Optimisation of Material Removal Rate and Surface Roughness of MoS2 Reinforced Aluminium Metal Matrix Composite in Wire-EDM Process-A Review

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Abstract - In this study, based on the literature review ofAluminium Metal matrix composites and combined effect of reinforcements on aluminium alloys are discussed. For the preparation of the composites Aluminium is taken as matrix material and varying weight percentage of Molybdenum Disulphide (MoS_2) is considered as reinforcement. Stir casting technique is considered for the preparation of composite. A series of mechanical tests are observed through literature studies. Optimisation of Metal Removal Rate (MRR) and Surface roughness are studied during the Wire-EDM process.

Key words - Wire EDM, Taguchi methods, AMMC, Stir casting.

1. Introduction

MMC (Metal matrix composites) are metals rein- forced with other metal, ceramic or organic com- pounds. They are made by dispersing the reinforcements in the metal matrix. Reinforcements are usually done to improve the properties of the base metal like strength, stiffness, conductivity, etc. Aluminium and its alloys have attracted most attention as base metal in metal matrix composites. Thealuminium matrix composites (AMCs) represent a class of MMCs possessing properties like low density, high stiffness and strength, superior wear resistance, controlled co-efficient of thermal expansion, higher fatigue resistance and better stability at elevated temperature. Due to this, these composites are used for the design of a wide range of components for advanced applications.It has been found that the use of AMCs in engine applications can reduce the overall weight, fuel consumption and pollution in the automobiles and aircrafts.

Tirumavalan *et al.* [1] optimized the process parameters during machining of AA6061 by Severe Surface Mechanical Treatment (SSMT). By using Taguchi design of experiments the process parameters were optimized. ANOVA is used to analysis of the results.

G.G.Hosmani *et al.* [2] studied the wear characteristics, microstructure and the mechanical properties of cast silicon carbide (SiC) reinforced aluminum matrix composites (AMCs). AMCs of varying SiC content (0, 3 and 7 wt.%) were prepared by stir casting process. Wear performance, microstructure, hardness, tensile strength and compressive strength of the prepared composites were analysed. Adding SiC reinforcements in aluminum (Al) matrix increased wear resistance, tensile strength and compressive strength and 7 wt. % SiC reinforced AMC showed maximum wear resistance, tensile strength and compressive strength.

Rajesh Prabha N. *et al.* [3] investigated the mechanical properties like hardness, tensile strength and thermal evaluation for Aluminium alloy AA7075 reinforced with numerous percentages of TiC particles via the usage of high energy stir casting method additionally added with MoS2 as hybrid composite material. This work revealed that the addition of TiC improves the damage resistance of aluminium composites. The outcomes confirmed that the mechanical residences, along with tensile electricity, spectrum examine expanded with the aid of the proportion of TiC present within the samples when compared with base aluminium alloy. The outcomes of composites have a higher composition in addition with Al7075. The SEM-XRD analysis found out the occurrence of TiC in the metal matrix. The best composition of hybrid composite become found with nine 9wt% TiC composite in comparison to different compositions.

Meena *et al.* [4] study and experimentation on aluminum (Al-6063)/SiC Silicon carbide reinforced particles metal-matrix composites (MMCs) are fabricated by melt-stirring technique. The MMCs bars and circular plates are prepared with varying the reinforced particles by weight fraction ranging from 5%, 10%, 15%, and 20%. The average reinforced particles size of SiC are 220 meshes, 300 meshes, 400 mesh respectively. The stirring process was carried out at 200 rpm rotating speed by graphite impeller for 15 min. The microstructure and mechanical properties like Proportionality (MPa) limit, Tensile strength upper yield point (MPa), Tensile strength lower yield point (MPa), Ultimate tensile strength (MPa), Breaking strength(MPa), % Elongation,% Reduction in area, Hardness (HRB), Density (gm/cc), Impact Strength (N.m) are investigated on prepared specimens of MMCs. It was observed that the hardness of the composite is increased with increasing of reinforced particle weight fraction. The tensile strength and impact strength both are increased with rising of reinforced weight fraction. Different mechanical tests were conducted and presented by varying the particle size and weight fractions of SiC.

MoS_2 is an attractive layered structure that has gained a considerable amount of interest in the scientific community, especially in recent years. MoS_2 is a relatively cheap material as it occurs in nature as its mineral, molybdenite.

