SURFACE CHARACTERISTICS BEHAVIOUR OF THE EDM ERODED SURFACE OF AL-SIC METAL MATRIX COMPOSITE

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Abstract: Metal Matrix Composites (MMCs) have proved to be extremely difficult to machine using conventional manufacturing processes due to heavy tool wear caused by the presence of the hard reinforcement. This paper briefly deals with the surface characteristic behaviour of the EDM eroded surfaces of Al-10% SiC MMC and Al-20% SiC MMC (volume %), utilising binocular stero microscope (BSM), Metallography and Surf Coder. The influence of work piece material, electrode material, current, pulse duration and polarity on the EDM eroded surfaces were anlaysed.

The increment in pulse duration results not only in the increase of surface roughness but also in the increment of depth of cracks. Surface roughness is low at low current but increases with increasing current. As the current is increased, the crater size also increases with more number of pin holes. Surface roughness increases in the order of Al-20% SiC MMC, Al-10% SiC MMC and Base alloy. Surface roughness (Ra) value is more on machining Al-Sic MMC with brass electrode compared to copper electrode. Surface roughness (Ra) Value increases drastically on machining Al-20%, SiC, MMC, Al-10% SiC MMC and base alloy with positive polarity of copper or brass electrode.

Micro examination of EDM surface shows that very smooth surface are found in metal matrix composite compared to base alloy. EDM eroded surface of Al-SiC MMC showing individual smooth craters and small globules of composite on the surface. Very smooth surface are found on machining composite with copper electrode.

Keywords : Al-SiC MMC, EDM, Eroded Surfaces, Surface roughness.

1. INTRODUCTION

Since the late 1980s there has been considerable interest in the development of materials with improved specific strength greater than that of ferrous-based materials, particularly in the transportation industries. Aluminum and magnesium alloys, plastics, carbon fibres etc, are being used more frequently in Automotive industries.

Nowadays, Metal Matrix Composites (MMCs), a combination of a high strength ceramic reinforcing a light metal alloy to deliver exceptional specific mechanical and physical properties is becoming a reality. The properties of the resulting composite are generally controlled by three critical components the matrix, the reinforcement and the interface.

Among modern composite materials, particle reinforced MMCs are finding increased application due to their very favourable properties including high mechanical properties and good wear resistance. SiC reinforced aluminum is among the most common and several compositions for the matrix are available commercially.

Particle reinforced metal matrix composites are a class of materials with a wide potential for application in the automotive and aerospace industries. However, the full potential of these materials is hindered by the high manufacturing costs associated with the difficulties experienced in machining these composites. Machining MMCs using conventional machining processes such as turning, drilling, etc., generally results in excessive tool wear due to the hardness and abrasive nature of the SiC or other reinforcing particles (1). Consequently non-conventional machining processes such as Electric Discharge Machining (EDM) (2,3) and abrasive water jet techniques are increasingly being used for the machining of MMCs.

When machining work piece with EDM, a multilayered, heat affected zone is formed at the surface of the workpiece, (4,5,6). The upper layer of this zone is called white layer. During the EDM process, both tool and work piece undergo surface modification. This paper briefly deals with surface characteristic behaviour of the EDM eroded surfaces of Al-10% SiC and Al-20% SiC MMC (volume %) by copper and brass electrode, utilising binocular steromicroscope, metallography and surf coder. Experimental results confirm that the surface roughness increases with the increment in pulse duration regardless of type of composites, polarity and current. Surface roughness is low at low current but increases with increasing current. As the current is increased the crater size also increases with more number of pin holes.

2. EXPERIMENTAL PROCEDURE

The composite consists of an aluminum alloy reinforced with 10% and 20% SiC (volume %) particles of approximately 40 µm size. This composite was produced by stir casting technique copper and brass electrodes were used for the machining of Al-SiC MMC.

The experiments were carried out in an Electronica model T3822 machine equipped with a transistor switched pulse generator and electromechanical servo control. The electrode was fed downwards under servo control into the workpiece.

2.1 Parameters of Machining

Test conditions are given below :

Electrodes	-	Copper or brass
Shape and size	-	Cylindrical dia 4mm and dia 8mm
Dielectric	-	Kerosene (Commercial grade)
Discharge Current	-	3, 6 and 10A
Pulse duration	-	143, 192, 331 and 425 µs
Flushing pressure	-	3.5 kg/cm^2
Servo system	-	Electromechanical
Flow type	-	Pressure flushing

2.2 Machining and Evaluation Procedure

Blind hole drilling operations were carried out for a depth of 6 mm on Ai base alloy, Al-10% SiC MMC and Al - 20% SiC MMC (volume %). The experiments were performed with pulse current, pulse duration and volume percentage of SiC as variables. The pulse currents selected for this study were 3, 6, and 10A. The selected pulse duration were 143, 192, 331 and 425 µs. The surface roughness of the machined surface was measured at differents position by using surf coder SE40.

