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EFFECT OF MACHINE FEED RATE ON KERF-WIDTH, MATERIAL REMOVAL RATE, AND SURFACE ROUGHNESS IN MACHINING OF AL/SIC COMPOSITE MATERIAL WITH WIRE ELECTRICAL DISCHARGE MACHINE

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Abstract: The impact of machine feed rates of Wire Electric Discharge Machining on the kerf-width (K-width), material-removal-rate (MR-R), and surface-roughness (S-R) in the machining of Al/SiC composite is practically analysed. The relation among the feed rates of machine and K-width, MR-R, S-R is graphically acquired. It is demonstrated that lesser rate of feed is responsible for generation of larger K-width, lesser MR-R, and good finish as compared to more feed rate.

Keywords: Wire Electrical Discharge Machine, Kerf-width, Material removal rate, Surface roughness, Machine feed rate, Al/SiC composite material etc.

1 Introduction

Wire Electrical Discharge Machine (W-EDM) is generally utilized in the manufacturing of smaller components of complex shape. Material is disintegrated by discrete discharge of sparks among the wok-piece and brass wire. These sparks releases liquefy and vaporize little measures of the work-material. These eroded materials from work-piece are flushed out by the dielectric-fluid. In W-EDM, the work-piece and the brass wire don't have contact; only conductive material can be machined [1].

In the production of such components by W-EDM, one of the significant attributes is the kerf-width (K-width) formed by the brass wire electrode. As displayed in Fig. 1, the K-width (δ) is the summation of the brass wire diameter (d), and double gap-spark (Δ). In W-EDM, material is dissolved from the composite material workpiece by a progression of discrete flashes happening between the composite material and the wire isolated by a stream of dielectric liquid, which is ceaselessly moved to the machining zone. The procedure utilizes a fine brass wire as the anode and the composite material is mounted on a PC numeric-controlled (CNC) positioning system.

Parameters' influencing the K-width in W-EDM is the properties of the working liquid and the properties of the material of work-piece, as mentioned in [1, 2]. In W-EDM, the K-width is the primary determinative factor of the machining exactness. The few scientists, [3, 4, 5] examined on the different features of the advancements of Electrical Discharge Machining (ED-M) research. These features are optimization of process-factors, enhancement in process

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effectiveness, simplify design of electrode and fabricate, spark mechanism and its control, and enhancement in surface finish of W-EDM process, etc. De et al. [6] performed the tests on W-EDM with sintered Ti (titanium). They contemplated the impact of different parameters i.e., T_{on} (pulse on time), T_{off} (pulse off time), wire-feed, and wire-tension on material removal rate (MR-R), surface roughness (S-R), K-width, and over-cut. They utilized Response Surface Methodology (RS-M) for the evolution of model of the responses. Raturi et al. [7] conducted the tests on W-EDM with Al 6063/SiC/Al_2O_3 composite. They revealed that the MR-R and S-R enhance with increment in % weight division of SiC and Al_2O_3 particles in Metal Matrix Composites (M-MCs), and Hybrid Metal Matrix Composites (HM-MCs).

The numerous investigators reported that the machining of composite material with W-EDM, the K-width enhanced fundamentally by the variation of procedure factors [8, 9]. The impact of procedure factors on MR-R was studied on M-MC of Al 6063 with W-EDM. It was studied that the rise in volume percentage of SiC brought about diminished MR-R [10]. Surface roughness rises with the increment in SiC particles volume percentage in the M-MCs [11]. Modi et al. [12] reported about the study of W-EDM process and its various process parameters. Modi et al. [13] did the experiments on EDDSG process with Inconel 600. They reported in this research work about the modelling of process parameter by RS-M and parametric optimization through Grey-WPCA (Weighted Principle Component Analysis) approach.

