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MECHANICAL AND DRY SLIDING WEAR BEHAVIOUR ON FLYASH/GRAPHITE/ MAGNESIUM PARTICLES REINFORCED ALUMINIUM (AL6061) METAL MATRIX COMPOSITES

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Abstract

The present investigation aims to evaluate the mechanical properties and wear behaviour of aluminium (AL-6061) reinforced with flyash, graphite and magnesium. The stirr-casting technique was used to fabricate the composites specimen as per ASTM standards. The reinforcement content was varied from 0 to 6wt.% of Flyash & Graphite and constant 5 wt.% of magnesium. A Mechanical properties was carried out on universal tensile testing equipment (Instron-1195). From the results it was found that the specimen made of Al6061+Mg 5wt.%,fly ash 6wt.% & graphite 3wt.% shows better modulus of elasticity. A pin-on disc wear test rig was used to evaluate the wear loss of composites. The results reveal that the wear loss of composites was less than that of the pure aluminium composites, but increased with increase of reinforcement in load and sliding speed. It was found that the wear resistant will increase with increase in percentage of filler content. The better wear resistance was observed by 6wt.% flyash filled Aluminium composites.

1. Introduction

Composite Materials in general are well established engineering materials with most of them possessing the advantages of higher specific weight and specific modulus and also better thermal stability, fatigue properties and wear resistance compared to many of the metals and alloys. Metal matrix composites (MMCs) are the forerunners amongst different classes of composites. Over the past two decades metal matrix composites (MMCs) have been transformed from a topic of scientific and intellectual interest to a material of broad technological and commercial significance. MMCs offer a unique balance of physical and mechanical properties. Aluminium based MMCs have received increasing attention in recent decades as engineering materials with most of them possessing the advantages of high strength, hardness and wear resistance. The stir casting method is widely used among the different processing techniques available. Stir casting usually involves prolonged liquid-reinforcement contact, which can cause substantial interface reaction.

Wear is an important property in the selection of discontinuous reinforced Al MMCs. Wear is not an intrinsic material property but characteristics of the engineering system which depend on load, speed, temperature, hardness, and the environmental conditions. Wear performances of aluminum matrix composites reinforced with various reinforcements ranging from very hard ceramic particulates such as SiC and Al-6061 to a very soft material such as graphite have been reported to be superior when compared with unreinforced alloys. In this present investigation an attempt is to find the influence of wear parameters on dry sliding wear and to establish correlation between sliding speed, load, sliding distance of these parameters on dry sliding wear of the aluminum and its composite using DOE's techniques. It can be concluded that fly ash, a low cost reinforcement can be used to make the composite material suitable for tribological applications From the literature review, it can be concluded that in order to study the influence of the Graphite and weight fraction of reinforced of fly ash as reinforcement on the aluminum alloy (Al-6061) composite and to study its effect on mechanical and tribological properties weight fraction of fly ash have been selected in the present study. Even though some of earlier investigations showed that the mechanical properties will be enhanced with increase in particle size, but a systematic study has not been carried out. Hence an attempt is made to the influence of these parameters on the various properties so as to explore it as an interesting and useful engineering material. The poor wettability of the phases in the matrix is the major problem at higher weight fraction of reinforcement, due to this problem the strength decreases after certain limit. From this problem we can overcome by adding small amount of Magnesium and by pre heating the composites and the die. The incorporation of fly ash particles in aluminium Alloy has the potential for conserving energy intensive aluminium, and thereby reducing the cost of aluminium products, and at the same time causing a reduction in the weight of the products. Graphite and graphite powders are widely used in industrial applications for their excellent dry lubricating properties. So, if a solid lubricant like graphite is contained in the aluminium alloy, it can be released automatically during the wear process [1]. HMMCs containing up to 15% fly ash and SiC particles could be easily fabricated. Uniform distribution of fly ash was observed in the matrix. The fluidity and density of HMMCs decreases, whereas hardness increases with increase in percentage of particulates. The tensile strength, compression strength, and the impact strength increases with increase in percentage of particulates [2]. By varying the reinforcing particulate from 0% to 4% found that as the graphite content was increased, there were significant reduction in hardness and monotonic increases in the ductility, ultimate tensile strength (UTS).The graphite contents used for the preparation of the composites were 0%, 1%, 2% and 4%. This is because graphite compositions of 7% and above would lead to rejection from the melt [4].J.Babu rao et al. given results that with increasing the amount of fly ash the density of the composites was decreased and the hardness was increased. The increase in compression strength was observed with increase in amount of fly ash. Fly ash

