

Wear Analysis of Aluminium Based Composites by Stir Casting Process: A Literature Review

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ABSTRACT: This literature considers the major use of aluminium due to its superior property low density, ductility, electrical and thermal conductivity. Firstly important properties are find which explore use of aluminium in many industrial applications keeping the limitations in mind. So the composites materials fabricated by stir casting by using different types of reinforcement materials are the better replacement with aluminium. Wear behaviour of composites materials made by stir casting are reviewed in this literature and also the effect of the wear parameters on the properties of aluminium composites.

KEYWORDS: Composites, Stir casting, Pin on disc method, Aluminium, Wear, Stir casting.

I. INTRODUCTION

We are surviving in the environment of active change and materials are not the exception case. Engineering and technologies had done a lot of research in the field of materials, science and technology. Many engineering materials have own limitation in achieving the superior level of properties such as toughness, wear resistance, low density, strength and hardness [1]. But the composites materials have given opportunity to get these properties. Basically materials are categorised in four categories such as composites, polymer, metals and ceramic [2]. The composite materials based on metals and alloys are known as metal matrix composites. And composite material made of single reinforcement particles is known mono MMC and of more than one reinforcement particles is known as hybrid MMC. Composites have wide area applications such as military, defence, automobile and many general engineering applications because of its certain properties like high specific strength, wear resistance, hardness and low density [3]. Properties of aluminium composites can be customized to the demands of many industrial applications by appropriate combinations of matrix, reinforcement and fabrication route [4]. The MMCs can prove considerably lower wear rates than unreinforced alloys over wider ranges of load, sliding distances and sliding speeds. The wear resistances of MMCs can be improved by making hybrid composites with fibers, particles, whiskers and nanoparticles with different wt. % of reinforcement particles [5]. Before, some studies on the wear behavior of mono and hybrid MMCs have been reported.

II. RELATED WORK

This emphasis basically on the number of materials and the fabrication methods for fabrication of the composites. Metal matrix composites (MMCs) are advanced materials resulting from a mixture of two or more materials (one of which is a metal and the other a nonmetal) in which superior properties are realized. They have acknowledged significant attention in recent years because of their high strength, stiffness, and low density [5, 6].

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MATERIALS:

A wide variety of matrix cast aluminium alloy are used to fabricate composites based on different reinforcement materials depends on their applications in industries. Aluminium A356, A359 and A6061 are mainly used because of their application in defence, military, automobiles and general engineering purposes. The chemical compositions are given in table 1

Table 1: Chemical composition of aluminium A356, A359 and A6061 [6, 7, 8]

Alloy	Si (%)	Zn (%)	Mn (%)	Fe (%)	Cu (%)	Mg (%)	Ti (%)	Ni (%)	Cr (%)
A356	7.2	0.02	0.35	0.12	0.01	0.02	0.01	0.04	
A359	8.5	0.1	0.1	0.2	0.2	0.5	0.2		
A6061	0.8		0.15	0.7		1.2	0.15		0.35

Composites are manufactured with great achievement by the use of fiber reinforcement materials (SiC, Al₂O₃, fly ash, CNT, AlN) in matrix metallic materials. The aim concerned in designing MMC materials is to unite the attractive attributes of metals and reinforcement [6]. In reinforced MMC, reinforcement particle is mixed to the matrix of the mass material to boost its stiffness and strength. Applications which are subjected to serious loads, or tremendous thermal variations, such composite is superior to any other fusion welding process [7, 8, 9].

METHODS:

Among the numbers of fabrication techniques existing for metal matrix composites, stir casting technique is usually accepted as a mainly promising way, at present practiced commercially. Its advantages are simplicity, flexibility and applicability to large quantity production. It allows a conventional composites fabrication route to be used, and therefore minimizes the final cost of the product [10]. Metal matrix composites are usually fabricated by Liquid Metallurgy Route or stir casting technique. A comparison of different fabrication methods are given in table 2

Table: 2 Comparative evaluations of the different techniques used for MMCs fabrication [9]