The surface features of the machined surface was observed under binocular steromicroscope at a magnification of 10x and typical features were photographed.

3. RESULTS AND DISCUSSION

The effect of EDM variables namely polarity, current, pulse duration electrode material and volume percentage of SiC on surface roughness, micro examination of EDM surface of base alloy, Al-10% SiC MMC and Al-20% SiC MMC were studied and the results are as follows.

3.1 Surface roughness

The variation in surface roughness (Ra) values with different current levels, different pulse duration, different electrodes and different composites were shown in Fig. 1, 2, 3, 4, 5 & 6.

The EDM eroded surface is composed of many microscopic craters associated with the random spark discharge between the electrodes. The size of the craters produced on the workpiece surface defends mainly upon the energy of the discharge. The change in surface finish as a function of discharge current and pulse duration is illustrated in Fig. 1, 2, 3, 4, 5 & 6. In general, metal removal rate (MRR) increases the surface obtained becomes rougher for single and multiple discharge (7). It can be seen that the surface roughness values vary between Ra=2.0μm and Ra=7.5μm. Surface roughness is low at low current but increases with increasing current. Higher current results in a higher thermal loading on both the cathode and anode followed by a higher amount of material being ejected. It is concluded from these curves that surface roughness increases with the increment in pulse duration, regardless of type of composites, polarity and current. Longer pulse duration results in a larger removal per discharge. If pulse duration increases, the surface temperature increases and consequently the melting boundary becomes deeper and wider (8). The surface integrity is dependent strongly upon the state of the work gap, material of the electrode and the dielectric. In this investigation after several discharge on the same composites under the same discharge condition, the surface roughness value showed very good responsibility.

It can be seen that surfaces obtained for the base material (Al alloy) are rougher than those observed for the metal matrix composite material machine under the same condition. Surface roughness values decreases in the order of, Basealloy (Al alloy) Al-10% SiC MMC and Al-20% SiC MMC. Further more the SiC particles were not melted during the machining process. Whilst machining the composite, less material is removed and smaller crater is produced. The absence of reinforced particle (SiC) in the base alloy, the shark occurring during the EDM of base alloy are concentrated on the aluminum alone and therefore larger crater formed, resulting in a higher surface roughness value.

The present investigations indicate that the SiC particles seem to shield and protect the aluminum matrix from being removed. This results in less material becoming super heated or molten during the discharge phase. When machining with copper electrode the surface roughness value was less than with brass electrode.

3.2 Micro-examination of EDM surface

Fig. 7 shows various types of surface textures, crater formation and cracking characteristics during EDM. In all the micrographs a matty surface is observed, which is formed due to over lapping of craters, after ejection of metal and resolidication of molten metal on the workpiece. These surfaces contain a series of craters obtained with multidischarges, which are random in size and location.

The surfaces produced are usually very complex in nature and possess many characteristics peculiar to EDM. Fig.7 compares the surface produced with different currents, different pulse duration and different electrodes. The properties of the surface depend on the properties of the composites / alloys which are formed in the surface layers due to the diffusion of tool electrodes and the dissolved dielectric. The increment in pulse duration is one of the many influencing parameters, results not only in the increase of surface roughness but also in the increment of depths of cracks in particular (6). In some of the micrographs a white zone of variable thickness around the rim of crater is observed which is believed to have been formed during the resolidification of the metal which does not get ejected during the process (7,8,9). Fine surfaces are found in Al-20% SiC MMC compared to Al-10% SiC MMC and base alloy. It is due to harder the material better will be the surface finish. It is also due to deformation produced by EDM may be relatively small. Fine surfaces are found on machined Al-SiC MMC with copper electrode.

The microscopic examination of machined surface of Al-SiC MMC showed individual smooth craters and small globules of composites on the surface. The amount of deformation is dependence upon the operating conditions, the compositions and surface of the workpiece. Deformation becomes less, the finer the surface finish. The material is initially in a strained condition, the deformation produced by EDM may be relatively small. As the current is increased, the crater size also increases with more number of pin holes. Blind hole drilling results in less number of pin holes.

3.3 Crater Formation

Figs - 8 shows various types of craters formed during EDM. Typical surface texture can be analyzed by using binocular stero microscope.

