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A Study on Surface Roughness and Cutting Width for Circular Contour Machining of Stir Cast AA6063/SiC Composites in WEDM

Dr. I.Balasubramanian[1], Dr. R. Maheswaraan[2], Dr. Ranganath M Singari[3], S Velayutha Ganesh[4]
1 Assistant professor, Department of Mechanical Engineering, VV College of Engineering, Tisaiyanvilai, India.
balacim@vvcoe.org
2 Professor, Department of Mechanical Engineering, MEPCO Schlenk Engineering College, Sivakasi, India.
rmaheshin@yahoo.com
3 Associate professor, Department of Mechanical and Production Engineering, Delhi Technological University,
New Delhi, India.
ranganathdce@gmail.com
4 Lecturer, Department of Mechanical Engineering, Ramana Polytechnic College, Tirunelveli, India.
Ganesh270286@gmail.com

Abstract

Wire electrical discharge machining is used in machining electric conductive materials with intricate shapes and profiles. This paper presents an experimental investigation on the influence of cutting conditions of WEDM on surface roughness and cutting width of machining of AA6063/SiC composites. Here a semi cylindrical piece is removed from a rectangular plate of AA6063/SiC composites plate fabricated with reinforcing SiC in 0%, 5%, 10% and 15% weight fractions through stir casting. The effect of WEDM parameters such as pulse on time, pulse off time and peak current on surface roughness and cutting width on different composition of AA6063/SiC were analyzed for circular contour machining. The experimental results show that increase in percentage of SiC has high influence in mechanical behavior of AA6063/SiC composites and the effect of pulse on time is very significant in reducing the surface roughness and pulse off time plays an important role in producing minimum cutting width.

Keywords Wire Electric Discharge Machining, Circular contour, Surface roughness, Cutting width

1.Introduction

Metal Matrix Composites (MMCs) have evoked a keen interest in recent times for potential applications in aerospace and automotive industries owing to their superior strength to weight ratio and high temperature resistance. For many decades, Silicon Carbide (SiC), a ceramic material having higher hardness is being used as a reinforcement material in lightweight Aluminium metal matrix [1]. Advanced composites with different composition of aluminium and silicon carbide, which have enhanced hardness and high temperature resistance properties, are under study [2]. In this field, many research works have been carried out on AA6063/SiC Composites which were prepared by a casting process by melting the constituent alloy AA6063 and incorporating the SiC particles in the solidifying metallic slurry of AA6063 [3]. Stir casting is the widely used method of processing where the aluminum matrix is completely melted and ceramic particles (SiC) are added into the molten metal in a vortex created by a mechanical stirrer [4]. Generally a stir casting setup has been integrated by an electric resistance muffle induction furnace with a melting zone of separate preheating chamber, and a mild steel stirrer rotated by a coupling motor. AA6603/SiC composites are stir casted by melting AA6603 aluminum ingots in melting zone and preheating SiC in the preheating chamber and mixing using the stirrer in the molten stage and solidify in a reform die with required dimensions [5-12]. Stir cast AA6063/SiC is an electrically conductive material that can be machined by nontraditional WEDM process independent of their hardness, shape and toughness [13-19].

