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# An investigation of mechanical properties and material removal rate, tool wear rate in EDM machining process of AL2618 alloy reinforced with $Si_3N_4$, AlN and $ZrB_2$ composites

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ABSTRACT

It is submitted that new approach is tried to find out what would be the outcome if Aluminum 2618 reinforced by AlN (Aluminum Nitride), $Si_3N_4$ (Silicon Nitride) & $ZrB_2$(Zirconium Boride) particles were fabricated in Wt % (x = 0,2,4,6,8) by stir casting method. If the wt% is increased, the mechanical properties of the composite will proportionally increase. There will be no other promising technique than Electrical Discharge Machining (EDM) for machining metal matrix composites when they were conducted on the Aluminum 2618 composite work piece using a copper electrode in an EDM machining. It becomes very vital in the field machines and mechanism to find out Current(I), Pulse on time($T_{ON}$), Pulse off time ($T_{OFF}$) on Metal Removal Rate (MRR),Tool Wear Rate(TWR) on the machining of hybrid Al2618 metal matrix composites. Taghuchi's design of experiment was used to analyse the machining characteristics of hybrid composites. To effect the parameters like current (I), Pulse on time($T_{ON}$), Pulse off time ($T_{OFF}$) has been chosen as the input parameters of this work. Machining results go to show that Al2618 composites have improved mechanical properties and as a result of Material Removal Rate (MRR) and Tool Wear Rate (TWR) are reduced. Hence ANOVA (Analysis of Variance) and signal to Noise ratio are used to determine the influence of input parameters on the Material Removal Rate and Tool Wear Rate (TWR).



## 1. Introduction

Aluminium metal matrix composites (MMC's) and their potential applications in manufacturing sophisticated machines used in aerospace and automotive industries because of their superior strength to weight ratio and high and good elevated temperature resistance, Hence the study of MMC's provoke the keen interest is that field of machines. MMC's have to chemically and physically distinct phases. Which are distributed to provide properties which are not obtainable either of the individual phases [1] the matrix retains the reinforcement to form the desired shape and at the same time the reinforcement enhances the overall mechanical properties of the matrix. If designed the new combined material would give out better strength than each individual material would be [2] MMC's are produced in a different way of conventional metal alloying. These composites are produced by combining two pre-existing constituents [3]. MMC's have high stiffness, high wear resistance and very good elevated temperature properties. These qualities would invoke to make use to have the desired result and better benefits. The previous work on MMC's focused on continuous fibre reinforcement, However it proved to be costly due to complex fabrication techniques controlled the usage where the end could justify the means [4,5]. However the advent of advance machining like water jet machining and wire cut EDM machines become possible for cutting operations, and finally EDM machines has been primarily used in drilling operations. This paper will help to investigate the effect of Current(I), Pulse on time($T_{ON}$), Pulse off time ($T_{OFF}$) on Metal Removal Rate (MRR),Tool Wear Rate(TWR) on the machining of hybrid Al2618 metal matrix composites. With the help of Taguchi's Design of experiment the machine parameters are analysed. The influence parameters are analysed with Analysis of Variance and Signal to Noise ratio on the MRR and TWR.

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## 2. Experimental details

### 2.1. Material selection

Aluminium grade of 2618 is used as the base material in this study. Very few particles are as popular reinforcing phases as aluminium particles, Because it posses many aluminium alloy based metal matrix composites as its properties [6,7] there are many processes for particle reinforced MMC's [8,9]. There are two types of salts namely $K_2ZrF_6$ & $KBF_4$ are used to synthesize the $ZrB_2$ reinforcement in addition to $Si_3N_4$ (Silicon Nitride), AlN (Aluminium Nitride) are suitable to any research activities for its good properties and excellence. Solid state sintering cannot justify $Si_3N_4$ sintering additives create a liquid phase at high temperature. It allow mass transport through a solution re precipitation process, It leads finally full densification. A silicate phase which is liquid at the sintering temperature [10] is formed when it react with $SiO_2$. This liquid phase sintering is sub-divided into three stages namely (i) The development of the capillary forces among the particles becomes possible by particles rearrangement due to the formation of an electric melt consisting of used to additives and $SiO_2$ on the $Si_3N_4$ surface. (ii) Solution of α- $Si_3N_4$ the diffusion of Si and Al through the liquid phase and re precipitation of β- $Si_3N_4$ [11] and β-$Si_3N_4$ coarsening [12] of additives. While the properties of sintered strongly depend on the morphology of the silicon nitride grains and the character of the intergranular phase [13] Aluminum Nitride plays a very vital role in electronic industry due to smaller and more reliable integrated circuit. As AlN contains high thermal conductivities it suit well for its application. It has a greater strength and lower thermal expansion and good electrical properties [14] and more benefits for this purpose. AlN consist of the lowest density and high specific modulus. AlN used for both monolithic and composite materials [15]. It is an established fact that Zirconium Boride ($ZrB_2$) have high electrical conductivity, high hardness and high melting point and remarkable corrosion resistance against molten iron and slags. Several industrial sectors such as foundry and refractory industries make use of this as a promising material for high temperature applications and also found in aerospace industries, rocket nozzle needle edges [16–19]. The chemical composition of the base material is shown in Table 1.

Al2618 is melted in a graphite crucible furnace; a stirrer is used to stir the melt. At the time of melt reaching the temperature 510°c the dried $K_2ZrF_6$ & $KBF_4$, $Si_3N_4$, AlN salt powders with weight ratio (x wt%) of (x = 0,2,4,6,8) were added to molten aluminum 2618. More or less 1 kg of alloy was melted 820°c in the resistance furnace with stir casting setup. The matrix metal and the reinforcement was pre heated at 800°c and it was done for an 1 h to remove moisture and gases from the surface of the particulates. The stirrer was fixed vertically from the bottom of the crucible up to 3 cm (total height of the melt was 9 cm). Gradually the speed of the stirrer was raised up to 800 rpm. The reinforcements were added with molten metal at the rate of 10–20 g/min.

A constant speed was maintained with the help of speed controller particulates were added to the melt at the time of increasing viscosity of the melt and stirrer speed got reduced by 50–60 rpm. After the mixture of $Si_3N_4$, AlN, $ZrB_2$ were added stirring was continued for 10mins for better distribution. The melt was kept in the crucible for a minute in static condition and it was poured in the metal mould. The casting samples are shown in Fig. 1.

**Table 1**
Chemical composition of Al2618 alloy in wt%.

| Element | Cu | Mg | Fe | Ni | Si | Ti | Al |
|---|---|---|---|---|---|---|---|
| Wt% | 2.30 | 1.60 | 1.1 | 1.0 | 0.18 | 0.07 | Bal |

**Fig. 1.** Casting samples.

**Fig. 2.** Experimental set up of EDM.

### 2.2. Vicker's hardness test

The Hardness of the composites has been measured using Vickers Hardness Testing machine. The Hardness value is obtained for all various Wt% of Al2618 composites. The hardness has been measured at the different locations in the each specimen. The was carried at the room temperature (30 °C). An overall average value has been taken from each samples.

### 2.3. Tensile test

The Tensile test was carried on as per the ASTM Standard on the cylindrical rod of casted samples. The 1200grade abrasive sheet was used to polish the samples so as to reduce the scratches and effects on the sample during the casting. The universal testing machine with 10 KN loaded capacity was used to conduct the tensile strength.

### 2.4. Compression test

The compressive test was taken with the help of computerized universal testing machine. The test was performed as per the ASTM standard at the room temperature on the samples. The test results were observed accurately because the machine was fully computerized.