strength to the composite and also serve the other supplementary purposes like thermal resistance, thermal conduction, confrontation to corrosion & inflexibility. The reinforcement particles always possess much stronger and much stiffer properties than the base metals. Fibers and ceramics particulates are generally considered as reinforcement
particles. The approach used for production of the MMC may be different route. The practices can be labeled into 5 extraordinary categories: (i) Liquid state strategies (ii) solid phase techniques (iii) two segment methods (iv) Deposition techniques (v) In situ methods. In the stir cast processing, the reinforced particulates are very well blended right into a nicely molten metallic matrix.

Manufacturing sector is growing quickly by accommodating technology modernization. The mechanism for machining hard reinforced materials, complex shapes and contours which are very difficult to cut by conventional methods which created many unconventional methods. CNC wire cut machine was build up in the year 1969. WEDM which involves moving very thin wire electrode continuously. Wire electrode materials such as raw brass, diffused coated brass and zinc coated brasswire of diameter ranges from 0.05-0.35 are widely applied in industry. The gap between work and wire electrode is generally maintained range from 0.025mm to 0.050mm along with is continuously maintained by a computer program controlled coordinating scheme. To achieve smooth surface quality on the tool as well as in the component, optimum process parameter setting is a very important. Machining control parameters are optimized by using different methods for the improvement of the quality. Taguchi method which is widely applied mainly experimental design in manufacturing application. It allows the optimization of parameters in machining by turning, milling, Electro Discharge Machining, wire cut EDM, welding, grinding etc. The optimization is achieved with lesser number of experiments by this overall cost and time is saved.

2. Materials & method

2.1. Hybrid Composite manufacture

Herein investigation, the hybrid MMC has been created by blend mixing practice. The hybrid composite incorporates 5 wt% SiC along with 5 wt% Al2O3 fine particulates in metal cross section Al6063 compound. The Al combination of 6xxx arrangement is having the capacity to be used in aviation and car ventures in light of its high quality to-weight proportion and great protection from consumption. The weight % piece of Al6063 composite is appeared in Table 1. Fortifications SiC furthermore graphite in particulate frame are utilized to fabricated the hybrid composite. The weight % structure of SiC and Al2O3 are appeared in Table 2. These fortifications have 5 -10 micron measure particles of SiC and graphite. Figure.1 shows the stir casting device used for fabrication of hybrid composite.

| Table 1. Al6063 alloy composition |
|----------------------------------|
| Mg | Si | Fe | Cu | Cr | Mn | Zn | Ti | Al |
|-----|----|----|----|----|----|----|----|----|
| 1.1 | 0.2 | -0.6 | 0.35 | 0.1 | 0.1 | 0.1 | 0.1 | Remaining |

2.2. Machining control variables

Four information process control variables in Wire EDM, to be specific, Pulse on time, Pulse off time, and current in addition to control speed were considered. The scopes of these procedure parameters were chosen on the premise of the pilot tests. The stages of different control variables and their assignments are exhibited in Table 2.
Table 2. Process parameters and their levels

| Process parameter   | Level-1 | Level-2 | Level-3 |
|---------------------|---------|---------|---------|
| Pulse on time (A)   | 110     | 117     | 124     |
| Pulse off time (B)  | 48      | 52      | 56      |
| Pulse current (C)   | 120     | 160     | 200     |
| Control speed (D)   | 40%     | 50%     | 60%     |