In WEDM process, the material is eroded from AA6063/SiC composite work piece by a series of continuous discrete sparks occurring between the work piece and the electrode wire separated by a stream of deionized dielectric fluid [20]. Due to the abrasive nature of reinforcement traditional machines are very limited for machining composites. High tool wear and very low performance of traditional machinery to machine hard composite materials cause way to non-traditional methods like water jet and laser cutting but these processes are limited to linear cutting only. Garg et al (2010) suggested that Wire Electrical discharge machining (WEDM) shows higher capability for cutting complex shapes in composites [21]. The effect of WEDM parameters such as pulse on time (T_{on}), pulse off time (T_{off}), peak current (IP) wire feed (WF), servo voltage(V), flushing pressure (FP), wire tension (WT), open voltage (OV), servo voltage (SV), and dielectric pressure (DP) on the performance measure like surface roughness (R_a) and cutting width (Kerf) and metal removal rate (MRR) are investigated by many researchers [22-24]. Yan et al (2005) found that T_{on} has the significant effect on R_a during rough machining by WEDM. For finish cutting, cutting feed rate has the significant effect on R_a [25]. Nilesh et al (2010) found that the volume fraction of ceramic reinforcement in the composite, T_{on} and T_{off} were found to be significant on metal cutting, surface finish and Kerf [26]. Nihat Tosun (2003) proved experimentally that increasing pulse duration, open circuit voltage, wire speed and dielectric fluid pressure increase the cutting speed. The surface quality of the work piece increases with the decreasing pulse duration, open circuit voltage and wire speed, and with increasing dielectric fluid pressure by [27]. Plaza et al (2009) results in machining show that part thickness and taper angle are the most influencing variables in taper cutting through WEDM [28]. Mahapatra et al (2007) discusses factors like discharge current, pulse duration, and dielectric flow rate and their interactions have been found to play a significant role in rough cutting operations for maximizations of MRR, minimization of R_a and minimization of Kerf [29]. In the investigation of Kapilkumar et al (2012) informs that IP, T_{on}, T_{off}, WF, WT and FP effect on the material removal rate and surface finish in a significant way [30]. A significant amount of research has been going to find the different methodologies of achieving the ultimate WEDM goals of optimizing the numerous process parameters by analysis with the total elimination of the wire breakages, Ra and maximum Kerf [31-33].

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In this work it has been proposed to remove a semi cylindrical piece from a stir cast rectangular AA6063/SiC composite plate with different compositions by circular contour machining in WEDM. Then the effect of parameters such as T_{on}, T_{off} and IP were studied with performance measures like R_a and Kerf. The results of this work would help to select various WEDM parameters with respect to different levels provided to ensure appropriate WEDM process parameters to machine circular contour in AA6063/SiC composite at various proportions.

2. Materials and Methods

2.1 Composition of Samples

AA6063/SiC composites are formulated by the process of stir casting which is a liquid phase transformation method, with different weight ratio of AA6063 and SiC as proposed by different researchers [34-35]. In this study, the raw materials were prepared with four different weight ratios as given in Table 1.

Tab.1. Samples and their composition

S.No.	Sample Number	Weight percentage of Composition	
		AA6063	SiC
1	1	100%	0%
2	2	95%	5%
3	3	90%	10%
4	4	85%	15%

2.2 WEDM Machining Process

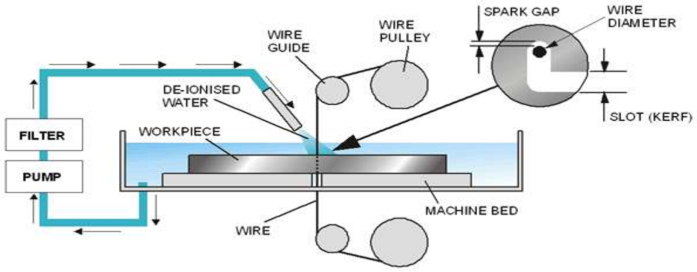

Fig.1. Schematic view of Circular Contour Machining

WEDM is a nontraditional, thermoelectric process which erodes material from the conductive AA6063/SiC composite work piece by a series of discrete sparks using travelling brass wire of diameter of 0.175 mm. These electrical discharges melted and vaporized minute amounts of the AA6063/SiC composite plate, which were flushed away by dielectric fluid. The sparks occur at high frequency continuously and effectively remove the AA6063/SiC composite plate material by melting and erosion. The brass wire is programmed and controlled by control unit to travel along a circular contour corresponding to the work piece table movement and also driving the wire accurately at constant tension. The machining power supply unit energizes the wire electrode. The deionized dielectric water supply was properly controlled by separate control unit. The Schematic view of WEDM is shown in Figure 1.

2.3 WEDM Process Parameters

In WEDM, the amount of material melts and evaporates depend on the duration of sparks produced, which is represented by pulse on time (T_{on}). The melted part of the AA6063/SiC composite plate form as a small crater in the machining zone. The crater material was removed by the flow of deionized dielectric fluid and the remaining part resolidifies rapidly on the surfaces of the brass wire for a period known as pulse off time (T_{off}). Application of consecutive pulses with high frequencies together with the forward movement of the brass wire towards the AA6063/SiC composite plate resulted in a form of a circular contour shape. The breakdown in the dielectric medium during material removal process is due to high local electric field represented by peak current (IP). In this paper, the effect of all the above three electric parameters T_{on}, T_{off}, and IP plays significant role in performance measures R_a and Kerf for machining circular contour in AA6063/SiC composites were studied.