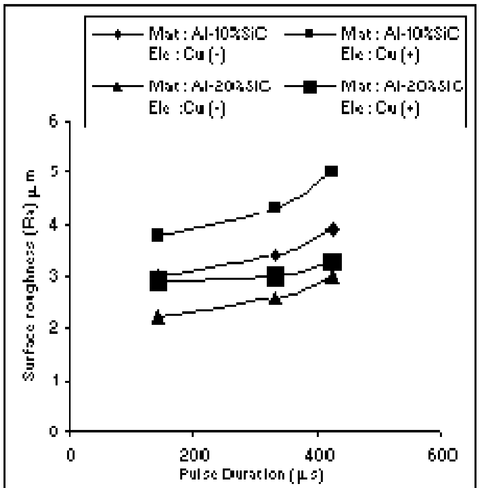


Fig.1 : Variation of surface roughness with pulse duration

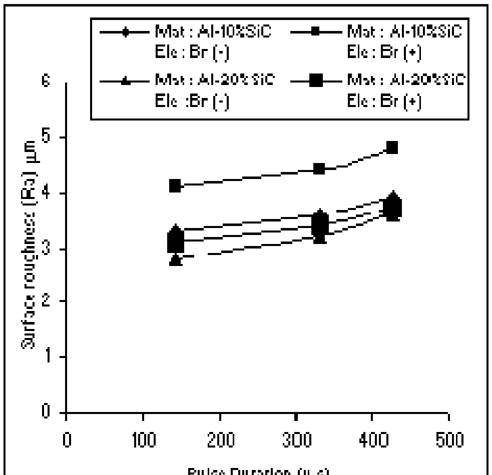


Fig.2 : Variation of surface roughness with pulse duration

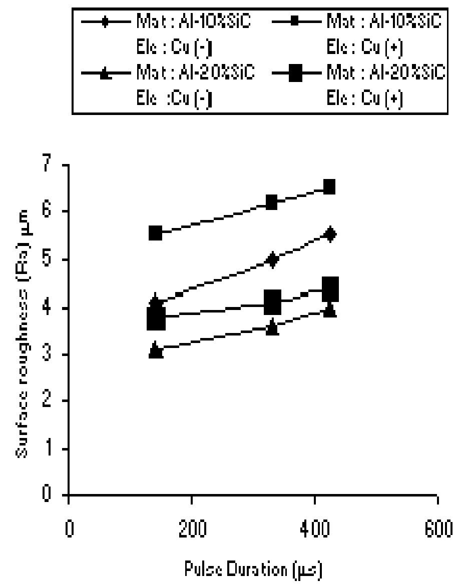


Fig.3 : Variation of surface roughness with pulse duration

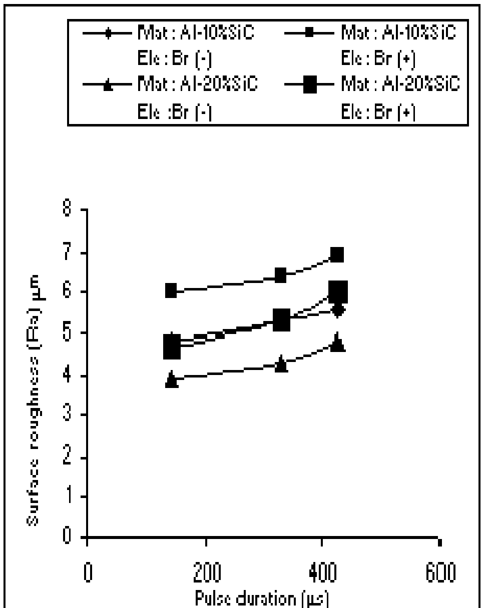


Fig.4 : Variation of surface roughness with pulse duration

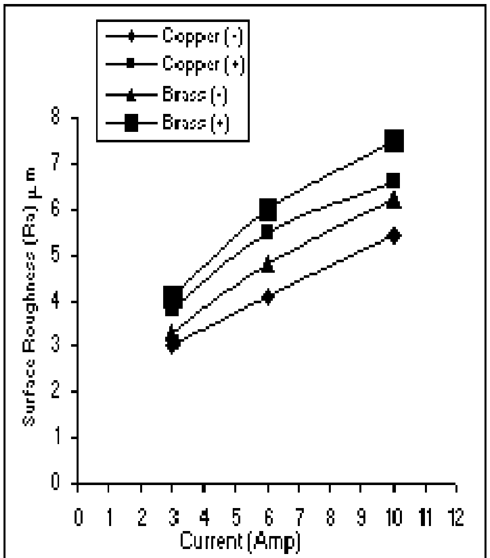


Fig.5 : Variation of Surface Roughness with current

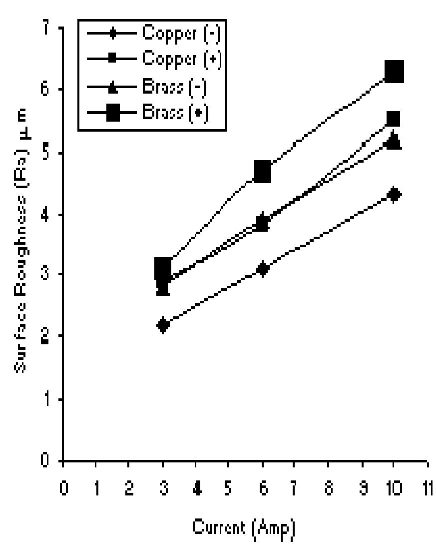


Fig.6 : Variation of surface roughness with current

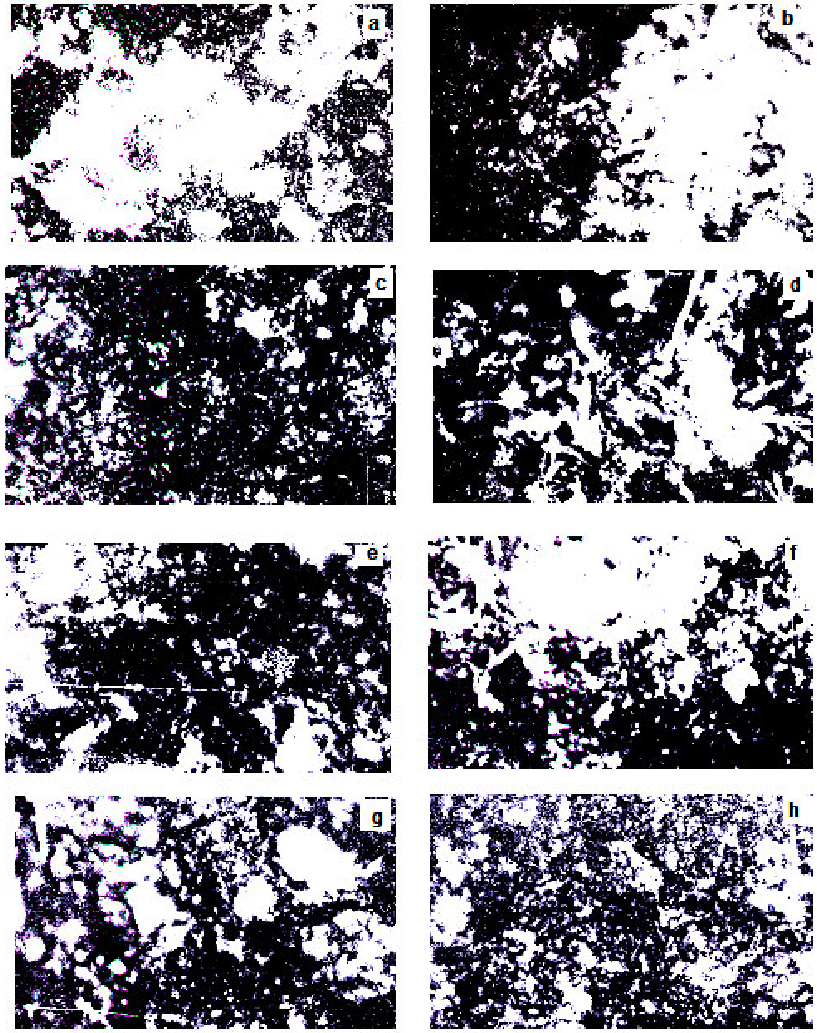


Figure 7: Micrographs of surface textures (a) base alloy, electrode Cu (-), Current: 3A, Pulse duration: 331µs (b) base alloy, electrode Cu (-), Current: 3A, Pulse duration: 192µs (c) base alloy, electrode Cu (+), Current: 3A, Pulse duration: 192µs (d) Al-10% SiC MMC, electrode Cu (-), Current: 10A, Pulse duration:192µs ((e) Al-20% SiC MMC, electrode Cu (-), Current: 3A, Pulse duration:331µs (f) Al-20% SiC MMC, electrode Cu (-), Current: 10A, Pulse duration:192µs (g) Al-10% SiC MMC, electrode Br (-), Current: 10A, Pulse duration:192µs (h) Al-20% SiC MMC, electrode Br (-), Current: 3A, Pulse duration:425µs.

