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Evaluation of mechanical and dry sliding wear behaviour of Al 2214 aluminium alloy – graphite metal matrix composites

Aluminium metal matrix composites (AMMCs) gained an extensive popularity in different engineering fields monotonically due to their enhanced mechanical properties when compared to traditional monolithic metals. In the present investigation composites were produced using liquid metallurgy technique with modified stir casting approach with bottom pouring arrangement. Al 2214 aluminium composites have been successfully prepared with various percentage (viz. 0, 1.5, 3, 4.5, 6) of graphite reinforcement and their physical and wear behaviour have been analyzed. The experiment revealed that the amount of graphite in the matrix increased and the density reduces, hardness decreases beyond 1.5% of graphite, ultimate tensile strength and wear resistance of composites improved with increased addition of reinforcement. Optical microscope and energy dispersive X-ray (EDX) results shows uniform distribution and confirmed the existence of graphite particles in Al 2214 matrix phase.

Keywords: Al2214 alloy, graphite, tensile strength, microstructure, wear.

1.0. Introduction

In the recent day activity, utilization of aluminium metal matrix composites (AMMCs) enormously increasing in the various field of engineering with its virtue of strength to weight ratio and improved mechanical, wear resistance and thermal properties. AMMCs are extensively used in advanced automotive and aeronautical applications [Hemanth Joel, 2009; Kumar G. N, et.al., 2010; Wang J. 2009]. The need of light weight high performance, heat dissipation, structural materials made to prefer Al-cu alloys for automotive, aeronautical and consumer based materials manufactured industries. Thus instigate and urge are to develop and research of aluminium based metal matrix materials. Aluminium and flyash combination composites fabrication and characterization have been investigated by several researchers and published several research articles. As reported by past research investigations of aluminium with flyash were used to manufacture composites by following liquid metallurgical stir casting route [Singla Manoj, et al., 2009; Mahendra K V et al., 2007]. The matrix and reinforcement of common boundary surface reaction are most significant the formation of intermetallic bonding in liquid metallurgical route castings [Rajan T. P. D et.al., 2007; Ashok Kumar B et.al., 2012]. The proportionally adequate number of research investigations have been done on wear behaviour of graphite reinforced aluminium metal matrix composites and revealed a substantial growth in the wear resistance of cast ZA-27/Gr composites with increase in graphite reinforcement up to 1% addition (by weight). On further addition of graphite follow marginal enhancement of wear resistance. The dry sliding test of Al/Gr indicated that graphite smears at the sliding contact reduces wear losses, as well as reducing mechanical characteristics of the composites by more than 1.5 per cent [Seah K.H.W. et.al., 1995; Srivastava S. et.al., 2002]. The difference in coefficient thermal expansion composites with flyash cenospheres reinforcement and aluminium reinforced alloy was measured using dilatometer and revealed the coefficient thermal expansion of composite lower than pure alloy [Rohatgi P K. et al., 2005]. In wide range of structural and automobile applications, along with increase in wear resistance the mechanical properties also increase by combination of alluminium alloy reinforced with ceramic and graphite composite reveled transition to mild severe wear loss at load and sliding speed combination and were also higher than those of SiC reinforced composites and unreinforced aluminium alloy [Riahi A. R, Alpas A. T. 2001; Rhee S K. 1974]. The bottom pouring arrangement is the most essential set up for stir casting as compared to conventional stir casting method hence the stirred slurry should be immediately shifted into a preheated dies to control deposition at bottom end of the crucible [Harun M B. et al., 2006]. Although increased addition of percentages of flyash content is to raise porosity in composite which leads to decrease hardness and having

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TABLE 1: CHEMICAL COMPOSITION OF AL 2214 ALLOY (WT.%)

Element	Cu	Mg	Mn	Fe	Si	Zn	Ti	Cr	Al
Weight %	3.9-5	0.5-1.2	0.4-1.2	0.3	0.5-1.2	0.25	0.15	0.1	balance

highest porosity at 15 weight % of flyash and lowest hardness but hardness increases significantly with addition of SiC by developed a stir casting with bottom pouring for manufacturing metal matrix composites [Raj Ritesh. et al., 2016]. Further, the coefficient of friction reduces and it is more stable with increase in graphite content.