The examination of input procedure factor like O_2 gas, utilized as dielectric fluid, in the dry W-EDM process was conducted. They noticed a critical impact on the cutting speed, and surface [14]. Madhavadev et al. (2018) studied the formulation of a numerical model dependent on the working conditions and its comparison with the analytical-model to anticipate the deflection of wire in Wire-Electrical Discharge Grinding (W-EDG). In this work Finite-Element Analysis (F-EA) for the deflection of wire is investigated and compared with the analytical-model. Gauri et al. (2010) utilized Grey Relational Analysis (GRA), Multiple Response signal-to-noise Ratio (MRSNR), Weighted signal-to-noise (WSNR), and VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) methods in multi-response optimization on the data's with W-EDM. They also reported the comparative performance of these methodologies. Phate et al. (2019) conducted the experiments on W-EDM with Al/SiC composite and determine the optimum set of procedure parameters by Taguchi based Grey-Fuzzy methodology. Similarly, the various hybrid/Taguchi methodologies have been applied in various research articles for determination of optimum process factors either in non conventional hybrid process or in conventional process [18-22].

Based on the literature review, the impact of machine feed rate (MF-R) on kerf width, MR-R, and S-R in W-EDM of Al/SiC composite material is the area under development.

The aim of this work is to thoroughly investigate the impact of machine feed rate on kerf width, MR-R, and S-R in W-EDM of Al/SiC composite material. To fulfil this aims, one set of 4 experiments with Al/SiC composite material were conducted on W-EDM. Further, kerf-width images investigation has been conducted on produced machine surfaces through W-EDM process. This is also another area under development.

2 Experimental materials and methods

This paper utilizes terminology given in Appendix A.

The Al/SiC composite material workpiece of size (30 mm x 25 mm x 20 mm) is machined on W-EDM. The composition of Al/SiC composite material is Al = 85 %, and SiC = 15%. In this experimental work brass wire of diameter 0.25 mm is used as an electrode. The deionised water is used as a dielectric fluid.

Figure 1 display the K-width is the summation of wire diameter (d), and the double spark-gap (Δ).

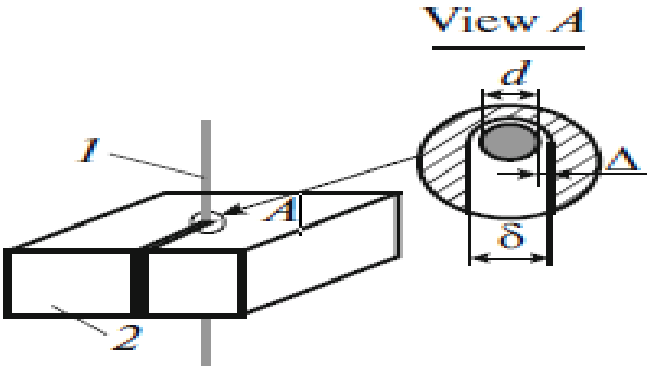


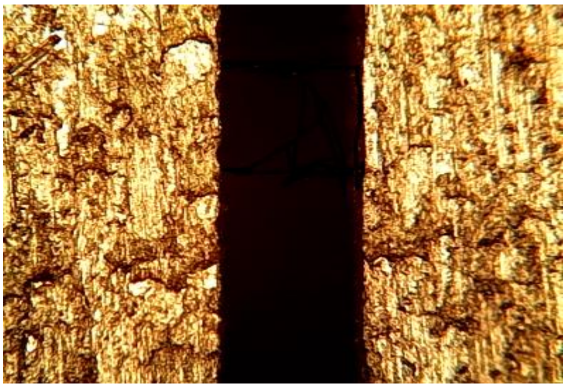
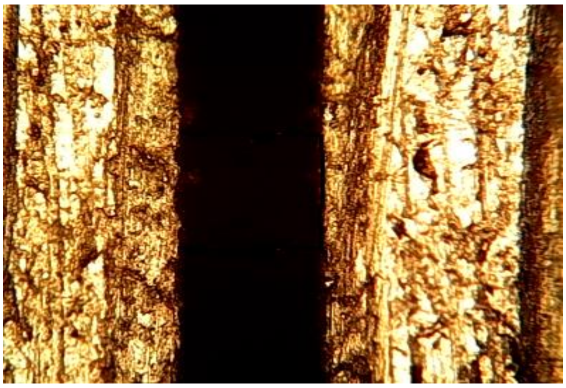
Fig.1 Formation of K-width (δ): (1) wire electrode; (2) work-piece of composite material