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particles lead to an enhanced pitting corrosion of the aluminum –fly ash (ALFA) composites in comparison with unreinforced matrix (AA 2024 alloy).

Experimental investigation of hybrid metal matrix composites with fly ash and graphite reinforced aluminum alloy (Al 6061) composites samples, processed by stir casting route are reported. The aluminum alloy was reinforced with 3 wt. %, 6 wt. %, 9 wt. % fly ash and fixed 3 wt. % of graphite to mixture the hybrid composite. Hardness of the hybrid composite were tested it was found that when the hardness of the hybrid composites can be increased when compared to (Al 6061)[9].

2. Preparation of MMCs

Fly ash / graphite reinforced Aluminium alloy (Al6061) composites, processed by stir casting route were used in this work. Liquid metallurgy route was used to synthesize the hybrid composite specimens. The matrix alloy was first superheated above its melting temperature and then the temperature was lowered gradually until the alloy reached a semisolid state. The required quantities of fly ash (3, 6 Wt. %), graphite (3,6 Wt %) and magnesium (5 Wt% constant) powder were taken in containers. Then the fly ash and graphite was heated to 450°C and maintained at that temperature for about 20 minutes. Fig 3.1 shows the furnace and stirrer. A vortex was created in the melt due to continuous stirring by a mechanical stirrer. At this stage, the blended mixture of preheated fly ash and graphite particles were introduced into the slurry and the temperature of the composite slurry was increased until it was in a fully liquid state. Small quantities of magnesium (5 Wt % fixed) were added to the molten metal to enhance wettability of reinforcements with molten aluminium. Stirring was continued for about 5 minutes until the interface between the particle and the matrix promoted wetting and the particles were uniformly dispersed. The melt was then superheated above the liquidus temperature and solidified in mould to obtain desired samples. Nitrogen gas was used as a degasified.

Fig 3.1: Stir casting Method

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3. Fabrication Process Parameters

3.1. Stirring speed

Stirring speed is the important process parameter as stirring is necessary to help in promoting wettability i.e. bonding between matrix & reinforcement. Stirring speed will directly control the flow pattern of the molten metal. Parallel flow will not promote good reinforcement mixing with the matrix. Hence flow pattern should be controlled turbulence flow. Pattern of flow from inward to outward direction is best. In this research work we kept speed from 300-600 rpm. As solidifying rate is faster it will increase the percentage of wettability.

3.2 Stirring temperature

Stirring temperature is related to the melting temperature of matrix i.e. aluminum. Aluminum generally melts at 650˚C. The processing temperature is mainly influence the viscosity of Al matrix. The change of viscosity influences the particle distribution in the matrix. It also accelerates the chemical reaction b/w matrix and reinforcement. In order to promote good wettability we had kept operating temperature at 630°C which keeps Al (6061) in semisolid state.

3.3 Reinforcement pre-heat temperature

Reinforcement was preheated at a specified 500˚C temperature 30 min in order to remove moisture or any other gases present within reinforcement. The preheating of also promotes the wettability of reinforcement with matrix.

3.4 Addition of Mg

Addition of Magnesium enhances the wettability. However increase the content above 1wt. % increases viscosity of slurry and hence uniform particle distribution will be difficult.

3.5 Stirring time:

Stirring promotes uniform distribution of the particles in the liquid and to create perfect interface bond b/w reinforcement and matrix. The stirring time b/w matrix and reinforcement is considered as important factor in the processing of composite. For uniform distribution of reinforcement in matrix in metal flow pattern should from outward to inward.