An attempt was made in the present research work to study mechanical and wear resistance behaviour of Al 2214 aluminium alloy and Al 2214-Gr composites. The various weight percentage of graphite reinforcement effect on matrix phase, varying load, speed and sliding distance on composites were investigated and studied. Effect graphite reinforcement on mechanical and wear resistance properties are discussed in detail.

2.0. Materials and experimental details

2.1 Materials

Aluminium (Al 2214) employed as matrix material in this study and the Table 1 shows the chemical compositions of Al 2214 alloy. This alloy was chosen because it has a good combination of strength and temperature tolerance. hence, it is suitable for high strength and thermal application like structural and heat dissipation due to its high thermal conductivity. Similarly, to its high temperature resistance, low density, low coefficient thermal expansion, and low coefficient of friction graphite selected as the reinforcement material.

2.2 Specimen preparation

After chemical composition density and hardness verification of Al 2214 alloy matrix material is cut into 25mm lengths, weighed, and hoarded in the crucible according to calculations, the recommended amount of aluminium alloy melted in a resistance heated muffle furnace. Simultaneously previously prepared cast iron dies with diameter 12.5mm and height 125mm were preheated before pouring molten metal composites. Once the melting point was attained at 720^{0}C the degassing of molten metal was sent out by using hexa chloro ethen tablets, at the same time graphite particles were preheated to the temperature of 400ºC for an hour to eliminate the moisture content. Further degasifying the slag incorporation are removing out from the melt and stirrer was brought into molten metal and also molten metal was stirred by an alloy stirrer at 200rpm about 45 minutes. Graphite was added into the melt in the formation of vortex. Melting temperature is maintained to 720ºC while adding preheated graphite particles of required amount in accordance with rule of mixture. After 45 minutes of stirred molten metal was poured into the preheated cast iron dies through bottom pouring manifold. The molten metal composites solidified and waited for natural convection to bring them to room temperature and taken out casted composites of dimensions of 12.5mm diameter and 125mm height. Further the samples were machined as per ASTM standard to various experiments.

2.3 Experimental procedure

2.3.1 Density measurement

The law of mixtures was used to determine the theoretical density of matrix material and composites. The physical density of pure Al 2214 and the composite was calculated using Archimedes' method, and the results are shown in Table 3.

2.3.2 Hardness measurement

Hardness of specimens were measured by Brinell scale as per ASTM E 10 standard using a 10 mm diameter ball indenter with a load of 500 kgf for 30 seconds, the load was applied. The specimen's hardness was tested at six different spots on its surface, and the average measurement is shown in Table 4.

TABLE 2: DETAILS OF REINFORCEMENT

Sl No.	Al 2214 (%)	Gr (%)
1	100	0
2	98.5	1.5
3	97	3
4	95.5	4.5
4	94	6

TABLE 3: EFFECT OF GRAPHITE ON COMPOSITES DENSITY

Material	Density in g/cc as per rule of mixture	Density in g/cc in actual measured
0.0% Graphite	2.74	2.74
1.5% Graphite	2.66	2.68
3.0% Graphite	2.62	2.64
4.5% Graphite	2.53	2.56
6.0% Graphite	2.50	2.52

TABLE 4: EFFECT GRAPHITE ON HARNESS OF COMPOSITES

Material	Hardness (BHN)
0.0% Graphite	56
1.5% Graphite	56
3.0% Graphite	52
4.5% Graphite	49
6.0% Graphite	45