Method	Range of shape and size	Metal yield	Range of volume fraction	Damage to reinforcement	Cost
Liquid metallurgy (Stir casting)	Wide range of shapes; up to 500 kg	Very high, > 90%	Up to 0.3	No damage	Least expensive
Squeeze casting	Limited to perform shape	low	Up to 0.45	Severe damage	Moderately expensive
Powder metallurgy	Wide range; restricted size	high		Reinforcement fracture	expensive
Spray casting	Limited shape; large size	medium	0.3-0.7		expensive
Lanxide technique	Limited by pre-form shape; restricted size	-	-	-	expensive

In stir casting the particulate phases are mechanically mixed in the liquid phase before solidification of the melt [11]. Parameters such as unusual particle sizes, density, geometries, pour or the progress of an electrical charge throughout mixing may direct to agglomeration. [12] In this method, incorporation of matrix and reinforcement is a vital step to get a homogenous distribution of reinforcing particles in matrix. The reinforcement particles were mixed in a calculated mixer by stirring for few minutes and cast in a steel mold or sand mould [13]. Magnesium (1%) addition during the stirring improves the wettability of reinforcement with the melt aluminium [14]. The molten degasses in completely liquid condition with (Na-Cl and KF) blend then skimmed, followed with degassing by pure argon for 30 to 40 seconds [15]. After stirring, the molten composites are poured into the permanent mold, which was preheated to 200°C [16].

International Journal of Innovative Research in Science, Engineering and Technology

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The wear behaviors of the samples are investigated by a pin-on-disc wear test machine according to ASTM G99-95 standards. Amount of wear depends upon the sliding load, sliding radius, sliding speed, duration and material properties [10].

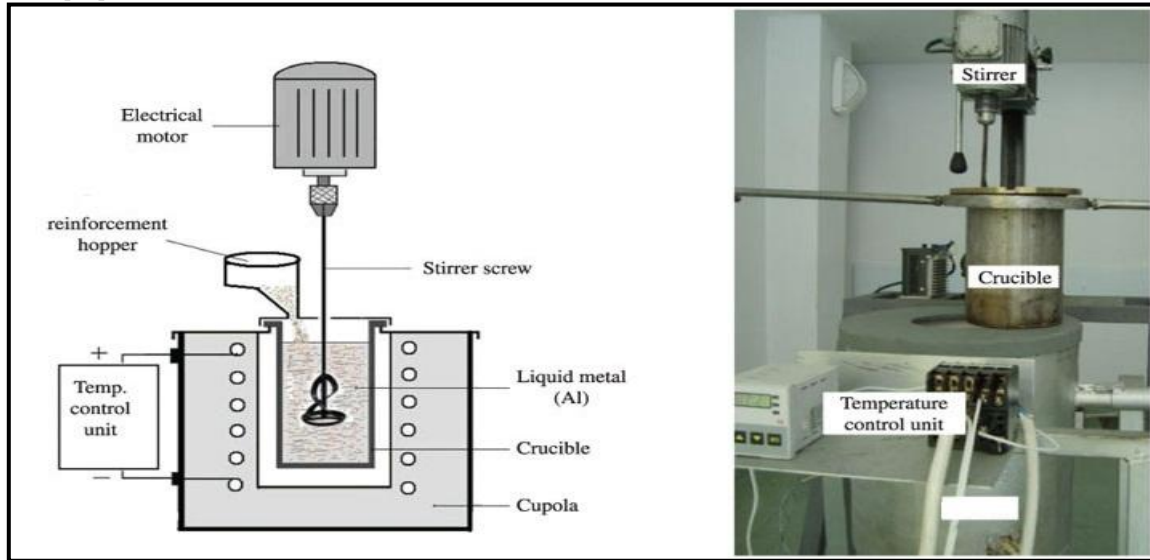


Fig. 1: Stir casting technique [20]

The tests perform under dry and lubricated conditions as per ASTM G99-95 standard. The pin at first cleans with acetone and weighed precisely by a digital electronic balance [17]. Throughout the test, the pin is held pushed touching a rotating steel disc (hardness of 65HRC) by applying load so as to acts as counterweight and balances the pin. The track diameter was varied for each batch of experiments in the range of 70 mm to 110 mm and the parameters such as the load, sliding speed and sliding distance are varies in the ranges known [18]. The difference between the first and last weights is measure of slide wear loss. For every condition, tests perform and the average value of weight loss is reported [19].