2.4 Specimen used for machining circular contour

WEDM specimen was machined from the raw composite plate material casted by stir casting to a dimension of 95 × 95 × 10 mm. The specimen and the circular contours are shown in Figure 2. The circular contour is of dimensions diameter 10 mm and radius 5 mm.

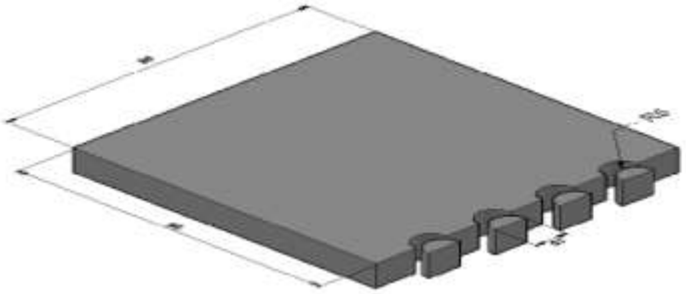

Fig.2. Specimen used for WEDM

2.5 Performance Measures for WEDM

The performance like surface roughness (R_a) and cutting width (Kerf) were measured as follows.

Surface roughness (R_a)

The R_a was measured by using Mitutoyo Surf Test machine SJ410. The average values of R_a were measured at various machined area by using the sensible probe for a travelling distance of 8 mm of the machine. At each experiment roughness values were measured in different location of circular contour machined by WEDM and the average value was taken as final R_a value in microns. The reciprocal value of R_a will normally give the value for surface finish.

Cutting width (Kerf)

To observe cutting width of the WEDM process Mitutoyo Crystaplus M443 Co-ordinate measuring machine (CMM) was used. Normally for measuring the cutting width of linear contour image processing system is used. In this investigation cutting width of circular contour was calculated by using a formula Kerf = R- r. The radius of the cut region in the work piece was considered as R and the radius of the cut piece is r as shown in Figure 3.

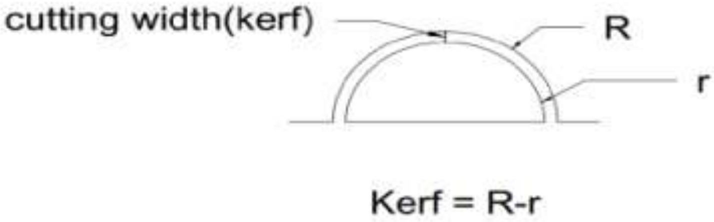

Fig.3. Cutting width (Kerf) of the process

3 Circular Contour Results

Machining of AA6063/SiC composites were performed in an Electronica 4-axis CNC Sprintcut wire electrical discharge machine and its machining zone are shown in Figure 4. A negatively polarized brass wire of 0.175 mm diameter was used as an electrode. Deionized water was used as a dielectric fluid

Fig.4a. Sprint cut 734 of Electronica Machine

Fig.4b. Machining Zone

The experiments were conducted to cut a circular contour of diameter 10mm and radius 5mm for each sample of composite. A small gap of 0.025 mm to 0.05 mm was maintained in between the wire and the work. Different machine setting parameters such as T_{on}, T_{off} and IP were varied at three levels. The machining parameters at different levels were selected based on the trial runs carried out in such a way to avoid wire breakage during machining of composite materials.

Fig.5a. AA6063/SiC Plate shows circular contour

Fig.5b. AA6063/SiC Plate after machining

According to the circular contour program fed into the control unit, the wire travel along the circular path and created a circular contour for the dimension of radius 5 mm and diameter 10 mm as shown in Figure 5. The removed piece of semicircular shape was used for finding the Kerf in CMM. The surface of the circular contour formed in AA6063/SiC plate was used for finding the R_a in Surftest machine. The values were recorded from the readings obtained from the CMM and Surftest machine as shown in Table 2.