2.3.3 Tensile strength testing

Ultimate tensile strength (UTS) was determined on the prepared samples of 60 mm gauge length and 12.5 mm diameter in accordance with an ASTM E- 82 standard at a room temperature by a computerized universal testing machine (BISS make 50 kN capacity). The results are shown in the Table 5

2.3.4 Wear testing

Dry sliding wear experiments were conducted by using pin on disc (Ducom make TR-201E, 200N capacity). The specimens prepared with diameter 10 mm and height 20 mm for experimentation. The tests were performed on various applied load 10 N, 20 N and 30 N with a speeds of 100 RPM, 200 RPM and 300 RPM. and results are shown in Tables 6, 7 and 8.

TABLE 5: EFFECT OF GRAPHITE (WT.%) ON TENSILE STRENGTH

Material	Tensile Strength (MPa)
0.0% Graphite	112
1.5% Graphite	120
3.0% Graphite	124
4.5% Graphite	120
6.0% Graphite	117

TABLE 6: WEIGHT LOSS OF MATERIAL AT 10N LOAD

% Graphite	100RPM	200RPM	300RPM
0.0	0.038	0.040	0.041
1.5	0.036	0.038	0.040
3.0	0.033	0.036	0.039
4.5	0.027	0.031	0.034
6.0	0.024	0.028	0.031

TABLE 7: WEIGHT LOSS OF MATERIAL AT 20N LOAD

% Graphite	100RPM	200RPM	300RPM
0.0	0.039	0.041	0.043
1.5	0.037	0.039	0.041
3.0	0.036	0.038	0.039
4.5	0.034	0.035	0.036
6.0	0.031	0.033	0.034

TABLE 8: WEIGHT LOSS OF MATERIAL AT 30N LOAD

% Graphite	100RPM	200RPM	300RPM
0.0	0.045	0.047	0.048
1.5	0.043	0.045	0.047
3.0	0.040	0.043	0.046
4.5	0.038	0.040	0.042
6.0	0.036	0.038	0.039

3.0. Results and discussions

3.1 MICROSTRUCTURE ANALYSIS

Metallographic studies tender a dominant and effective quality control and extensive analytical tool. The grain structure, size, shape and distribution of reinforced particle were observed using optical microscope. The samples were prepared using 120, 400, 800, 1000 grit size hand polishing silicon carbide sand papers. Finally, the samples polishing finished by cloth using diamond paste of 6 and 1micro meter and suspended in distilled water to get mirror finish surface. Microscopic investigation shows presence of reinforced graphite particles and fair distribution throughout the Al2214 matrix phase. The energy dispersive spectroscopy (EDS) analysis and microstructure of Al2214 + 3% Gr combination composite are shown in Figs.1 and 2. The EDS test reveals the peaks of Al, C, and O elements, as well as their weight and atomic percentages. As a result, the finding confirms the presence of graphite particles in synthesized composites.

