

# Development of Al-SiC MMC and Experimental investigation by Electro discharge machining - A Review

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**Abstract**— In recent years, aluminum alloy based metal matrix composites (MMC) are gaining importance in several aerospace and automobile applications. The researchers have adopted several processing techniques like ultrasonic assisted casting, powder metallurgy, high energy ball milling, and liquid stir casting for the production of Aluminum matrix composites. Different Aluminium alloys and reinforcements (SiC, B4C, Si3N4, AlN, TiC, TiB2) with varying % weight fraction have been used for development of AMC. The high abrasiveness of the SiC particles limits the conventional machining process. Rapid tool wear with poor performance even with advanced expensive tools categories it as a difficult-to-cut material. The use of nonconventional machining techniques in shaping aluminum metal matrix composites has generated considerable interest due to ease of machining. Electrical discharge machining (EDM) appears to be a promising technique for machining MMC by varying process parameters. In this paper, review on liquid stir casting followed by centrifugal casting and machining by EDM has been focused.

**Key words:** Metal matrix composites (MMC), Reinforcements, Liquid stir casting, Centrifugal casting, and Electrical discharge machining (EDM)

## I. INTRODUCTION

Nowadays, metal matrix composites (MMCs) can be used in wide applications ranging from civil structures, to aerospace and recreational products. This is due to the capability of MMCs to be designed to provide a vast variety of mechanical, thermal and dimensional accuracy properties. It is shown that uniform distribution of particulates in metal matrix has great effect on properties of composites, and homogeneously reinforced MMC components are well corresponding to homogeneous properties. Among various preparation methods, compocasting is a relatively simple process of mechanical agitation for the production of MMCs which can be easily scaled as required. But the volume fraction of SiC particles in the composites is below 35%; and pores of composites cannot be avoided completely. Therefore, it is necessary to form further by pressure forming processes, such as extrusion and centrifugal casting. Centrifugal casting is one of the most effective methods for processing functionally graded materials (FGMs) made of aluminum matrix composites (AMCs). [1]

Though AlSiC possess superior mechanical properties, the high abrasiveness of the SiC particles hinders its machining process and thus by limiting its effective use in wide areas. Rapid tool wear with poor performance even with advanced expensive tools categories it as a difficult-to-cut material. Nonconventional processes such as electrical discharge machining (EDM) could be one of the best suited methods to machine such composites. [2]

## II. LITERATURE REVIEW

**R. S. Rana, , Rajesh Purohit, and S.Das (2012)** [3] presents the views, theoretical and experimental results obtained and conclusions made over the years by various investigators in the field of aluminum alloy -MMCs. various studies has been done about the processing of Aluminum alloy composites, their physical properties, mechanical properties. Several processing techniques like ultrasonic assisted casting, powder metallurgy, high energy ball milling, friction stir casting are recently being used for the production of Aluminum matrix composites. The factors that affect the microstructure like- type, size, and distribution of reinforcement, matrix grain size, and matrix and secondary phase interfacial characteristics are studied. Stir casting is the most economical method Compared to other methods, stir casting costs as little as one third to one tenth for mass production. It has been concluded that further research is still awaited to control the microstructures under various processing conditions.

**Manoj Singla, , D. Deepak Dwivedi, Lakhvir Singh, Vikas Chawla (2009)** [4] demonstrated two step-mixing method of stir casting technique and subsequent property (hardness, impact strength) & Microstructure analysis has been made for Aluminium (98.41% C.P) and SiC (320-grit). Experiments have been conducted by varying weight fraction of SiC (5%, 10%, 15%, 20%, 25%, and 30%). An increasing trend of hardness and impact strength with increase in weight percentage of SiC has been observed. The best results (maximum hardness 45.5 BHN & maximum impact strength of 36 N-m.) have been obtained at 25% weight fraction of SiC .At higher % volume clustering increased which leads to nonuniform particle distribution.