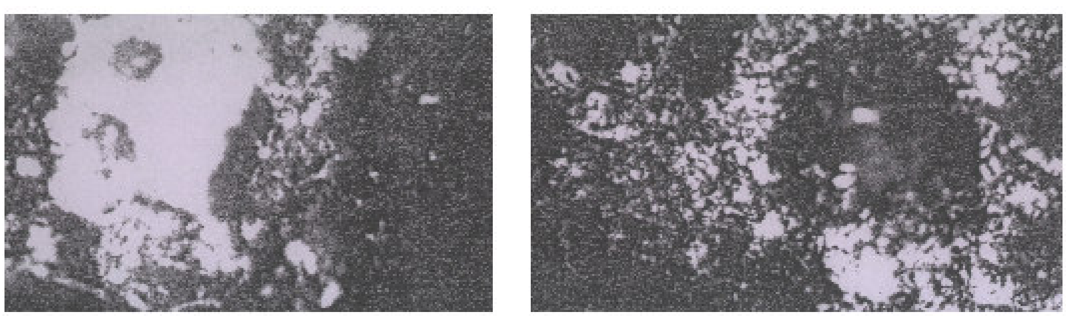
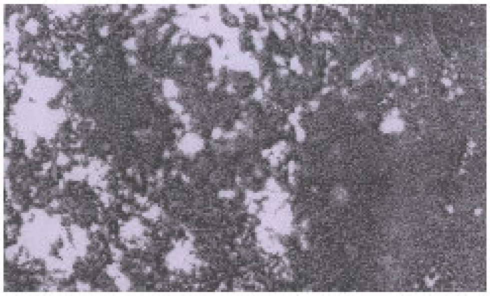


Figure 8: Micrographs showing different types of craters: (a) Al-10% SiC MMC, electrode Br (-), Current: 10A, Pulse duration:192µs (b) Al-10% SiC MMC, electrode Br (-), Current: 10A, Pulse duration:425µs



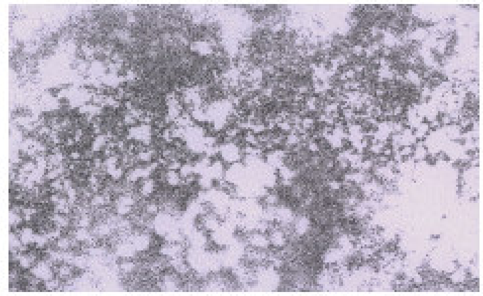


Figure 9: Micrographs showing different types of pck marks and pin marks: (a) Al-10% SiC MMC, electrode Br (-), Current: 10A, Pulse duration:192µs (b) Al-10% SiC MMC, electrode Br (-), Current: 10A, Pulse duration:425µs

From this picture it is noted that many craters were overlapped randomly in higher magnification. The small spherical debris particles and very small pock marks can also be identified from these figures. Similar observation were made by Bucklow and cole (10). In some of the micrographs a white zone of variable thickness around the rim of crater is observed which is believed to have been formed during the resolidification of the metal which does not get ejected during the process. Almost all the craters are approximately of circular in shape, but some of them appear to be elliptical which are formed due to over-lapping of circular craters.

Higher pulse durations produced a large crater which is clearly seen. Fig.8 The are many small pock marks. The pock marks indicates the sharp decrease in pressure as the discharge is cut-off. Fig.9 shows the pin holes on the surface, which intensity further to the formation of cracks. The spherical debris particles and globules are attached to the surface. When pulse duration is increased to very high value, the width of the crater becomes very large (unable to illustrate total boundary picture in this magnification) as shown in Fig.8 It can be concluded that higher pulse duration is undesirable because of occurrence of cracking on the surface.

CONCLUSIONS

It was confirmed that by increasing pulse duration the surface roughness increases in the order of Al-20% SiC MMC, Al-10% SiC MMC and base alloy. In most of the cases, a white zone of variable thickness around the rim of crater is observed. It was confirmed that by increasing current the surface roughness increase in the order of Al-20% SiC MMC, Al-10% SiC MMC and base alloy. As the current is increased the crater size also increases with more number of pin holes.

Surface roughness (Ra) is more on machining Al-SiC MMC with brass electrode compared to copper clectrode. Surface roughness (Ra) value increase drastically on machining base alloy, Al-10% SiC MMC and Al-20% SiC MMC with positive polarity of copper or brass electrode.

Micro examination of EDM surface shows that very smooth surface are found in composite compared to base alloy. Also EDM eroded surface of Al-SiC MMC showing individual smooth craters and small globules of composite on the surface. Very smooth surface are found on machining composite with copper electrode.

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