Tab.2. Experimental values

T_{on}= 100 T_{off}= 60 IP= 170		T_{on}= 100 T_{off}= 50 IP= 190		T_{on}= 100 T_{off}= 40 IP= 210		T_{on}= 110 T_{off}= 60 IP= 190		T_{on}= 110 T_{off}= 50 IP= 210		T_{on}= 110 T_{off}= 40 IP= 170		T_{on}=120 T_{off}= 60 IP= 210		T_{on}= 120 T_{off}= 50 IP= 170		T_{on}= 120 T_{off}= 40 IP= 190	
R_a	Kerf	R_a	Kerf	R_a	Kerf	R_a	Kerf	R_a	Kerf	R_a	Kerf	R_a	Kerf	R_a	Kerf	R_a	Kerf
2.26	0.47	2.32	0.58	2.20	0.57	1.87	0.60	2.45	0.61	1.88	0.63	2.35	0.56	1.95	0.64	2.12	0.65
2.54	0.52	2.44	0.63	2.13	0.63	1.98	0.65	2.67	0.66	2.21	0.68	2.54	0.61	2.05	0.69	2.20	0.69
2.65	0.56	2.55	0.62	2.23	0.64	2.09	0.63	2.78	0.65	2.35	0.66	2.65	0.61	2.17	0.65	2.31	0.69
2.76	0.61	2.64	0.68	2.35	0.69	2.21	0.68	2.89	0.70	2.46	0.70	2.78	0.66	2.31	0.70	2.42	0.74

The values of R_a and Kerf for all the four samples are tabulated as shown in Table 2 and then the graphs are plotted against all the parameters and discussed.

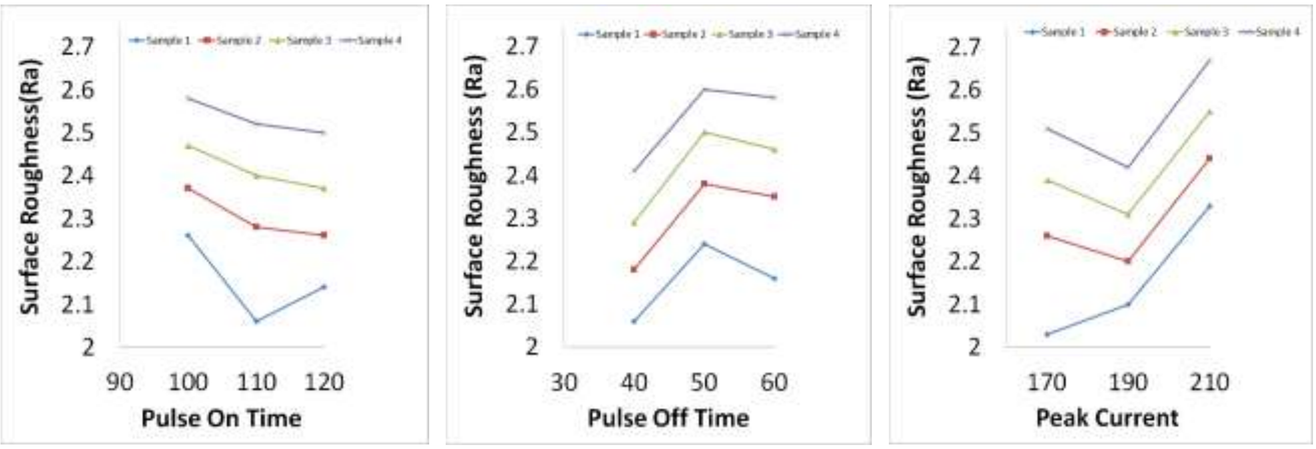

Fig.6. a) Effect of pulse on time on R_a , b) Effect of pulse off time on R_a , c) Effect of peak current on R_a

The effect of T_{on} on R_a is shown in Figure 6 and it was found that the R_a increases with decreases in T_{on} Moreover, when the T_{on} was lower, there was a poor surface finish of the samples. The Ra results obtained under different T_{off} were plotted in Figure 6. It is noted that the Ra increases as T_{off} increases to certain extent and then the trend changes. It was observed that 50 units of T_{off} provide maximum surface roughness. Further, it was confirmed that long gap between pulse left some impressions in machined surface which results in very poor surface finish. Figure 6 shows the effect of IP on surface roughness for various percentage of SiC. When the IP increases R_a also increases in sample 1, but in sample 2, 3, and 4 for 190 units of IP the R_a decreases as the sparks production decreases.