Fig. 2: Pin on disc wear testing machine [21]

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Vol. 4, Issue 8, August 2015

III. EXPERIMENTAL RESEARCH & RESULTS

A number of researchers had worked on wear analysis of aluminium based composites by stir casting process.

Y. Sahin [22] reported Optimization of testing parameters on the wear behavior of metal matrix composites based on the Taguchi method. In this research 2014 Al alloy was selected as the matrix whereas SiC particles with normal size of 50 and 100 μm were selected as the reinforcement particle. Composites materials were fabricated by stir casting technique. A standard Taguchi experimental plan with notation L16 (2^{15}) was chosen to find wear behavior in terms of signal to noise ratio. 4 parameters of 2 levels were selected. The parameters were 10 wt.% SiCp reinforced with 100 μm size & 50 μm , load of 5 N & 15 N, Abrasive grain size of 120 & 220 mesh, Sliding distance of 18 & 36 m. The results showed that grain size of the abrasive had the maximum effect on influence the most favorable testing condition. The weight loss noticeably amplified as grain size increased from 50 μm (220-mesh) to 100 μm (120-mesh). In addition, weight loss increased somewhat with the applied load and sliding distance.

S. Basavarajappa et. al [23] reported Application of Taguchi techniques to study dry sliding wear behavior of metal matrix composites. Aluminium alloy 2219 was used as the matrix. Two composites were fabricated by liquid metallurgy (stir casting), one with 15 wt% of SiCp reinforcement particles of size 25 μm and other with 15% SiCp reinforcement particles, 3 wt% of graphite is added with a particle size of 45 μm . The wear of the composite materials were studied as a meaning of the sliding distance, applied load and the sliding speed. In the present investigation, an L27 orthogonal array was chosen, which has 27 rows and 13 columns. The wear parameters chosen for the experiment was (i) sliding speed of 1.53 m/s, 3.06 and 4.59 m.s (ii) load of 9.81 N, 19.6 N and 39.2 N (iii) sliding distance of 500 m, 1000 m & 1500 m. And the results showed percentage contribution of all factors for SiCp reinforced composite were sliding distance ($p = 57.57\%$), load ($p = 24.34\%$) and sliding speed ($p = 6.8\%$). Though, the relations between sliding speed and load is ($p = 2.15\%$) and other factors were least. In case of Graphitic hybrid composite, the percentage contribution (p) of factors were sliding speed ($p = 57.24\%$) load ($p = 22.58\%$) and sliding speed ($p = 9.66\%$). However, the interactions between the factors were minimum. Sliding distance was the most predominant wear factor that had the maximum physical as well as statistical influence on the wear of both composites.

N. Natarajan et. al [24] reported Wear behavior of A356/25SiCp aluminium matrix composites sliding against automobile friction material. The wear behavior of brake drum material and its counterface friction material were determined in this investigation. A semi-metallic brake lining and two brake drum materials were chosen for the test. One of them is the commercially used gray cast iron and the other one is the MMC. The MMC was fabricated by the stir casting. A-356 aluminium alloy was chosen as matrix material and silicon carbide particle of size 43 μm as reinforcement particle. The results showed that. The wear of cast increased with applied load and sliding speed. The coefficient of friction was approximately stable because of the arrangement of stable friction film at the boundary. MMC is more wear resistance than the cast iron. The load and sliding velocity have less influence on the wear.

Sudarshan et. al. [25] reported Dry sliding wear of fly ash particle reinforced A356 Al composites. Aluminium A356 was chosen as matrix alloy and fly ash particles having wide size range (0.5–400 μm) and sieved fly ash particles having narrow size range (53–106 μm) as reinforcement material. Composites were made-up using stir-cast route. Composites having different particle sizes and volume fraction of fly ash were: composites with 6 vol. % fly ash particle (sieved), (C6S), composites with 12 vol. % fly ash particle (sieved), (C12S) and composites with 12 vol. % fly ash particle (C12AR). Wear tests were performed in air at ambient temperature using a Pin-on-Disc Machine. And the results showed decrease in wear rates of A356 composites at 10N & 20 N when reinforced with 6 vol. % fly ash. At 12 vol. % of fly ash, composites showed lower wear rates when compared to unreinforced aluminum. Increase in friction co-efficient were noted when volume fraction of fly ash increased from 6% to 12%.