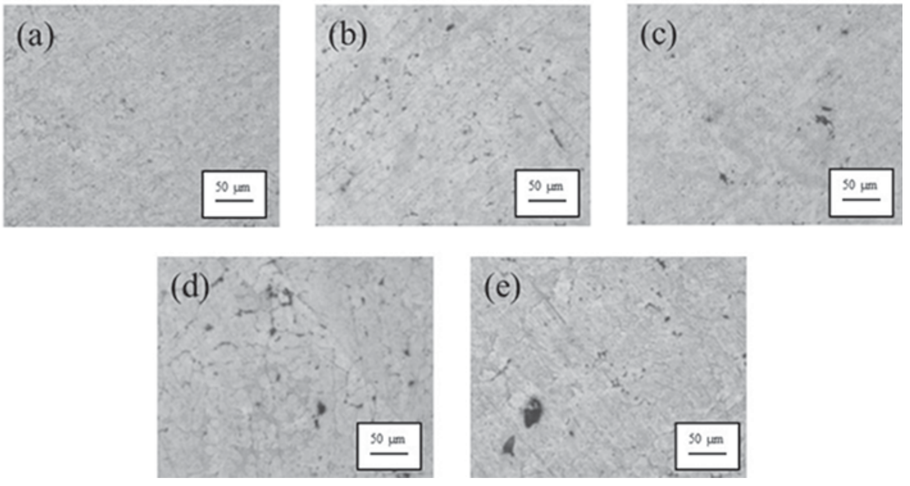

Fig.1: Microstructure of (a) 0%, (b) 1.5%, (c) 3%, (d) 4.5%, (e) 6% of Graphite - Al2214 composites

3.2 DENSITY

Fig.3 shows density variation of unreinforced alloy and composites with various graphite reinforcement presented in Table 1. The density was measured and calculated in both theoretical and experimental methods. Further the density values in both the methods almost aligning with each other and it reveals that there is a decrease in density with addition of graphite particles reinforcement. Thus indicating the composites fabrication is reliable with respect to the density.

3.3 HARDNESS

Fig.4 shows hardness disparity of the unreinforced alloy and composites and as mentioned in Table 2 Because of its

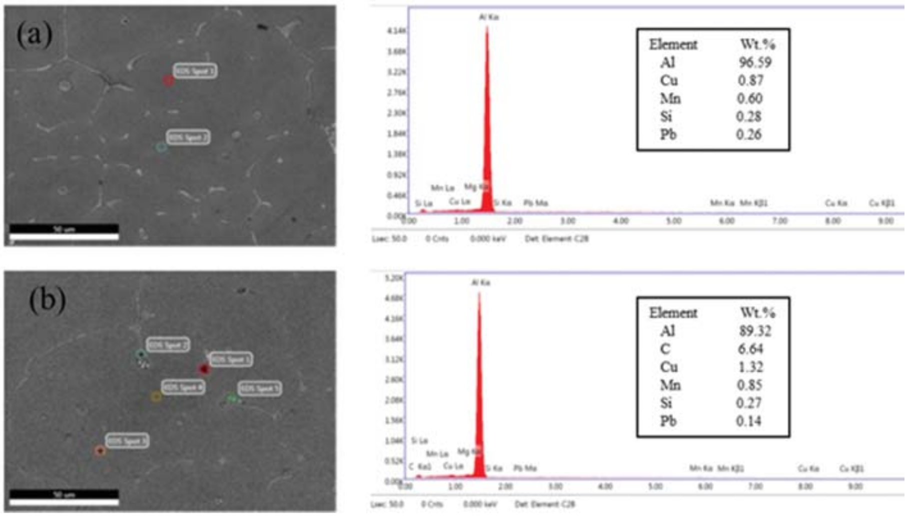

Fig.2: Energy-dispersive spectrum of (a) Al2214-0%, (b) Al2214-3% Gr particles composites

soft physical character and decreases density, the hardness of the composite material falls monotonically as the graphite particles increase, and these compromises are necessary to other property enhancements such as ductility and wear resistance by adding graphite

3.4 Tensile strength

Fig.5 shows the ultimate tensile strength (UTS) variation of Al 2214 alloy and its composites are as shown in Table 3. Due to increased ductility, there is a rise in ultimate tensile strength with increasing the proportion of graphite particle reinforcement up to 3 per cent, and thereafter the tensile strength declines marginally with further graphite reinforcement.