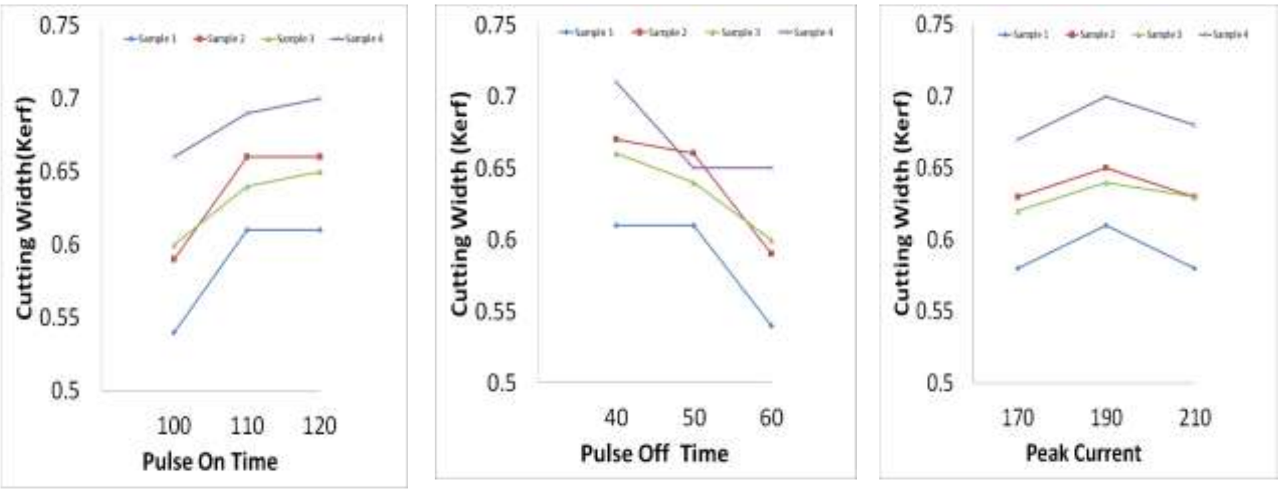

Fig.7. a) Effect of pulse on time on Kerf , b) Effect of pulse off time on Kerf, c) Effect of peak current on Kerf

It is observed from the Figure 8 that there is an increase on Ton results in increase in kerf. In composite samples the cutting width was not evenly produced, due to it uneven distribution of particles. From the Figure 7, it is observed that 40 units of Toff produces the high Kerf and also 60 units of Toff resulted in very low Kerf for all samples. From Figure 7, the effect of 50 units IP is high in producing a large size Kerf and the 210 units IP resulted in small Kerf gap.

4. Conclusion

In this investigation, WEDM is used for removing semi cylinder pieces from rectangular AA6063/SiC composite plates fabricated with reinforcement of SiC in 0%, 5%, 10% and 15% weight fractions in AA6063 aluminium matrix through stir casting. In these experimental investigation the influence of cutting conditions of WEDM are analyzed and the following conclusions are drawn from the analysis.

The WEDM performance measures like R_a and Kerf varies for the different composition of AA6063/SiC composite plates at same cutting conditions.

Then the effect of WEDM parameters such as T_{on}, T_{off} and IP on R_a and Kerf on different composition of AA6063/SiC were significant.

The medium values of T_{on}, IP and low value of T_{off} result in lowest R_a. The low value of T_{on}, medium value of T_{off} and high value of IP produces highest R_a.

The low values of T_{on}, IP and high value of T_{off} result in small size in Kerf. The high values of T_{on}, IP and low value of T_{off} produces large size Kerf.

