Investigation On Specific Wear Behaviour Of Al7075 Metal Matrix Composite Material With Nano Tio2 Particles

G T Danappa, R P Swamy, Raghavendra C R

Abstract: The hybrid metal matrix composite coating has found wide spread applications in the field of aerospace and automobile industries. In the present work the Al7075 is used as the major material and Gr micro particles along with nano TiO2 particles are reinforced in the composite material. The influence of nano TiO2 particles and Graphite particles in the composite material on specific wear rate is carried out. Normal load, sliding speed and sliding distance are kept constant for all the samples. Further work is concentrated on the influence of percentage of nano particles on the microhardness are evaluated. The results reveal that decrease in the specific wear rate by the presence of hard TiO2 and Graphite particles.

Keywords : nano composite material, specific wear rate, microhardness.

1. INTRODUCTION

The composite materials are not a new or recent one Nature is full of examples wherein the idea of composite materials is used. Nevertheless, one can safely mark the origin of the distinct discipline of composite materials as the beginning of the 1960s. The demands made on materials for better overall performance are so great and diverse that no one material can satisfy them. This naturally led to a resurgence of the ancient concept of combining different materials in an integral-composite material to satisfy the user requirements. Metal matrix composites (MMCs) generally consist of light weight metal alloys of aluminum magnesium, or titanium, reinforced with ceramics particulates, whiskers, of fibres. The Al-Cu and Al-Zn-based alloys are commonly used for making engineering components used in automobile and aeronautical industries [1]. Kalra et al. [2] Studied on the Hybrid Al/ (Al2O3+SiC+C) MMCs were fabricated by liquid stir with squeeze casting. In addition, an electrochemical micro-machining (ECMM) setup has been developed and utilized for micro-machining of hybrid MMC. They found increase in the wear resistance by 64.28 and 85.29%, when carbon particles reinforcement content increased from 3 to 5% and 3 to 7.5%, respectively. Papagiannakis. [3] worked on hybrid Aluminum matrix composite fabrication through stir casting route. Titanium Oxide (TiO2) and graphite (Gr) particles were used as reinforcement phases for the present study.

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The hybrid MMC was prepared with varying the TiO2 particles volume fraction ranging from 5% to 10%.and fixed quantity 3% of graphite. The average on reinforced particles size of TiO2 and graphite are 25 microns and 45 microns respectively. Singh and Goyal. [4] Worked on the micro structural and mechanical behavior of hybrid metal matrix composite based on aluminum alloy 6082-T6 reinforced with silicon carbide (SiC) and boron carbide (B4C) particles was investigated. For this purpose, the hybrid composites were fabricated using conventional stir casting process by varying weight percentages of 5, 10, 15, and 20 wt. % of (SiC +B4C) mixture. As compared to the un-reinforced alloy, the improvement in hardness and tensile strength for hybrid composites was found to be 10% and 21%, respectively. Baradeswaran and Perumal. [5] Investigated on the influence of graphite on the wear behavior of Al 7075/Al2O3/5 wt. % graphite hybrid composite. The investigation reveals the effectiveness of incorporation of graphite in the composite for gaining wear reduction. Similar work is also carried out using SiO2 and TiO2 [6]. Rajendran and Suresh. [7] Studied on the Aluminum Metal Matrix Composite (AMMC) to minimize defects usually associated in stir casting for materials during experimental evaluation. SiC and Fly ash was added in the composites in varying levels of 6%, 12% & 18%. Rao. [8] Experimental investigations done on the effects of the reinforcement particulate size and content on the Al7075/SiC composite. Sharma et al. [9] Work focuses on the effect of graphite particles addition on the properties of AA 6082 metal matrix composites fabricated by conventional stir casting method. The percentage of reinforcement was varied from 0% to 12% in a step of 3%. The results revealed that with the addition of graphite particles the micro and macro-hardness decreased by 11.11% and 10.44% respectively. Hence the present work concentrates on the fabrication of Al7075+Gr+TiO2 particles metal matrix composite materials by E-cap method. Further work is carried out on wear behaviour and microhardness of the metal matrix composites.