M. Geeta Rani *et al.* [5] investigated on the characterization of Al 6061 base metal matrix composite (MMC) reinforced with Molybdenum disulphide (MoS2) samples .Aluminium MMC reinforced with MoS_2 powder of particle size of less than 2µm, with weight ratios of 1, 2, 3, 4, 5 & 5.5 %. were prepared by using stir casting technique. Sequences of tests were conducted to evaluate mechanical properties such as tensile strength, yield strength, impact strength and hardness for the specimen. The results were compared with base alloy. The results revealed that the hardness and tensile strength increased with increase in wt. % of reinforcement particles in the matrix up to 4% and the hardness and tensile strength decreased for 5 % , 5.5% addition of reinforcement in the matrix.

2. Stir Casting

Various techniques are developed to manufacture metal matrix composites but out of them stir casting process is most widely used because it is simple and cost effective. Stir Casting is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring. The liquid composite material is then cast by conventional casting methods and may also be processed by conventional metal forming technologies.In stir casting we use stirrer to agitate the molten metal matrix. The stirrer is generally made up of a material which can withstand at a higher melting temperature than the matrix temperature. Generally graphite stirrer is used in stir casting. The stirrer is consisting of mainly two components cylindrical rod and impeller. The one end of rod is connected to impeller and other end is connected to shaft of the motor. The stirrer is generally held in vertical position and is rotated by a motor at various speeds. The resultant molten metal is then poured in die for casting. Stir casting is suitable for manufacturing composites with up to 30% volume fractions of reinforcement. A major concern in associated with the stir casting is segregation of reinforcement particles due to various process parameters and material properties result in the non-homogeneous metal distribution. The various process parameters are like wetting condition of metal particles, relative density, settling velocity etc.

N.Ramanaiah *et al.* [6] investigated the mechanical properties of molybdenum disulphide powders reinforced in aluminium alloy (Al-2024) composite samples. MOS2 powders of approximately 40µm particle size were reinforced in an aluminium alloy matrix to produce composite samples of ratios, 1, 2, 3, 4 & 5 weight % through **stir casting technique**. The fabricated composite specimens were subjected to a series of tests to evaluate the mechanical properties such as hardness and tensile strength. The same are compared with the base alloy. SEM and XRD analysis was carried out to analyse the microstructure and the dispersion of the reinforced particles in the alloy matrix. It was fairly observed from the results that, the hardness and tensile strength increased with the increase in wt. % of reinforcement particles in the matrix up to 4% addition of reinforcement and the hardness and tensile strength decreased for 5% addition of reinforcement in the matrix. The SEM and XRD results revealed the homogeneous dispersion of MOS2 particles in the matrix.

B.Nagaraju *et al.* [7] made an attempt to study the study the effect of Wire Electric Discharge Machining (WEDM) parameters like pulse-on time, pulse-off time and peak current on Surface Roughness (Ra) and Material Removal Rate (MRR) in Aluminium Metal Matrix Composites (AMMCs). The composite material containing aluminium alloy as matrix, silicon carbide as reinforcement is produced by **Stir castingtechnique**. Experimentation was conducted in a series of tests called runs, in which changes are made in the input variables in order to identifythe reasons for changes in the output response using Response Surface Methodology.

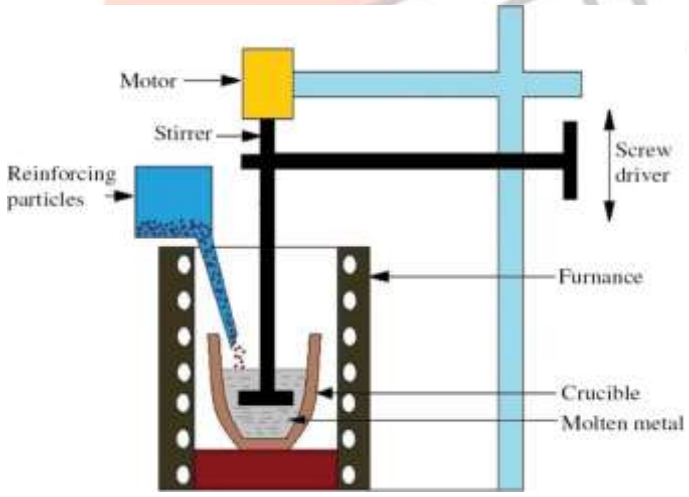

Fig. 1 Stir Casting Process

The distribution of particle in the molten metal matrix is also affected by the velocity of stirrer, angle of stirrer, vortices cone etc. In this method first the matrix metal is heated above its liquid temperature so that it is completely in molten state. After it is cooled down to temperature between liquid and solidus state means it is in a semi-solid state. Then preheated reinforcement particles are added to molten matrix and again heated to fully liquid state so that they mixed thoroughly each other.