The various input parameters levels and the output responses are displayed in Table 1. In these tests, the levels of input parameters have been chosen after the conduction of pilot tests. In these experimental work, the value of input parameters i.e. current = 5 ampere, Wire-Speed = 5 m/min., Wire-Tension = 1.3 Kg, and Voltage = 60 Volts were remains the same except the machining feed rate. The Wensar electronic balance was used with readability of 1mg for the measurement of weight of workpiece before and after the machining. The Surtronic-25, SR analyzer at a cut-off value of 0.8 mm was utilized for the measurement of S-R.

Table1: W-EDM input parameters and responses

S. No.	Machining Feed-Rate (mm/min.)	K-Width (δ) (mm)	MR-R (mm^3/min.)	S-R (μm)
1	3	0.342	3.81	1.38
2	6	0.339	7.52	1.41
3	9	0.338	10.83	1.45
4	12	0.334	13.81	1.48

Nikon optiphot microscope at 100 magnifications has been used to measure the K-width of machined work-piece. The K-width (δ) is analysed on an image analyser at 100 magnifications. Fig. 2 demonstrates the microscope images of machined work-piece for the K-width.

1)  2) 

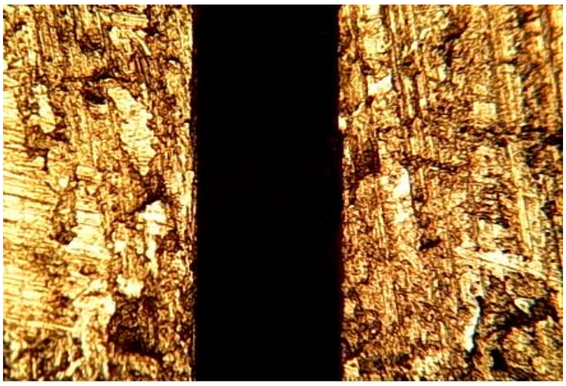
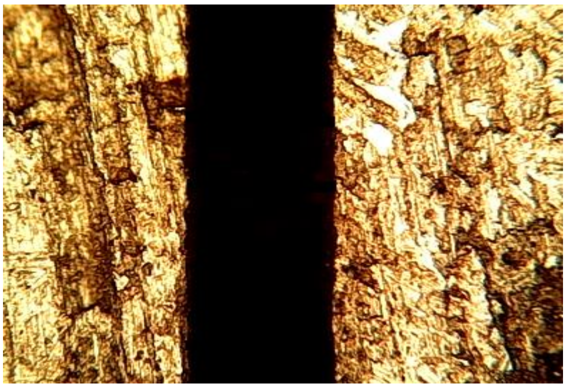
3)  4) 

Fig. 2 K-width in tests 1 to 4, 1) Test 1; δ = 0.342 mm; 2) Test 2; δ = 0.339 mm; 3) Test 3; δ = 0.338 mm; 4) Test 4; δ = 0.334 mm; (current = 5 A, wire speed = 5 m/minute, wire tension = 1.3 kg, and voltage = 60 volts).

3 Results and discussion

3.1 K-width

Figure 3 displayed that K-width increases, as the feed-rate of machine decreases. Test with smaller feed rate provide greater K-width. Kodalagara et al. [23] doesn't suggest the utilization of large feed-rate since it created higher irregularities in the K-width.