Table 3. Trial states in CC design for four variables

| Ex. No. | Std Order | Run Order | PtType | Blocks | Pulse on Time | pulse off Time | Curren t | Control speed (%) | Kerf (mm) |
|---------|-----------|-----------|--------|--------|---------------|---------------|----------|-------------------|-----------|
| 1       | 2         | 1         | 1      | 1      | 124           | 48            | 120      | 40                | 0.309     |
| 2       | 31        | 2         | 0      | 1      | 117           | 52            | 160      | 50                | 0.311     |
| 3       | 14        | 3         | 1      | 1      | 124           | 48            | 200      | 60                | 0.304     |
| 4       | 28        | 4         | 0      | 1      | 117           | 52            | 160      | 50                | 0.309     |
| 5       | 9         | 5         | 1      | 1      | 110           | 48            | 120      | 60                | 0.29      |
| 6       | 24        | 6         | -1     | 1      | 117           | 52            | 160      | 60                | 0.306     |
| 7       | 23        | 7         | -1     | 1      | 117           | 52            | 160      | 40                | 0.314     |
| 8       | 4         | 8         | 1      | 1      | 124           | 56            | 120      | 40                | 0.287     |
| 9       | 20        | 9         | -1     | 1      | 117           | 56            | 160      | 50                | 0.315     |
| 10      | 10        | 10        | 1      | 1      | 124           | 48            | 120      | 60                | 0.323     |
| 11      | 19        | 11        | -1     | 1      | 117           | 48            | 160      | 50                | 0.308     |
| 12      | 6         | 12        | 1      | 1      | 124           | 48            | 200      | 40                | 0.31      |
| 13      | 8         | 13        | 1      | 1      | 124           | 56            | 200      | 40                | 0.308     |
| 14      | 21        | 14        | -1     | 1      | 117           | 52            | 120      | 50                | 0.313     |
| 15      | 5         | 15        | 1      | 1      | 110           | 48            | 200      | 40                | 0.287     |
| 16      | 27        | 16        | 0      | 1      | 117           | 52            | 160      | 50                | 0.309     |
| 17      | 29        | 17        | 0      | 1      | 117           | 52            | 160      | 50                | 0.309     |
| 18      | 22        | 18        | -1     | 1      | 117           | 52            | 200      | 50                | 0.313     |
| 19      | 13        | 19        | 1      | 1      | 110           | 48            | 200      | 60                | 0.289     |
| 20      | 26        | 20        | 0      | 1      | 117           | 52            | 160      | 50                | 0.309     |
| 21      | 17        | 21        | -1     | 1      | 110           | 52            | 160      | 50                | 0.285     |
| 22      | 18        | 22        | -1     | 1      | 124           | 52            | 160      | 50                | 0.312     |
2.3. Experimental Set Up

Analyses were led on Electronica Sprint cut CNC wire cut EDM to think about the surface finish quality in addition to kerf width influenced by the machining control variables at various stages. Wire EDM is a start disintegration process. The flashes are produced among the work piece as well as the wire terminal. Dielectric liquid is ceaselessly encouraged into the machining region by means of required weight. The substance is getting forced out by a progression of discrete sparkles occurring at the region chosen machined through electro-thermal system. Test set up of the wire EDM is appeared in Figure 2. Amid machining process little opening kept up among the work with wire material. The machined particles were washed out & carried away by the persistent stream of the dielectric medium. The wire is detained by a stick direct at the upper & lower parts of the work piece. The work example measure utilized a part of this examination is 95mm x 80mm x 8 mm rectangular plate. Zinc covered metal cathode wire of 0.25 mm width was utilized to a part of this investigation. Deionized water was utilized as dielectric liquid at space temperature. In the wake of machining, the examples were dirt freed with acid after machining. The KW was measured utilizing video measuring system framework. The KW esteems were measured at six spots stretch over the full length of cut. The kerf esteems utilized as a part of this examination are the numerical normal of three estimations produced using the example in each cut.

3. Result and discussion

Response surface e methodology (RSM) is an statistical and trial techniques. RSM needs adequate number of trial procedures information to break down the issue and create numerical models for some info parameters and yield responses.[7-8]. With application of the RSM, the needy factor is seen as a surface to which a scientific sculpt is fitted. In the present examination, four control factors are set at three levels. Along these lines, a standard second request test configuration called confront focused central composite design (CCD) has been received for breaking down and demonstrating the Wire EDM factors for kerf width. This outline comprises of full factorial having 31 runs including 6 essential issues. The inside focuses, as inferred of every parameter run. In light of the exploratory design appeared in table 2, the investigations were performed and one reaction was estimated. Minitab 18, a measurable device is utilized to create the relapse condition for KW in coded and real terms as given in equations 3 and 4. Analysis of variance (ANOVA) has been performed on the exploratory information to test the decency of attack of the model.
Figure 1. Effect of WEDM parameters on kerf width

3.1 Effect of WEDM parameters on kerf width

Toward study the outcome of Wire EDM parameters on kerf width, response surface charts had been plotted as shown in figure 2. RSM chart displays that the KW enlarges with increasing rate of pulse on time along with control speed. Consequence of Pulse on time is highly noteworthy as compared to Pulse off time, current as well as control speed. Increasing Pulse on time raises the discharge energy across the electrode and therefore results in elevated melting as well as evaporation of material. Enhanced melting in addition to evaporation combined with high dielectric supply causes in larger kerf width [9]. Increasing Pulse off time reduces the effective discharge frequency furthermore hence reduces the discharge energy transversely the electrodes resulting in small kerf width.