**Kratus Ranieri, Carlos Kiyari; Antonio Fernando Branco Costa; Alexandre Zirpoli SimõesI. (2012)** [5] proposed a combined route of stirring at semi-solid state followed by stirring at liquid state. AA 356alloy (Al-7si-0.3Mg) and calcined Alumina are used as matrix and reinforcement respectively. A fractional factorial design was developed to investigate the influence and interactions of factors as: time, rotation, initial fraction and particle size, on the incorporated fraction. The role of the alloying element Mg as a wettability-promoting agent is discussed. It was found that Processing in totally liquid state does not produce incorporation of particles in matrix, for good result it is necessary to processing in semi-solid state. Stir time has no influence on processing. And great impactful factors are particle size & initial fraction. Presence of Mg improves wettability.

**Rajeshkumar Gangaram Bhandare, Parshuram M. Sonawane (2013)** [6] presents an overview of stir casting process, process parameter, & preparation of AMC material by using aluminium as matrix form and SiC, Al2O3, graphite as reinforcement by varying proportion. It has

discovered that for uniform dispersion of material blade angle should be  $45^\circ$  or  $60^\circ$  & no of blade should be 4. For good wettability we need to keep operating temperature at semisolid stage i.e.  $630^\circ\text{C}$  for Al (6061). Preheating of mould helps in reducing porosity as well as increases mechanical properties.

**WANG Kai, XUE Han-song, ZOU Mao-hua, LIU Chang-ming. (2009).**[1] investigated the microstructural characteristics and Brinell hardness of a cylinder produced by centrifugal casting were using 20% (volume fraction) Al-SiCp compo cast composites. Macrostructure and XRD analysis showed that most of SiC particles segregate to the external circumference of the cylinder, the other SiC particles maintain in the inner circumference of the cylinder, and a free particle zone is left in the middle circumference of the cylinder. The agitation of centrifugal force promotes the dispersion of congregated SiC particles and the nucleation of amounts of primary  $\alpha$  (Al) phases in external reinforced zone. The larger the number of primary  $\alpha$  (Al) grains is, the more uniform the distribution of SiC particles in matrix alloy is, and vice versa. Uniform distribution and the high volume fraction of SiC particles in matrix alloy can improve Brinell hardness.

**J.W. Gao, C.Y. Wang. (2000)** [7] developed a one-dimensional solidification model, with particle transport taken into account. The model predictions are validated against experimental results. They found the factors of gradation of particles in cylindrical mould and investigated the effects of initial particle concentration, particle size, rotational speed, cooling rate. It was concluded that three factors can be identified to be responsible for creation of the particle concentration gradient in a cylindrical configuration. (1) Geometry of particle flow in cylindrical mould. (2) Angular velocity of the cylindrical mold. (3) Solidification rate. By optimizing processing conditions, such as the particle size ( $5\ \mu\text{m}$ ), initial particle concentration (25% vol.), rotational speed (500 rpm) of the mold, cooling rate ( $5000\ \text{w/m}^2$ ), one can engineer a desired gradient in the solidified part.

**T.P.D. Rajan, R.M.Pillai, B.C.Pai (2010)**[8] investigated on characterization of functionally graded composites based on 356 cast and 2124 wrought aluminum alloys reinforced with SiC particles of  $23\ \mu\text{m}$  average particle size and 15% vol. fraction processed by liquid metal stir casting followed by horizontal centrifugal casting. A maximum of 45 and 40% SiC particles are obtained at the outer periphery of the Al (356)-SiC and Al (2124)-SiC FGMMC casting respectively. The maximum hardness obtained at the outer periphery after heat treatment for Al (356)-SiC and Al (2124)-SiC FGMMC is 155 BHN and 145 BHN respectively. The freezing range of the matrix alloy has been found to dictate the nature of transition from particle enriched to depleted zone. These composites are suitable for making engineering components, which require very high surface hardness and wear resistances with high specific strength.

