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Effect of Heat Treatment on Wear Rate of Al-4.5% wt. Copper Matrix Reinforced with Graphite and Zircon Sand Hybrid Composites

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***Abstract*: In the earlier period the global necessitate for low cost, high performance and superior quality materials has made a shift in research from conventional materials to composite materials. In case of Metal Matrix Composites, aluminum matrix composites are broadly used in structural applications, aerospace and automobile industry due to their high strength to weight ratio, low cost and high wear resistance. In this investigation the effects of, individual and combined Zircons and, Graphite reinforcements and T6 heat treatment on the wear rate of Al-4.5%Cu alloy composites were examined. The matrix combination with Al-4.5%Cu as base was assorted in terms of weight percentages of zircon sand (2%, 4%, 6%, 8%) and constant 2% Graphite. of hybrid composite samples fabricated by using stir casting technique. The wear rate of these models was investigated prior to and after T6 heat treatment by means of pin on disc machine at room temperature under dry sliding conditions. These outcomes provide insight view of outcomes of reinforcements on particulate reinforced composites. These end results are compared with T6 Heat treatment and effect of the similar is evaluated.**

***Keywords*: Stir casting, T6 heat treatment, scanned electron microscope, wear rate.**

1. Introduction

Aluminum matrix composites (AMCs) are the proficient material in the industrial world. Due to its exceptional mechanical distinctiveness, AMCs are mostly used in aerospace, automobiles, marine etc. [1], [3]. Al MMCs are generally armored with continuous fibers, short or chopped fibers, whiskers and particulates. Interests have been heading towards particulate armored Al MMCs for their exceptional mechanical and wear resistance home. Particulate armored composites are recognizable in utilize owing to their accessibility, less cost, sovereignty of mechanical traits from particulate orientation [4].The diverse reinforcements that have been strived out to grow aluminium matrix composites (AMC's) are graphite, silicon carbide, titanium carbide, tungsten, boron, Al_2o_3, fly ash, Zr, TiB_2.It has been establish that the mechanical traits of aluminium matrix composites are influenced by the volume fraction of the reinforcement particles [5]. Stir casting method is the most capable method for manufacturing particulate armored aluminum alloy composite, since its simplicity and flexibility to all shapes of castings and stir casting is generally recognized processing route which is practiced commercially [6]. The homogeneity of reinforcement and identical distribution of reinforcement particles in metal matrix based upon stir casing factors [7]. Zircon has been established to be a capable reinforcement in aluminum alloys owed to its higher hardness and modulus of elasticity [8]. Self-lubricating composites are fabricated due to their less friction and wear, thermal expansion and damping capacity by accumulation of graphite as particulate reinforcement [9]. Heat treatment is a process in the production of an engineering materials system. The main intention of heat treatment is to compose the material structure physically and structurally fit for engineering application [10]. Wear is taking away of material from a solid exterior as a consequence of the sliding action of one more solid and is attributable to friction, fatigue or vibration [11]. The wear of materials can happen due to adhesion, abrasion, surface fatigue or tribolo chemical reaction [11]. Both sliding exteriors are flawed by these processes [12]. The sliding exteriors experience a little deformation that may be fully elastic or some additional plastic deformation [13].

2. Material Selection

In this research the materials employed for the fabrication of composites are: pure Aluminum, hardener, with 4.5%wt Copper powder as base matrix, Zircon sand with 40µm average particle size and Graphite of size 35µm as reinforcement materials, hexachloroethane (C_2Cl_6) and Scum powder. The chemical composition of base matrix Al-4.5%Cu is given in the Table 1.