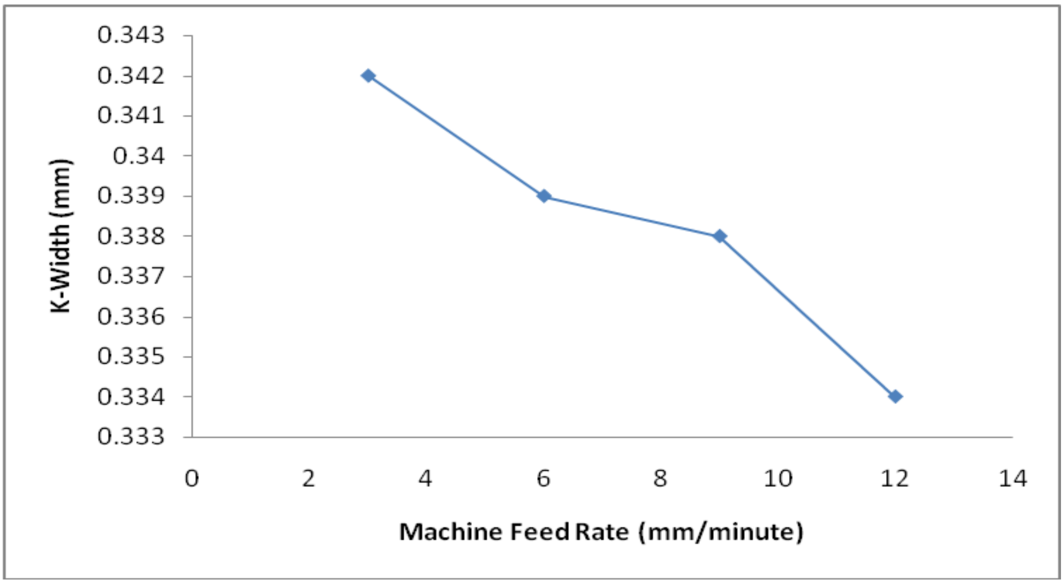


Fig. 3 Influence of machine feed rate on K-width

3.2 Material Removal Rate (MR-R)

Figure 4 displayed that MR-R increases, as the feed rate of machine increases. Test with smaller feed rate provide lesser MR-R. This outcome shows a similar example with Kodalagara et al. [23]. This is occurred in light of the fact that at the greater estimation of feed rate creates the closer space between the wire-cathode and the workpiece. The erosion of material is impacted by the spark energy. As feed-rate rises; MR-R likewise enhances till it arrives at optimal level. The MR-R declined with the declining of machine feed rate.

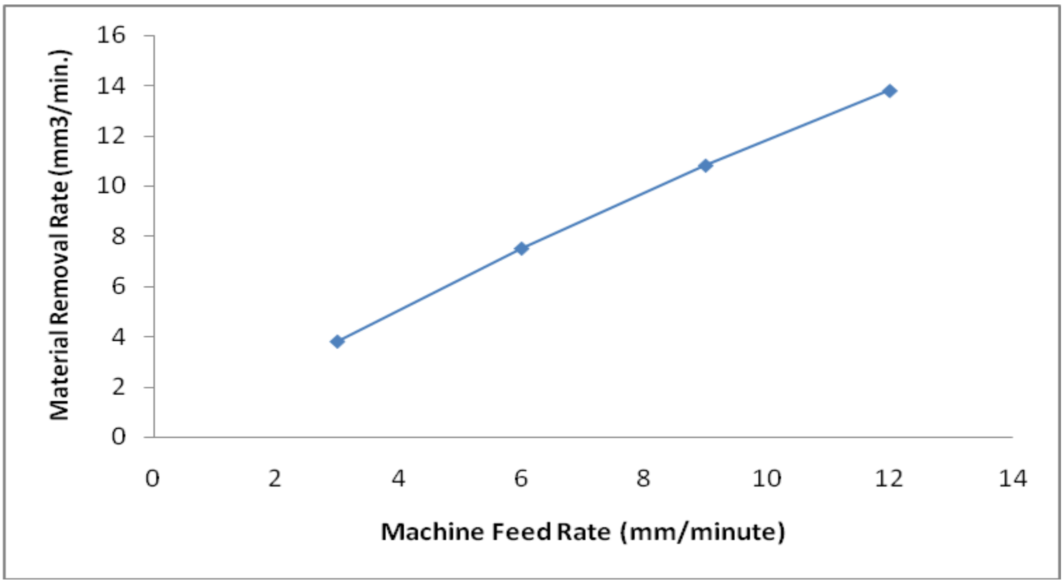


Fig. 4 Influence of machine feed rate on MR-R

3.3 Surface-Roughness (S-R)

Figure 5 displayed that S-R increases, as the feed rate of machine increases. Test with less feed rate provide less S-R. This is happened because at the bigger value of feed rate causes the closer gap among the wire electrode and the Al/SiC work-piece. Rao et. al. [24] referenced that, tension of wire and gap voltage of spark is seen as noteworthy factors in acquiring good finish of surface. This is happened because of the rise in tension of wire lessens its vibration and enhances the finish on the surface of machined component.