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4. Results and Discussions

The Metal Matrix Composites of aluminium 6061 reinforced with magnesium (constant proportion, 5% by weight), Graphite and Fly ash has got improved properties than the pure aluminium 6061 alloy. Following are the Graphs representing the properties of the various compositions.

4.1 Tensile Test

Tensile test specimens were prepared from the mmc according to the ASTM standards. Tensile tests were carried out in a universal testing machine on a INSTRON 1195 machine. The nature of the graph obtained for all the composition of composites is same but varying the values. Aluminium being the more ductile material, it is very difficult to find yield point.

The parallel line is drawn to a curve at 0.2% of strain value. The point of intersection of parallel line to the curve of stress strain diagram gives the yield point on the curve. The horizontal line which meets the stress axis drawn from the intersection point gives the proof stress value.

4.1.1 Al 6061

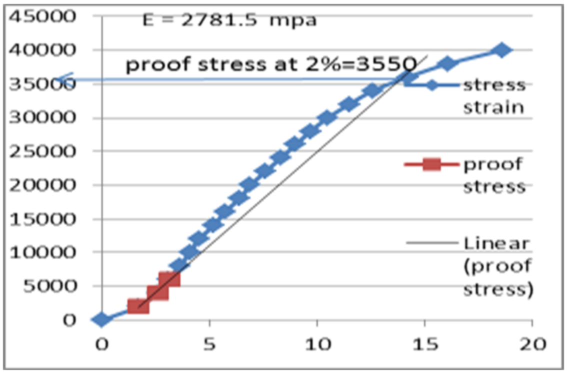

Fig 4.1.1: S-S Curve of composite for Al6061

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4.1.2 Al 6061 + 5% Mg + 3% Fly ash

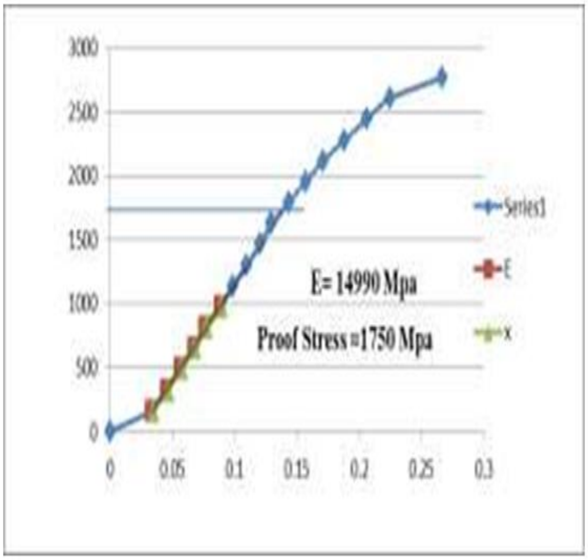

Fig 4.1.2: S-S Curve of composite for 3% fly ash

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4.1.3 Al6061, Mg=5%, flyash=6%