Table 1
Chemical composition of Al-4.5%Cu

Element	Cu	Mg	Si	Fe	Mn	Ni
wt. %	4.51	0.061	0.52	0.59	0.13	0.06

Pb	Sn	Ti	Zn	Al
0.03	0.02	.012	0.12	Balance

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3. Experimental Procedure

Stir Casting is a liquid state procedure of composite materials fabrication, in which a discrete phase (ceramic particles, short fibers) is assorted by means of means of mechanical stirring in a molten matrix metal. The liquid composite material is then shed by conventional casting methods and may also be practiced by conventional Metal forming technologies. The samples were produced by keeping the fixed percentage of copper, aluminum. High purity Aluminum free from contamination was charged in a graphite crucible kept in an electrical resistance furnace. At the beginning of melting of pure aluminum, the furnace temperature was increased to 750^{O}C. and 4.5% copper was bring in into the molten pure aluminum by means of hardener (50%Al–50%Cu). The cause was to make easy melting of the charged copper. By progressive liquefying the furnace temperature was increased to 800^{O}C. Dirt from the Aluminum liquefy or dross was then taken out from the surface of liquefy metal. The liquefy was degassed by using hexa chloromethane (C_2Cl_6) at 750°C, for confiscate dissolved hydrogen gas and Scum powder was utilized as slag removing agents. The accumulation of zircon sand and graphite will be further on the percentage weight of the aluminum alloy. The mixture begins from 2% by weight and added up to 8% by weight, with the augmentation of 2% per trial. First Zircon sand is assorted till 8% without accumulation of graphite and for a second time Zircon sand is assorted with Graphite with 2% by weight. Zircon average size 30µm and graphite of size of 35µm was pre heated to a temperature of 200^{O}C so as to confirm good interfacial bonding between the alloy matrix and the reinforcement. Then, the liquefy aluminum alloy is assorted with the preheated Zircon sand and graphite the mixture is stirred comprehensively with a mechanical stirrer for 3-5 min in a maneuvering way to ensure the entire inclusion of particles. In the finishing stirring stage the furnace temperature was restricted between 760 and 780^{O}C and dispensing was restricted to a temperature of about 750^{O}C. Slags and oxides are get rid of before pouring. The molten metal is dispensed into preheated finger mould die. The samples shown in table 2 were produced.

Table 2
Composition of different composites prepared

Sample No.	Composition of Composites
1	Al-4.5%cu base
2	Al-4.5%cu+2% Zr sand
3	Al-4.5%cu+4% Zr sand
4	Al-4.5%cu+6% Zr sand
5	Al-4.5%cu+8% Zr sand
6	Al- 4.5%cu+2% Zr sand +2% Gr
7	Al-4.5%cu+4% Zr sand+2% Gr
8	Al-4.5%cu+6% Zr sand +2% Gr
9	Al-4.5%cu+8% Zr sand +2% Gr

The composite samples were subjected to solution sing treatment at a temperature 530^{O}C for a period of 2 hours using muffle furnace, followed by quenching in Air to room temperature, then artificial ageing treatment was carried out for duration of 5 hours.

Pin on Disc equipment was used to conduct the Dry Sliding Wear Test on as cast along with heat treated samples in concurring to ASTM G99-95standards. The cylindrical specimens of 8 mm in dia along with 30mm height were buffed on the end earlier to investigating to coarseness (Ra) of 0.8µm level. Single pan electronic weighing machine was utilized to measure the earliest weight of the sample with the slightest count of 0.0001grams for the period of the test the pin be pushed in opposition to the counterpart revolving in opposition to disc made of EN32steel with 65 HRC hardness with exerting the load. Later than operating for a constant sliding distance, the samples were taken away, untainted by acetone, dried out as well as weighed to find out the weight loss owing to wear. The variation in the weight estimated before the test later than provides the wear of the composite sample after that the weight loss was estimated. Weight decrease was deemed as the basis for wear investigation (i.e., the variation between the initial and final weight).

4. Results and Discussion

A. Wear Test

Figure 1, illustrates the outcomes of dry sliding wear behavior of unheated treated and un heat treated cast Al-4.5% Cu and composites fabricated by means of varying wt. % of zircon reinforcement particles (2% -8% in increments of 2 %) with as well as without 2% wt. of graphite .The composites wear rate diminishes by increase in wt. % of zircon particles, this can be aspect to an assurance that the amalgamation of tough and the abrasive nature of Zircon particles progress the hardness of composites. The wear resistance enrichment and seizure opposition of the material essentially owes to progress in the hardness. As armored grains are robustly bonded by the base matrix, they safeguard the surface in opposition to the severe destructive action by the counteract face. The strong link between base matrixes in addition to reinforcement is the mainly vital aspect that convinces the wear that plays a vital function in changing loads as of the base matrix to hard reinforced particles. Moreover, it is examined that smaller permeability in the composite material can widen the necessary length of fracture propagation to an array by additional cracks to the reason for delimitation and augments the wear of the composite. We can examine that in amongst unheated treated composites Al-4.5%wt Cu armored by varying wt. % zircon (2% to 8%) of which Al-4.5%wt Cu+ 8% of Zircon encompass less wear confrontation cannot be unified by the higher hardness of the composite. Since supplementary parameters similar to gluing of material to the test sample along with the steel disc due to temperature should be taken into enlightenment.