5.References

1. Pathak, J.P., Singh., J.K and Mohan S, “Synthesis and characterization of aluminum – silicon – silicon carbide composite”, International Journal of Engineering Material Science, (2006), vol. 13, 238 – 246.
2. Dave, M.M. and Kothari, K.D., Composite Material-Aluminium Silicon Alloy -A Review, Indian Journal of Research, (2013), Volume 2, No. 3,148-150.
3. Ramanpreet, S. and Rahul, S. Tribological Characterization of Aluminium-Silicon Carbide Composite Prepared By Mechanical Alloying, International Journal of Applied Engineering Research, (2012), Volume 7, No. 11, 1-4.
4. Tarek, K.A. and Tamer, M.S. Elevated Temperature Mechanical Properties of Al Alloy AA6063/SiCp MMCs, Proceedings of the World Congress on Engineering, (2009), Volume: II, London, U.K.
5. Sukumaran, K., Pillai, S.G.K., Pillai, R.M., Kelukutty, V.S., Pai, B.C., Satyanarayana, K.G. and Ravikumar, K.K. The effects of magnesium additions on the structure and properties of Al-7 Si-10 SiCp composites, Journal of Material Science, (1995), Volume 30, No 6, 1469-1472.

6. Ramachandra M and Radhakrishna K (2004), Study of Abrasive Wear Behaviour of Al-Si (12%)-SiC Metal Matrix Composites Synthesized Using Vortex Method, International Symposium of Research Students on Materials Science and Engineering, Chennai, India.
7. Neelima, D.C., Mahesh,V. and Selvaraj, N. Mechanical characterization of Aluminium Silicon Carbide Composites, International Journal of Applied Engineering Research, (2011), Volume 1, No. 4, 793-799.
8. Mahendra, B.M., Arulshri, K.P. and Iyandurai, N. Evaluation of Mechanical Properties of Aluminium Alloy 2024 Reinforced with Silicon Carbide and Fly Ash Hybird Metal Matrix Composites, American Journal of Applied Sciences, (2013), Volume 10 , No. 3, 219-229.
9. Meena, K.L., Manna, A. and Banwait, S.S. Parametric Effects during Nonconventional Machining of PRALSICMMC by EDM, International Journal of Advancements in Research & Technology, (2013), Volume 2, No. 2, 1-8.
10. Manna, A. and Bhattacharyya, B. Investigation for optimal parametric combination for achieving better surface finish during turning of Al /SiC-MMC, International Journal of Advanced Manufacturing Technology (2004), Volume 23, 658–665.
11. [11]. Ramachandra M and Radhakrishna K (2006), Sliding wear, slurry erosive wear, and corrosive wear of aluminium/SiC, Composite Materials Science-Poland, Volume 24, No. 2/1, pp 333-349.
12. Manoj, S., Lakhvir, S. and Vikas, C. Study of Wear Properties of Al-SiC Composites, Journal of Minerals & Materials Characterization & Engineering, (2009), Volume 8, No. 10, 813-819.
13. Rajeev, K. and Shankar, S. Current Research Trends in Wire Electrical Discharge Machining- An Overview, International Journal on Emerging Technology, (2012), Volume 3, No. 1, 33-40.
14. VamsiKrishna, P., Surendra, B., BattulaMadar, V.P. and Swapna, M. Optimizing Surface Finish in WEDM Using the Taguchi Parameter Design Method, Journal of the Brazilin Society of Mechanical Science & Engineering, (2010), Volume 32, No 2, 107-113.
15. Mingqi, L., Minghui, L. and Guangyao, X. Study on the Variations of Form and Position of the Wire Electrode in WEDM-HS, International Journal of Advanced Manufacturing Technology, (2005), Volume 25, 929–934.
16. [16]. Nihat, T., Can, C. and Gul, T. A study on kerf and material removal rate in wire electrical discharge machining based on Taguchi method, Journal of Materials Processing Technology, (2004), Volume 152, No. 3, 316–322.
17. Adeel, I., Nadeem, A., Muhammad Q.S. and Ahmed, R.K. Parametric optimization for surface roughness, Kerf and MRR in wire electrical discharge machining (WEDM) using Taguchi design of experiment, Journal of Mechanical Science and Technology, (2010), Volume 27, No. 7, 2133-2141.
18. Vishal, P., Rehman, A., Bhagoria, J.L. and Pure, Y.M. Kerfs width analysis for wire cut electro discharge machining of SS 304L using design of experiments, Indian Journal of Science and Technology, (2010), Volume 3, No. 4, 369-373.
19. Susanta, K.G. and Shankar, C. Optimisation of multiple responses for WEDM processes using weighted principal components, International Journal of Advanced Manufacturing Technology, (2009), Volume 40, 1102–1110.
20. Sathish, k.D. and Kanthababu, M. Investigation of wire electrical discharge machining characteristics of Al6063/SiCp Composites, International Journal of Advanced Manufacturing Technology, (2011), Volume 56, 975-986.
21. Garg, R.K., Singh, K.K., Sachdeva, A., Sharma, V.S., Ojha, K. and Singh, S. Review of research work in sinking EDM and WEDM on MMC Composites, International Journal of Advanced Manufacturing Technology, (2010), Volume 10, 2534 – 2535.
22. Rajyalakshmi, G. and VenkataRamaiah, P. Multiple process parameter optimization of wire electrical discharge machining on Inconel 825 using Taguchi grey relational analysis, International Journal of Advanced Manufacturing Technology, (2010), DOI 10.1007/s00170-013-5081-z.
23. Aqueel, S., Nadeem, A., Dinesh, Rajwal. and Eberhard, B. Material Removal Rate, Kerf and Surface Roughness of Tungsten Carbide Machined with Wire Electrical Discharge Machining, Journal of Materials Engineering and Performance, (2011), Volume 20, 71-76.
24. Susanta, K.G. and Shankar, C. A study on the performance of some multi-response optimisation methods for WEDM processes, International Journal of Advanced Manufacturing Technology, (2010), Volume 49, 155–166.
25. Yan, B.H., Tsai, H.C., Huang, F.Y. and Lee, L.C. Examination of wire electrical discharge machining of Al2O3P/Al Composites, International Journal of Machine Tools and Manufacture, (2005), Volume 45, 251 – 259.
26. Nilesh, G.P. and Brahmankar, P.K. Some studies into wire electro-discharge machining of alumina particulate-reinforced aluminum matrix Composites, International Journal of Advanced Manufacturing Technology, (2010), Volume 48, 537–555.
27. Nihat, T. The Effect of the Cutting Parameters on Performance of WEDM, KSME International Journal, (2003), Volume 17, 816—824.