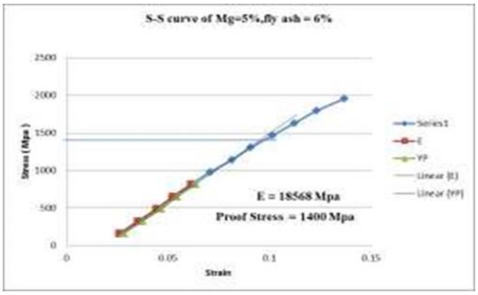

Fig 4.1.3: S-S Curve of composite for 6% fly ash

4.1.4 Al 6061, Mg=5 %, Fly ash = 3%, Graphite = 3%

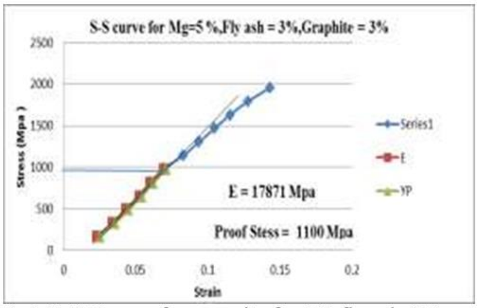

Fig 4.1.4: S-S Curve of composite for 3% fly ash, 3% graphite

4.1.5: Al 6061, Mg=5%, Fly ash =6%, Graphite = 3%

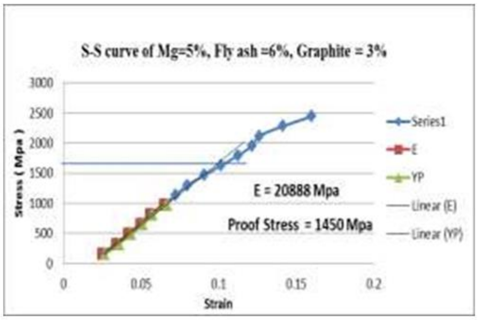

Fig 4.1.5: S-S Curve of composite for 3% fly ash, 6% graphite

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4.1.6 Al 6061 + Mg=5%, Fly ash= 6%, Graphite = 6%

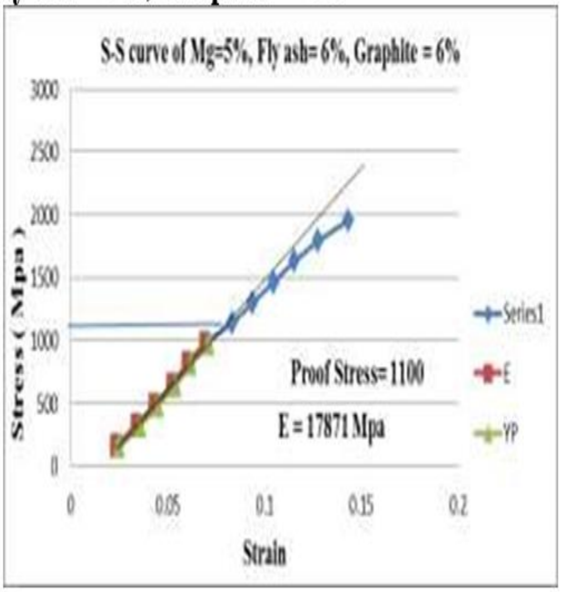

Fig 5.1.6: S-S Curve of composite for 6% fly ash, 6% graphite

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Table 1: Mechanical Property

Sl. no	Composition	Modules of elasticity (E) Mpa	Proof stress at 2% Mpa
1	Al6061	2781.5	3550
2	Al 6061, Mg 5%, Fly ash 3 %	14990	1750
3	Al 6061, Mg 5%, Fly ash 6 %	18568	1400
4	Al 6061, Mg 5%, Fly ash 3%, Graphite3 %	17871	1100
5	Al 6061, Mg 5%, Fly ash 6%, Graphite 3%	20888	1450
6	Al 6061, Mg 5%, Fly ash 6%, Graphite 6%	17871	1100

4.1.7 Comparison of Tensile properties of composite

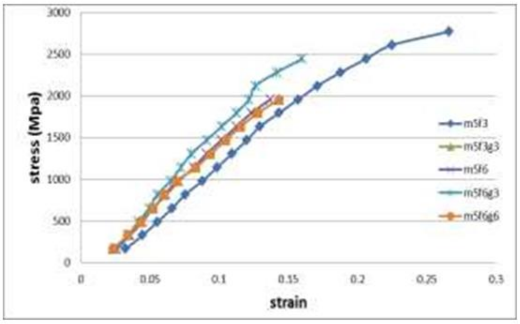

Fig 5.1.7: Comparison of Tensile properties of composite

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5. Sliding Wear test

Wear is the progressive loss of materials from contacting surfaces relative in motion. Along with fatigue and corrosion, wear has been known as one of the three major factors limiting the life and performance of an engineering component and an engineering system, whether the system is as big as a heavy machine, or as small as a tiny electronic device.