The wear further diminishes by the accumulation of 2% wt. of graphite, this drop in wear may be due to the accretion of graphite particles which that perform similar to a lubricant and devises a tinny film along with the coupling surfaces. In dry sliding state aluminum-graphite composites end consequence in the progress of a ceaseless layer of unyielding lubricant that had formed above tribo-surfaces. This occur as an outcome of incise of graphite particles which are located below the gliding surface of composite that serve in dipping the amount of shear stress, which relieves the plastic distortion in the subsequent surface area, hampers metal-to-metal contact, besides accomplish like firm lubricant in the middle of two sliding exteriors accordingly wear decreases. We can examine that between un heat treated composites Al-4.5%wt Cu armored by 2%wt graphite changeable wt. % zircon (2% to 8%) of which Al-4.5%wt Cu+ 8% of Zircon+2%wt graphite having a reduced amount of wear resistance.

Heat treated base matrix, and composite, showed progressed wear resistance. Furthermore, it was found that a decline in the wear rate of hybrid composite. The heat treatment procedure did not significantly modify the morphology conversely coagulating of the matrix by precipitation. Coagulating took place that guide to superior hardness and potency which effected in fewer tendencies in support of crack nucleation at the matrix along with reinforcement boundaries confirmed enrichment in wear resistance. The smallest amount diminish of resistance to wear is 82.69 % witnessed at 8% zircon along with 2% graphite intended for heat-treated composite.

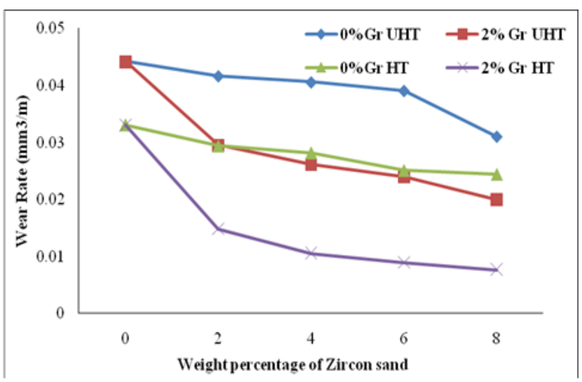

Fig. 1. Effect of reinforcement, graphite and T6 heat treatment on wear rate of Al-4.5% Cu reinforced with zircon and graphite composite samples

B. Morphological Analysis of Worm Surfaces

Figure 2, distinguishes that, the occurrence of grooves of changeable sizes was examined often on the worn exterior. The worn fragments are possible to work as third corpse abrasive specks. Zircon along with graphite specks trapped between the specimen and counter face grounds micro ploughing on top of the contact surface of the composite in stir casting. The wear exterior is described by a considerable transfer of matter stuck between the sliding surfaces. Zircon along with graphite may perhaps be discrete within the matrix alloy with superior bonding owed to which the wear confrontation occurred. further debris can be noticed in the tracks of gravity there is no crack initiation at matrix particle boundary.

The worn surface microstructure discovered the big amount of plastic deformation was examined on the exterior of the unarmored aluminum alloy. The worn-out exteriors are not even, also the grooves, scratches as well as parallel lines were viewed.

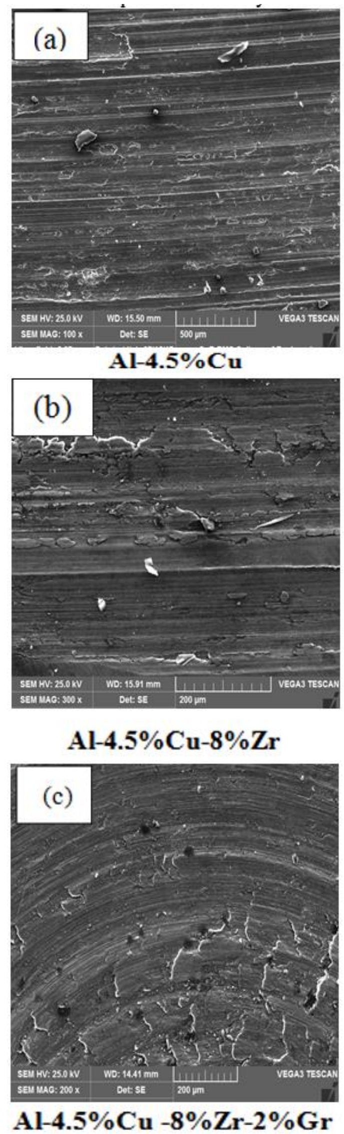

Fig. 2. Morphology of a) Al-4.5%Cu, b) Al-4.5%Cu-8, c) Al-4.5% Cu-4%Zr-2%Gr unheated treated wear samples

Figure 3, demonstrates the surface configuration of worn-out surfaces of heat-treated wear test samples. It is examined that the distance across and the extent of the grooves are fewer on top of heat-treated matrix alloy and its composites demonstrating higher wear opposition due to heat treatment process. This is for the reason that of enhanced hardness as well as strength of composites along with matrix alloy on heat treatment as discussed in the preceding section. Enhanced hardness and potency consequences in superior wear opposition to the material. But aged composites display superior wear opposition when contrast with matrix alloy.