28. Plaza, S., Ortega, N., Sanchez, J.A., Pambo, I. and Mendikute, A. Original models for the prediction of angular error in wire-EDM taper-cutting, International Journal of Advanced Manufacturing Technology, (2009), Volume: 44, 529–538.
29. Mahapatra, S.S. and Amar, P. Optimization of wire electrical discharge machining (WEDM) process parameters using Taguchi method, International Journal of Advanced Manufacturing Technology, (2007), Volume 34, 911-925.
30. Kapil, K. and Sanjay, A. Multi-objective parametric optimization on machining with wire electric discharge machining, International Journal of Advanced Manufacturing Technology, (2012), Volume 62, 617–633.
31. Rong, T.Y., Chorng, J.T., Yung, K. and Ming, H.H. Optimization of wire electrical discharge machining process parameters for cutting tungsten, International Journal of Advanced Manufacturing Technology, (2012), Volume 60, 135–147.
32. Ho, K.H., Newman, S.T., Rahimifard, S. and Allen, R.D. State of the art in wire electrical discharge machining (WEDM), International Journal of Machine Tools & Manufacture, (2004), Volume 44, 1247–1259.
33. Aminollah, M., Alireza, F.T., Ehsan, E. and Davoud, K. A new approach to surface roughness and roundness improvement in wire electrical discharge turning based on statistical analyses, International Journal of Advanced Manufacturing Technology, (2008), Volume 39, 64–73.
34. Narciso, J., Alonso, A., Pamies, A., Cordovilta, C.G.and Louis, E. Wettability scripta metallurgica et materialia of binary and ternary alloys of the system Al-Si-Mg with. SiC particulates, Scripta Metallurgica Materialia, (2004), Volume 30, No. 11, 1495-1500.
35. Subrata Ray S (1995), Casting of Metal Matrix Composites, Key Engineering Materials, (1995), Volume 104-107, No. 1, pp 417-446.

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