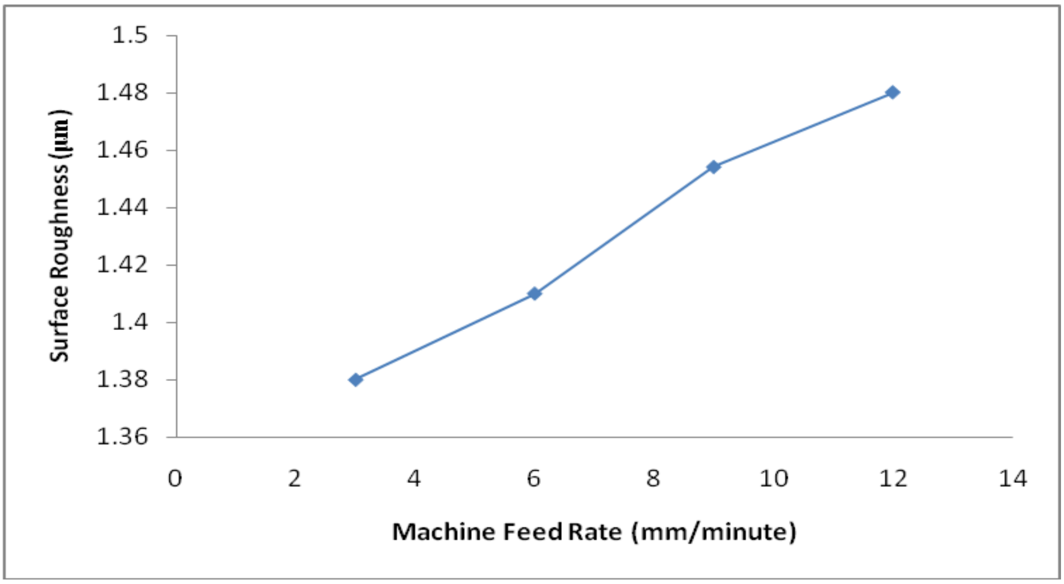


Fig. 5 Influence of machine feed rate on S-R

CONCLUSIONS

The following conclusions could be drawn based on the examination of kerf width images of machined work-piece, and understanding of figures from 3 to 5.

In machining of Al/SiC composite through W-EDM:

1. The kerf-width increases with the decrease in feed rate of machine.
2. The MR-R increases with the rise in feed rate of machine.
3. The surface roughness rises with increase in machine feed rate.
4. The MF-R has been demonstrated to play a significant role in this experimentation work.
5. Test 1 (current = 5 A, wire speed = 5 m/minute, wire tension = 1.3 kg, feed rate = 3 m/minute, and voltage = 60 volts) provides the larger K-width, better surface finish, and lesser MR-R.

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Appendix A

The following nomenclature is used in the paper:

ED-M	Electrical Discharge Machining
EDDSG	Electro Discharge Diamond Surface Grinding
F-EA	Finite Element Analysis
GRA	Grey Relational Analysis
HM-MCs	Hybrid Metal Matrix Composites
K-width	Kerf Width
MF-R	Machine Feed Rate
M-MCs	Metal Matrix Composites
MR-R	Material Removal Rate (mm^3/minute)
MRSNR	Multiple Response signal-to-noise Ratio
RS-M	Response Surface Methodology
S-R	Surface Roughness (µm)
T_{off}	Off-time of pulse (µs)
T_{on}	Pulse-on-time (µs)
VIKOR	VlseKriterijumska Optimizacija I Kompromisno Resenje
W-EDG	Wire Electrical Discharge Grinding
W-EDM	Wire Electrical Discharge Machining
WPCA	Weighted Principle Component Analysis
WSNR	Weighted signal-to-noise Ratio