2. EXPERIMENTAL PROCEDURE

This process involves forcing a sample through an ECAP die with two cross-sections intersecting at angle (ϕ) ranging between 90° and 120°. Some dies have a rounded corner having an angle (ψ) at outer radius. The work piece is introduced into the channel at the top and is forced through the channel below by a punch. During pressing the billet is subjected to plastic strain by simple shear but retains its geometry. Repetitive pressings can be carried out, each pass refining the grain. During shear deformation by this process, the grain size gets reduced to sub micron levels resulting in improved mechanical properties which can be controlled by proper selection of processing parameters.

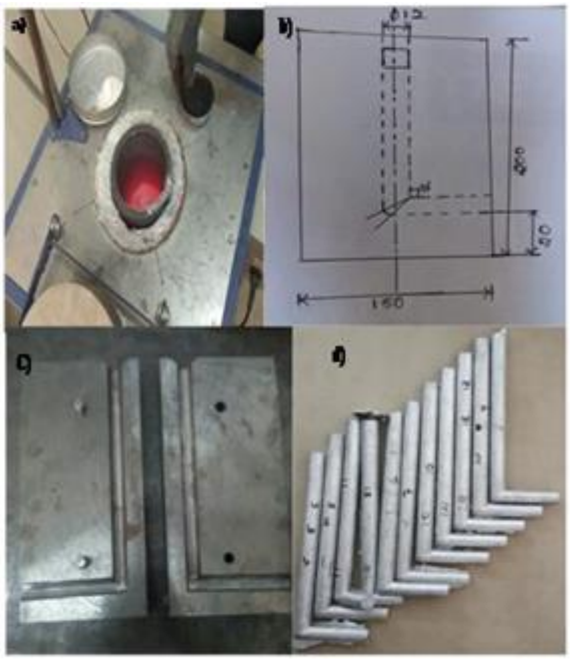

***Fig. 1**. Casting procedure and die details.*

The strain imposed by an ECAP die on a sample during a single pass primarily depends on the intersecting angle ϕ between the two channels. Besides, the outer radius represented by angle ψ has major implications on effective strain, homogeneity and texture. Experiments to date using ECAP has mostly used dies having ϕ= 90o and ψ= 0o. A single pass with this configuration gives an equivalent strain of 1.1 the amount of strain induced per pass reduces with an increase in angle ϕ as shown in Segal observed that rotating the sample between successive pressings modifies the shear directions and planes thus giving freedom to achieve distinct microstructure. The microstructure characteristics during ECAP depends on the precise processing conditions, and shear induced in each pass through the die Four processing 23 routes can be obtained by rotating the piece about its longitudinal axis between two successive passes.
Route A : there is no rotation of the sample between successive pressings
Route BA: alternate rotations of ± 90o
Route BC: forward rotations of + 90o
Route C: the billet is rotated by 180o between passes
The wear tests are carried out on pin-on-disc test rig. The wear parameters are maintained at constant applied load 10 N, sliding speed 200 rpm, and sliding distance of 600 m. The dry sliding wear tests are carried out on the coating surfaces by pin-on-disc test rig (Ducom Pvt. Ltd., Bangalore). Fig. 2 shows the pin-on-disc test rig used for the experimentation. The difference in the weight of the samples before and after the wear test is used to calculate wear rate. The testes were carried out for 3samples and the average value is considered for the analysis.