3. Wire EDM Process

WEDM is a non- traditional process of material removal from electrically conductive materials to produce parts with intricate shape and profiles. Wire Electrical Discharge Machining (WEDM) is one of the non-traditional machining processes, which works on the principle of spark erosion. WEDM is widely used for manufacturing complex two- dimensional (2D) and three-dimensional (3D) shapes with electrically conductive work piece by using a wire electrode of diameter that varies from 0.05–0.3 mm. WEDM is a non-traditional machining process used for machining electrically conductive materials that are

difficult to machine use conventional methods. Material removal in WEDM is by means of spark erosion that involves melting, vaporisation, and rapid cooling of molten metal.

Sankara Narayanan *et al.* [8] investigated the result of process parameters on the thickness of the work piece, time and wear and developed mathematical relationships using Artificial Neural Networks. From that they developed Algorithm for the input parameters and the process parameters by using Wire Cut Electric Discharge Machining.

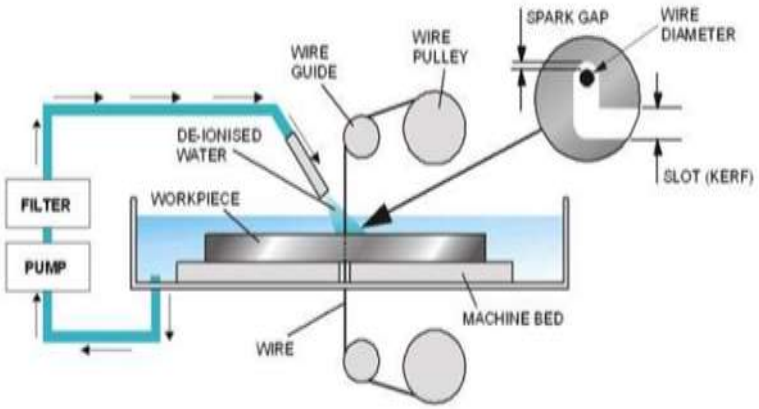

Fig. 2 Schmeatic diagram of Wire EDM

AshishSrivastava and AmitRai Dixit [9] presented an experimental study on composite of Al2024 reinforced with Sic to investigate the effects of WDEM and Response Surface methodology was applied to optimize the machining parameters for maximize the MRR and Surface finish.

PragyaShandilya *et al.* [10] optimized the process parameters during machining of Al6061/ Sic MMC by WEDM. The input parameters of WEDM namely pulse-on time, pulse- off time, wire feed were chosen as variables. ANOVA results were used to find out the contribution of parameters on MRR and Surface roughness.

Sateesh Kumar Reddy and Ramesh S [11] made an attempt to find the optimization of wire electrical discharge machining of Al/Sic MMC. The experiments were carried out to find the best affecting parameters for maximize MRR & Surface Roughness. **Taguchi method** was used as the Design of Experiment and for the analysis. ANOVA is used for the development of mathematical correlation equation.

Mahapatra and Patnaik *et al.* [12] made an attempt to determine the important machining parameters for performance measures like material removal rate, surface finish separately in the WEDM process. To obtain optimum parameters combination for maximization of MRR and SF, Taguchi's experimental design method is used.

Sarcar *et al.* [13] optimized the trim cutting operation of WEDM of γ-TiAl alloy for a given machining conditions by desirability function approach. Response Surface Methodology (RSM) was used to develop a prediction model of surface roughness for machining mild steel.

Puri and Bhattacharya [14] performed analysis of wire- tool vibration in order to achieve a high precision and accuracy in WEDM with the system equation based on the force acting on the wire in a multiple discharge process.

A wire EDM generates spark discharges between a small wire electrode and a work piece with de-ionized water as the dielectric medium and erodes the work piece to produce complex two and three dimensional shapes according to a numerically controlled (NC) path. The main goals of WEDM manufacturers and users are to achieve a better stability and higher productivity of the WEDM process. As newer and more exotic materials are developed, and more complex shapes are presented, conventional machining operations will continue to reach their limitations and the increased use of the WEDM in manufacturing will continue to grow at an accelerated rate (Guitrau, 1991). Wire electrical discharge machining manufacturers and users emphasize on achievement of higher machining productivity with a desired accuracy and surface finish.

4. Conclusion

Many Researchers reported that AMMC'S possess low density, high strength, wear resistance and fatigue resistance. Based on the study of different journal papers it is observed that percentage of reinforcement is varying from 1% to 10% .Stir casting Technique is observed as one of the most effective technique for preparing the metal matrix composites. Pulse on time pulse off time and input current are to observed to be the most effective parameters in wire EDM process. It is observed that many researchers adopted Taguchi design of experiments for finding the optimum experimental parameter.

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