Kenneth Kanayo Alaneme et. al. [26] reported Corrosion and wear behavior of Al–Mg–Si alloy matrix hybrid composites reinforced with rice husk ash and silicon carbide. Al–Mg–Si alloy was chosen as aluminium matrix for the research. Silicon carbide (SiC) of particle size 28 μm and rice husk ash (RHA) of particle size μm were chosen as reinforcement materials for the fabrication of the hybrid composites. The Al–Mg–Si alloy matrix hybrid composites reinforced with RHA and SiC were manufactured by double stir casting technique. The quantitative amounts of rice husk ash (RHA) and silicon carbide (SiC) required to produce 5, 7.5, and 10 wt% reinforcement consisting of RHA and SiC in weight ratios 0:1, 1:3, 1:1, 3:1, and 1:0 respectively. The results showed similar wear surface topographies characterized typically by abrasive wear which occasional worn debris welded to the surface of the samples. The

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(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 8, August 2015

samples C5 and A0 were the little exceptions that showed extra main adhesive wear mechanism due to the great accumulation of debris noticeable on the surfaces.

D. Sujan et. al [27] reported Physio-mechanical Properties of Aluminium Metal Matrix Composites Reinforced with Al₂O₃ and SiC. In this research aluminium A356 was chosen as matrix alloy and Al₂O₃ and SiC of particle size 400µm were selected as reinforcement materials. Composites were fabricated by liquid metallurgy route with the weight fraction of 5%, 10%, and 15% of both reinforcement materials. Wear analysis for the reinforced aluminium matrix composites were done by using the wear test on pin on disc machine. The test was done by applying a steady load of 10N onto the sample as the sample is in contact with a 600 grit SiC adhesive paper at 300 rpm and 400 rpm grinding speeds for a set time period of 5 minutes. The results showed that the wear rate increased with the increase of grinding speed (rpm). Composites reinforced with SiC showed lower wear rates as compared to composites reinforced with Al₂O₃. For instance, the wear rate for Al with 15% SiC composite was only 0.126 mm³/m which was about 50% of the wear rate of 1005 Al (0.255 mm³/m).

Mohsen Hossein-Zadeh et. al [28] reported Structural and mechanical characterization of Al-based composite reinforced with heat treated Al₂O₃ particles. In this research aluminium A356 was chosen as matrix alloy and Al₂O₃ particles with average particle size 30 µm was chosen as reinforcement material and composites were fabricated by stir casting by heating aluminium ingot at the temperature of 730°C with heating rate of 20°C/min to 500°C and 10°C/min later. The result of wear test showed that inclusion of Al₂O₃ particles to alloys contributes in improving the wear resistance of aluminum to a huge level. The wear resistance of Al–Al₂O₃ composite materials increased by the adding of 1.00 wt. % heat treated alumina particles in all distances. The wear resistance property of Al–Al₂O₃ composites is better than A356 alloy.

B. N. Pramila Bai et. al. [29] reported Dry sliding wear of A356-Al-SiC_p composites. Aluminium alloy A356-SiC_p composites were fabricated by casting method. Composites were made by stir casting having 15% and 25% by weight of SiC particles of average size 43 µm. Experiments were conducted using a pin on disc method, consisting of sliding pins of test samples touching hardened En24 steel discs. The SEM images showed diametric sections of wear surfaces, cut parallel to the wear tracks and perpendicular to the worn surface. SEM of 25% SiC composite showed comparatively a smaller amount material flow close to the surface. The enhancement in wear resistance was considered at this point to be due to changes in wear mechanisms brought about by the occurrence of SiC reinforcement particles which decreased the tendency for material flow at the surface, and the configuration of iron-rich layers on the surfaces of composites throughout sliding.