The measurement of wear is the most important property evaluation as all the mechanical parts are subjected to wear. Therefore the tribological measures describe the operating condition of the parts. Following table gives the reading of wear test. The wear rate can also be calculated to determine how much material in gm is removed per mm of the specimen. In a pin-on-disc wear tester, a pin is loaded against a flat rotating disc specimen such that a circular wear path is described by the machine. The machine can be used to evaluate wear and friction properties of materials under pure sliding conditions. Either disc or pin can serve as specimen, while the other as counter face. Pin with various geometry can be used. A convenient way is to use ball of commercially available materials such as bearing steel, tungsten carbide or alumina (Al_2O_3) as counter face, so that the name of ballon-disc is used. The wear can be obtained either in the form of volume loss or mass loss. If the mass loss is considered then the wear rate is the ratio of wear to the sliding distance. The equation of wear is given below:

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Wear rate = Wear loss/ (Sliding Distance * load)

Where,

Composition	Diameter Of Specimen (mm)	Applied load (kg)	Speed rpm	Initial Weight, w_1 (gm)	Final Weight, w_2 (gm)	Wear (w_1-w_1) (gm)	% Wear (w_1-w_1)/ (w_1)	Wear rate Wear/(πD) in gm/m
Pure Al 6061	6	0.5	1000	2.723	2.720	0.003	0.110173	0.001194
	6	1	1000	2.582	2.581	0.001	0.03873	0.000398
	6	1.5	1000	2.586	2.581	0.005	0.193349	0.00199
Al 6061 + Mg 5% + Fly ash 3 %	6	0.5	1000	2.571	2.570	0.001	0.038895	0.000398
	6	1	1000	2.570	2.569	0.001	0.038911	0.000398
	6	1.5	1000	2.569	2.567	0.002	0.077851	0.000796
Al 6061 + Mg 5% +Fly ash 6 %	6	0.5	1000	2.611	2.610	0.001	0.0383	0.000398
	6	1	1000	2.610	2.607	0.003	0.114943	0.001194
	6	1.5	1000	2.607	2.604	0.003	0.115075	0.001194
Al 6061 + mg 5% + Fly ash 3%+ Graphite3 %	6	0.5	1000	2.473	2.472	0.001	0.040437	0.000398
	6	1	1000	2.472	2.470	0.002	0.080906	0.000796
	6	1.5	1000	2.470	2.469	0.001	0.040486	0.000398
Al 6061 + mg 5% + Fly ash 6% + Graphite 3%	6	0.5	1000	2.732	2.731	0.001	0.036603	0.000398
	6	1	1000	2.731	2.729	0.002	0.073233	0.000796
	6	1.5	1000	2.729	2.722	0.007	0.256504	0.002787
Al 6061 + mg 5% + Fly ash 6% + Graphite 6%	6	0.5	1000	2.706	2.703	0.003	0.110865	0.001194
	6	1	1000	2.703	2.701	0.002	0.073992	0.000796
	6	1.5	1000	2.701	2.700	0.001	0.037023	0.000398

6. Conclusions

The Metal Matrix Composites of aluminium 6061 reinforced with magnesium (constant proportion, 5% by weight), Graphite and Fly was prepared by the stir casting method with Al6061 as the matrix and Fly ash as the reinforcement. The various weight fractions of fly ash and Graphite were used with fixing Al-6061& mg. The Tensile Strength and Hardness increased with the increase in the weight fraction of reinforced fly ash. The enhancement in the mechanical properties can be well attributed to the high dislocation density. However, for composites with more than 15% weight fraction (from literature survey) of fly ash particles, the tensile strength was seen to be decreasing.

The following conclusions are obtained from the experimental work,

1. For 3% addition of fly ash, the modulus of elasticity is increased by 23.86%, proof stress is decreased by 20 %, wear rate is increased by 50%.
2. For 3% increase in graphite, the modulus of elasticity is increased by 19.2194%, proof stress decreased by 37.14%, wear rate is decreased by 50%.
3. For 3% addition of fly ash and 3% increase in graphite the modulus of elasticity is increased by 39.34%, proof stress decreased by 17%, no change in the wear rate.
4. For 3% addition of fly ash and 6% increase in graphite the modulus of elasticity is increased by 19.219%, proof stress decreased by 37.142%, wear rate is decreased by 50%.
5. From the above data the stiffness of the material seems to increase for every 3% addition of fly ash and 3% addition of graphite, decrease in proof stress indicates that the plastic deformation can be done easily.

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