The SEM and EDAX of Al-5 wt. %-Cu alloy wear sample reveal in the Figure 4. It was examined that the wear exterior with deep grooves because of plastic deformation. The ear rate is high the alloy. It is clear from EDAX the Fe peaks are also detected with Al and copper peaks, since that the fragments of the Fe particles detached from the disc is entrenched to the test sample surface.

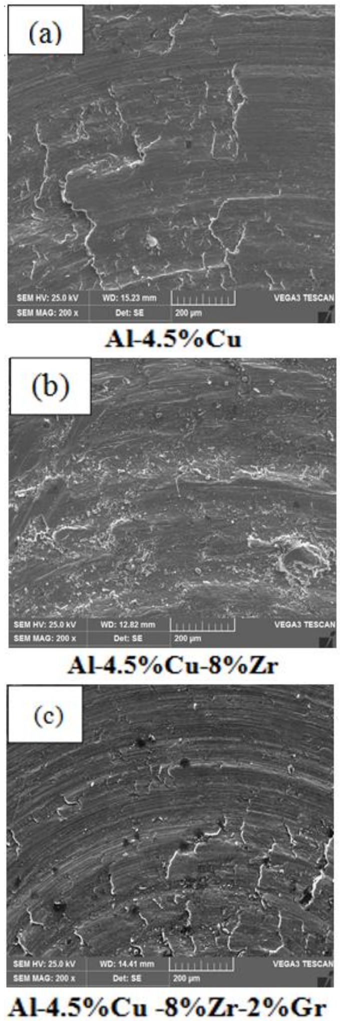

Fig. 3. Morphology of a) Al-4.5%Cu, b) Al-4.5%Cu-8, c) Al-4.5% Cu-4%Zr-2%Gr heat treated wear samples

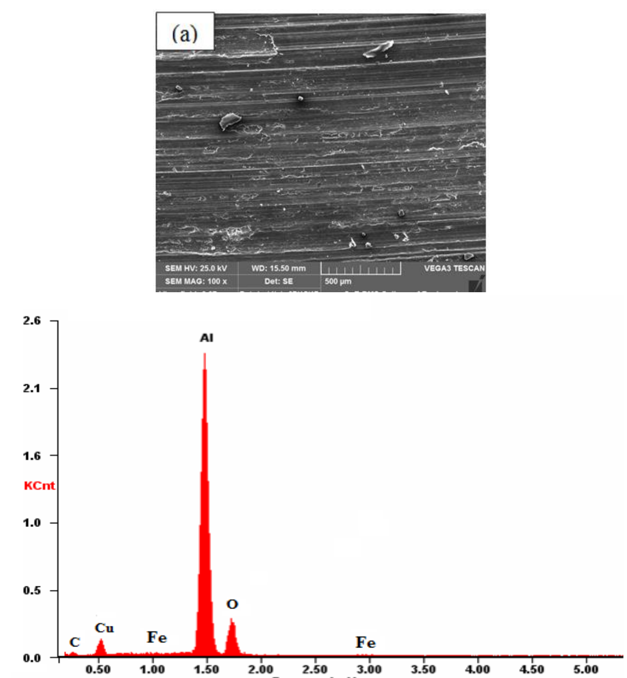

Fig. 4. a) & b) SEM of Al-4.5 wt.%Cu worn surface and its corresponding EDAX analysis

5. Conclusion

1. Al-4.5% wt. Cu armored by zircon and graphite Composites fabricated success fully by using sir casting method.
2. The resistance to wear of composites augments with increase in weight percentage of zircon, with addition of 2%graphite and with heat treatment.
3. The minimum decrease of wear resistance of 82.69 % is recorded at 8% zircon and 2% graphite for heat-treated composite.
4. The worn surfaces of the composites SEM demonstrates that composite alloy is commonly much uneven than that of the alloy. The distance and the number of grooves is less on the top of heat-treated matrix alloy as well as its composites.

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