3.5 Wear analysis

The present investigation dry slide wear behaviour of composite is studied at a room temperature by pin-on-disc wear testing equipment. The prepared composites with various reinforcement samples with a diameter of 10mm and a height of 20mm were used in this experiment, and the samples radial face was placed normally to the flat circular disc

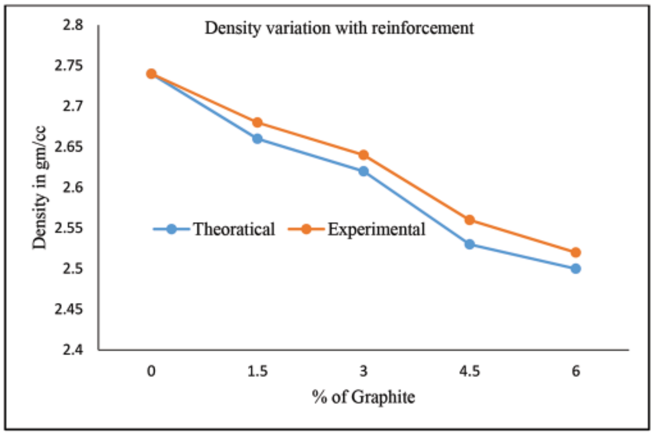

Fig.3: Theoretical and experimental density of Al2214-Graphite composites

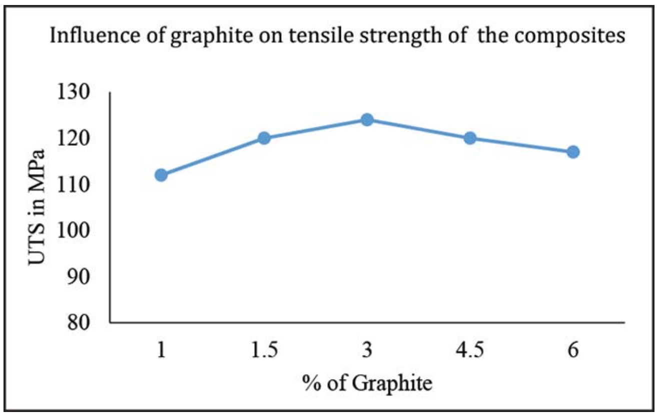

Fig.5: Tensile strength of AL2214-Graphite composites

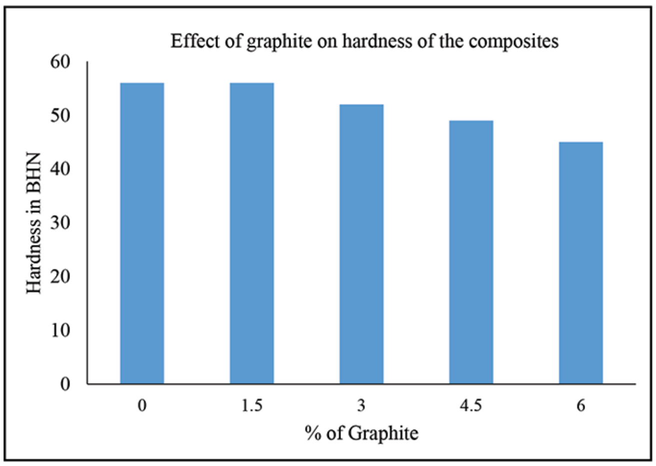

Fig.4: Hardness of AL2214-Graphite composites

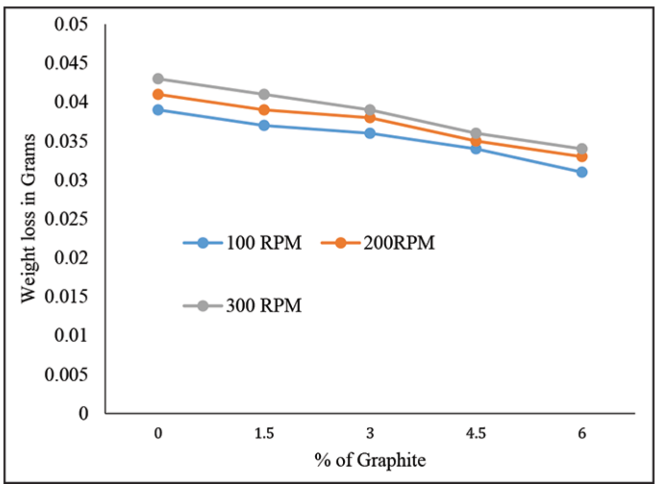

Fig.6: Variation of composites weight loss at 10N

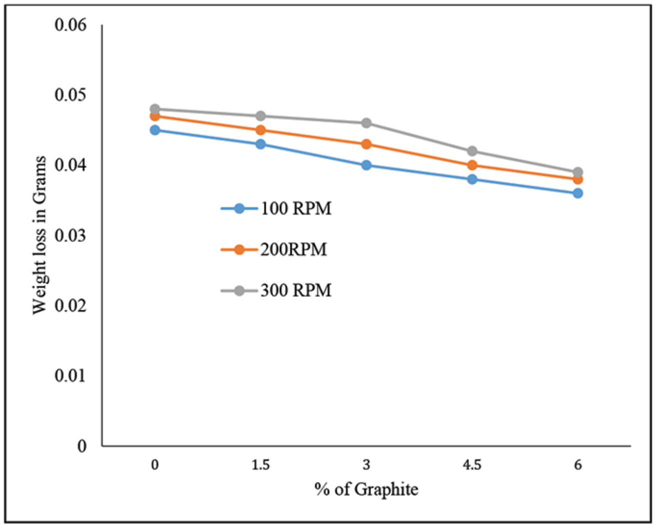

Fig.7: Variation of composites weight loss at 20N

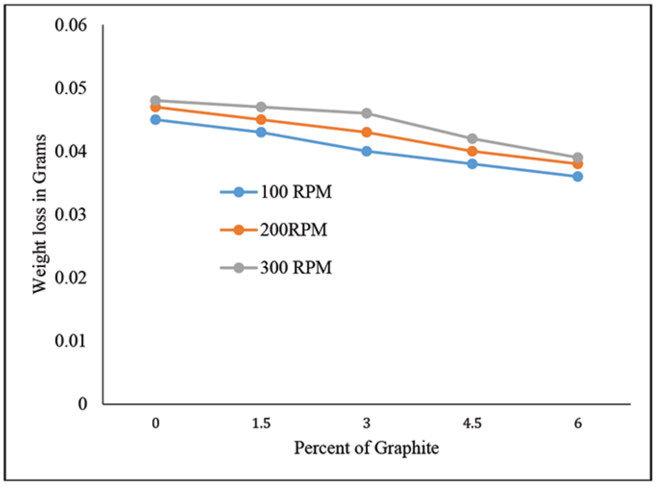

Fig.8: Variation of composites weight loss at 30N

and pressed against the disc at 10N, 20N and 30N loads with various speed 100RPM, 200RPM and 300RPM. The weight loss of samples as a result of dry slide wear was measured using a precision digital weighing machine. The results are shown in Table 4, and they show that as reinforcement increases, wear losses decrease, but wear rate increases as speed increases. The graph shows intensity of wear loss with increased percentage of composite reinforcements, load, and speed.

4.0 Conclusions

A series of Al 2214 aluminium alloy matrix composites containing 0, 1.5, 3, 4.5, and 6 weight percentage of graphite particulates were fabricated by modified bottom pouring stir casting method. Conclusions are derived based on microstructure, physical properties (density, hardness, UTS), sliding wear resistance with load and speed in addition to weight percentage of reinforcement. The important results of the study are:

- The relatively uniform dispersion of graphite particles are observed in Al 2214 matrix phase.
- EDX patterns ensure the existence of graphite particles in the matrix phase.
- The density decreases with increase in reinforcement of graphite in the composite.
- The hardness value of composites decreases with increase in graphite reinforcement due to increase in porosity.
- UTS of composites 15% is more at 3% of graphite as compared to unreinforced alloy.
- Dry sliding wear loss of Al 22114 and Al 2214/Gr composites were found under various load and sliding speed. The wear loss increases with an increase in load and decreases with an increased wear speed with the addition of graphite particles.

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