N. Radhika et. al. [30] reported Tribological Behavior of Aluminium/Alumina/Graphite Hybrid Metal Matrix Composite Using Taguchi's Techniques. Al-Si10Mg alloy was selected as the matrix materials as its properties can be modified through heat treatment. And graphite of average size of 50 to 70 microns and alumina of average particle size 15-20 microns in particulate were chosen as reinforcement particles. Care was taken to keep optimal casting parameters of stirring speed (350 rpm), stirring time (3 min) and pouring temperature (700°C). Wear tests of the composites were performed on the pin on disc test machine. And the results showed that Sliding distance (46.8%) has the maximum effect on wear rate followed by applied load (31.5%) and sliding speed (14.1%) and for coefficient of friction, the contribution of sliding distance is 50%, applied load is 35.7% and sliding speed is 7.3%. Inclusion of graphite as reinforcement material increased the wear resistance of composites by forming a shielding coating between pin and counter face.

J P Pathak et. al. [31] reported Synthesis and characterization of aluminium – silicon- silicon carbide composites. In this research pure aluminum Al-20 wt. % Si (master alloy) as matrix alloy and 2 wt. % and 3 wt. % SiC was selected as ceramic particles. Composites were fabricated by stir casting route. Wear tests were performed on pin on disc machine of cylindrical test specimen of 8mm diameter and 35 mm length. And the results showed that wear resistance amplified with increase in quantity of silicon carbide under the load applied. Wear resistance increased both due to the occurrence of SiC particles and oxides build up on the sliding surface. Junction hardening and removal of the particles are decelerated with increased hardness of the composites.

K. V. Mahendra et. al. [32] reported Characterization of Stir Cast Al-Cu-(fly ash + SiC) Hybrid Metal Matrix Composites. In this investigation Aluminum with 4.5% Cu was preferred as the matrix alloy. And fly ash and SiC of particle size 10 µm were chosen as reinforcement particles. The percentage inclusion of SiC and fly ash were 5 wt. %, 10 wt. % & 15 wt. %. Composites were fabricated by stir casting route. Wear tests were carried out in ambient conditions on pin on disc method. The wear tests on samples were carried out for applied load of 4.9 N, 9.8 N, 14.7 N,

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 8, August 2015

and 19.6 N and with constant sliding velocity of 80 m/s. It was observed from results that with increase in reinforcement's content wear decrease. This may be due to abrasive character of fly ash and SiC. It was also observed that with increase in applied load wear increases for loads of 4.9 N, 9.8 N, 14.7 N, and 19.6 N. Lesser diameter castings showed less wear than larger diameter castings.

Md AI Mehedi et. al [33] reported Tribological characteristics of aluminium matrix hybrid composites reinforced with SiC and Al₂O₃. Pure aluminium ingot (> 99.5% Al) and magnesium ribbons were used to make the matrix alloy. SiC and Al₂O₃ of particle size 106 µm were used as particulates. Pin on disc machine was used to analysis the wear. The results showed that weight loss had increased as the sliding speed increased for all samples. When reinforced with reinforcements weight loss gradually decreased for speed 1.89 m/s and 2.10 m/s. When the percentage of SiC was increased, i.e. doubled the weight loss decreased considerably. SiC particles were found to be superior wear resistant. The increase of load decreased the wear and increase of sliding velocity increased the wear rate. The increase in load moves the wear mechanism from abrasion to delamination wear mechanism.

IV. CONCLUSIONS

For every substance or materials to be used in military areas and defense, a number of properties must be achieved. These can be achieved by fabricating composites materials by different techniques. While the precise set of essential properties such as low density, good fatigue resistance, high hardness and high wear resistance are seen as common requirements for well-organized performance in the industrial areas. So this literature review makes a case of wear properties of aluminium based metal matrix composites by stir casting.

From this literature it composites materials can be manufactures by stir casting with different types of reinforcement materials,, which have been used by many researchers. And for wear analysis of composites samples are made in form of pin to test at pin on disc machine by different wear parameters such as load, sliding distance and sliding speed. Also the effects of these parameters on the wear behavior are taken into consideration. Some of the researchers have done their analysis by taguchi method, which is used to optimize the wear parameters to obtain minimum wear rate. it is really thought that Al-based MMC has amazing possible materials for use in the industry.

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Vol. 4, Issue 8, August 2015

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