Figure 2. Contour plot for kerf width

3.2 Analysis of kerf width
Table 3 shows that p value for quadratic model is significant effect on output response. Figure.2 shows that p parameters. It is comprehensible that all input parameters have great effect and strong impacts on kerf width which is confirming by a ANOVA results. At the same time kerf width increased by percentage such as the pulse on time (Ton) increased change from low to high of different level at constant middle amount of set of values of other input operating factors. Long pulse on time(Ton) lead to the high performance in heat transfer inside the dielectric fluid and work piece, the is capable to remove the molten or liquid metal, such as make flushing of dielectric pressure in constant certain amount. The operating parameters have more significant effect on kerf width were the. Pulse on time(Ton), pulse off time(Toff), current(Ip), control speed(Vs), pulse on time(Ton) *pulse off time(Toff), pulse on time(Ton) * current(Ip), pulse on time(Ton) *control speed(Vs), pulse off time(Toff)* current(Ip), pulse off time(Toff) * control speed (Vs), current(Ip) * control speed(Vs) with the estimate the worth f a parameters a confidence specified range of 95%. The predicted value of optimum kerf width is 0.265 mm for Pulse on time (100), pulse off time (48), current (200), control speed (60).

4. Conclusion

The operating parameters have more significant effect on kerf width were the. Pulse on time(Ton), pulse off time(Toff), current(Ip), control speed(Vs), pulse on time(Ton) *pulse off time(Toff), pulse on time(Ton) * current(Ip), pulse on time(Ton) *control speed(Vs), pulse off time(Toff)* current(Ip), pulse off time(Toff) * control speed (Vs), current(Ip) * control speed(Vs) with the estimate the worth for a parameters a confidence specified range of 95%.

The final test result refers that with a view to getting a low amount of value of kerf width during the work period of this research, Pulse duration of current (Ip) and Pulse duration on time (Ton) must be stable as less as much as possible to be done, whereas the control speed has to be medium value.

The predicted value of optimum kerf width is 0.265 mm for Pulse on time (100), pulse off time (48), current (200), control speed (60).

This study assists researchers and industries in developing productivity a strong, trustworthy knowing range and prediction based on evidence of kerf width without a doubt achieve more experiments with a (WEDM) machining work in process for Al6063/SiC/Al2O3 hybrid composite.

5. References

[1] Surappa M.K., (2003) Aluminium matrix composites: Challenges and opportunities Sadhana, Vol. 28, Part 1 & 2, pp. 319-334.
[2] Manna, A., Bains, H.S., Mahapatra. P.B. (2011). “Experimental study on fabrication of Al–Al2O3/Grp metal matrix composites”. Journal of Composite Materials, Vol.45, No.19, pp.2003-2010.
[3] Tosun N., Cogun C. and Tosun G. 2004. A study on kerf and material removal rate in wire electrical discharge machining based on Taguchi method. Journal of Materials Processing Technology. 152,316-322.
[4] Hung, N.P., Loh, N.L., Xu, Z.M . (1996). “Cumulative tool wear in machining metal matrix composites part II: machinability”. Journal of Material Processing Technology, Vol.58, pp.114–120.
[5] Yan BH, Tsai HC, Huang FY, Lee LC (2005) Examination of wire electrical discharge machining of Al2O3p/6061Al composites. Int J Mach Tools Manuf 45:251–259
[6] G. Selvakumar, G. Sornalatha, S. Sarkar, S. Mitra (2014) Experimental investigation and multi-objective optimization of wire electrical discharge machining (WEDM) of 5083 aluminum alloy, Trans. Nonferrous Met. Soc. China 24, pp. 373 - 379.

[7] Selvakumar G, Sarkar S, Mitra S. Experimental investigation on die corner accuracy for wire electrical discharge machining of Monel 400 alloy [J]. ProclMeChE Part B: J Engineering Manufacture, 2012, 226(10): 1694_1704.

[8] Hewidy M S, El-Taweel T A, El-Safy M F. Modelling the machining parameters of WEDM of Inconel 601 using RSM [J]. Journal of Materials Processing Technology, 2005, 169: 328_336.

[9] Tatar, C., Ozdemir, N. (2010). “Investigation of thermal conductivity and microstructure of the α-Al2O3 particulate reinforced aluminum composites (Al/Al2O3-MMC) by powder metallurgy method”. Physica B Condensed Matter. Vol.405, pp.896-899