**WANG Kai, SUN Wenju (2010)** [9] two ingots were produced by centrifugal casting at mould rotational speeds of 600 rpm and 800 rpm using 20 vol% SiCp/AlSi9Mg composite melt, respectively. The microstructure along the radial direction of cross-sectional sample of ingots was presented. SiC particles migrated towards the external

circumference of the tube, and the distribution of SiC particles became uniform under centrifugal force. Voids in 20 vol% SiCp/AlSi9Mg composite melt migrated towards the inner circumference of the tube. The quantitative analysis results indicated that not only SiC particles but also primary  $\alpha$  phases segregated greatly in centrifugal casting resulting from the transportation behaviour of constitutions with different densities in the SiCp/AlSi9Mg composite melt. In addition, the eutectic Si was broken owing to the motion of SiCp/AlSi9Mg composite melt during centrifugal casting.

**B.Mohan, A. Rajadurai, K.G. Satyanarayana (2002)**[10] studied the effect of electric discharge machining (EDM) parameters namely polarity, current, electrode, pulse duration, and rotation of electrode on metal removal rate (MRR), tool wear rate (TWR), surface roughness (SR) value in EDM of Al-SiC MMCs with 20 & 25 % SiC. With respect to electrode material, polarity of electrode % vol. SiC, MRR increased with increase in discharge current and for a specific current it decreased with increase in pulse duration. Increase in % vol. SiC had an inverse effect on MRR, and positive effect on TWR and surface roughness. Increasing speed of rotating electrode resulted in a positive effect on MRR, TWR, and better SR than stationary. MRR increased with brass tool compared to copper tool. Optimum parameter found for MRR ( $43.27\ \text{mm}^3/\text{min}$ .) At 20% SiC, with Brass tool, + ve polarity, 6.07 amp,  $92\ \mu\text{s}$  pulse duration.

**ZhanBo Yu, Takahashi Jun, Kunieda Masanori (2004)** [11] compared dry EDM milling and oil EDM milling in groove machining to clarify dry EDM characteristics then compared dry EDM milling and traditional EDM for three-dimensional machining of cemented carbide. Copper tungsten pipe was used as the tool electrode and Oxygen gas used as a dielectric medium. Dry EDM milling and oil EDM milling were carried out in three steps: roughing, first finishing, and second finishing. It was found that Dry EDM milling and oil EDM milling were carried out in three steps: roughing, first finishing, and second finishing. In comparing dry EDM with oil die sinking EDM for machining the same shape using cemented carbide, oil die sinking EDM shows shorter machining time. But because oil die sinking requires time for producing electrodes, dry EDM should be more useful in actual Production.

**M. Kathiresan, T. Sornakumar (2010)** [12] developed LM 24-SiC composites using a new combination of vortex method and pressure die casting technique and measured hardness and density. Electrical Discharge Machining (EDM) studies were conducted on composite work piece using a copper electrode. The pulse current used is 1.5, 3 and 4.5 A. The pulse-on duration is  $200\ \mu\text{s}$  and the pulse-off duration is  $30\ \mu\text{s}$ . The voltage used is 80V dc straight polarity. The dielectric used is commercial grade EDM oil. The flushing pressure is  $1.5\ \text{kg/cm}^2$ . Results showed that the hardness of the aluminum alloy-silicon carbide composite increases with amount of silicon carbide reinforcement and The density of the composite increases with amount of silicon carbide reinforcement. The EDM studies showed that the MRR increases with an increase in the current and decrease in the percent weight of silicon carbide. The surface finish improves with decrease in the current and increase in the percent weight of silicon carbide.

### III. CONCLUSION

Two step stir casting method is most economical and effective route to develop Al-Sic MMC among various processes. The factors that affect the microstructure like-type, size, and distribution of reinforcement, matrix and secondary phase interfacial characteristics, and stirrer specification like speed, angle of blade, position are studied. Some research work carried out by centrifugal casting to develop uniformly distributed reinforcement particles and examined effects of mould rotation and % volume fraction on the mechanical properties and microstructure. Electrical Discharge Machining (EDM) studies were conducted on various composite work piece and also studied the effect of EDM parameters namely polarity, current, electrode, pulse duration, and rotation of electrode on metal removal rate (MRR), tool wear rate (TWR), surface roughness (SR).

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