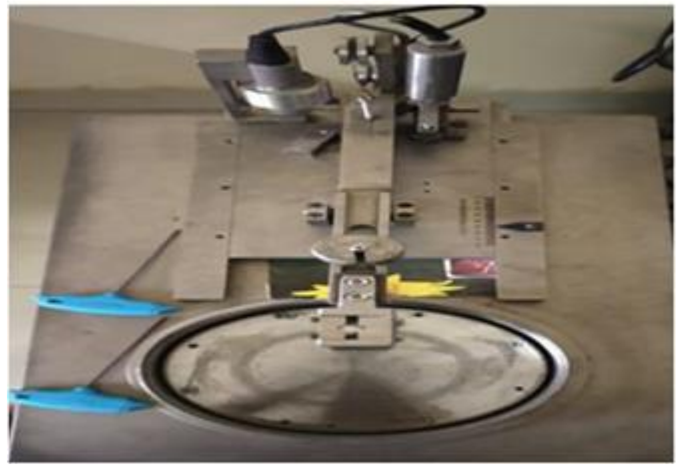

***Fig. 2**. Pin-on-disc test rig*

3. RESULTS AND DISCUSSION

A. Fabrication and composition analysis of Al70075+Gr+TiO2 composite materialAfter studying the literature survey we selected the Al7075, Graphite and Titanium Oxide. For the fabrication process we make different composition as shown in below table.

***Table 1** Different composition of composite coating*

% Al7075	% Gr	% TiO_2
100	0	0
95	2.5	2.5
97.5	2.5	0
97.5	0	2.5

After selection of the composition of the material we prepared the die for the casting process of the material by using ECAP method. The samples are casted by ECAP method where all the composition are weighed to mix as per our requirement , first we melted the AL7075 in a furnace and then for the proper mixing and for the proper weight composition the required amount of AL7075 is weighed and mixed up with TiO2 and Pb.

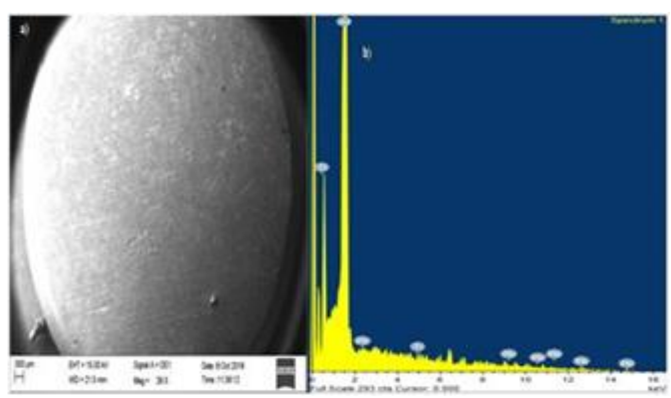

***Fig. 3** SEM and EDS analysis of composite material*

So as mentioned above by using the ECAP method the samples are casted for required composition and dimensions. Fig. 3 shows the SEM micrograph image of the composite material. The EDS analysis confirms the presence of the Al, TiO2, and Graphite in the composite material.

B. Study on wear behaviour of composite material.

Further work is carried out in order to study the influence of Nano TiO2 particles percentage in the composite material. The wear test was conducted for different % of nano TiO2 particles and results are tabulated in the below Table 3. The specific wear rate is found to be minimum for the combination of Gr 2.5 % and TiO2 particles of 2.5 %, where as the highest is found to be for the bare Al7075 without any reinforcement. That is a significant increase in the specific wear rate of

***Table 3**. Result of Wear test on the influence of Wear Parameter*

% Al7075	% Gr	% TiO_2	% of Vol. loss (mm^3)	Specific wear rate $x10^{-4}$ (mm^3/Nm)
100	0	0	4.326	7.21111
95	2.5	2.5	0.3605	0.600925
97.5	2.5	0	1.0816	1.80278
97.5	0	2.5	0.721	1.20185

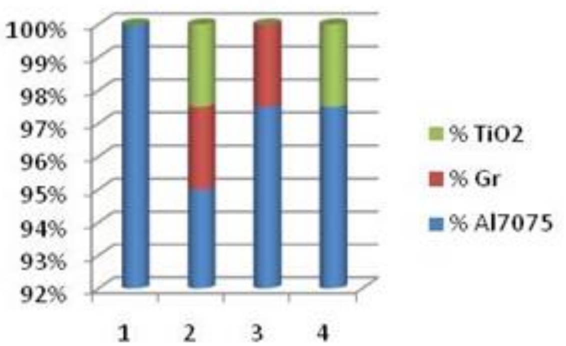

***Fig. 4**. Variation of specific wear rate with varying % of nano TiO2 particles*

By adding the above composition we got the following properties

1. The composition of Al7075 100% , Gr 0 % and TiO2 0% which improves the tensile strength, fatigue strength, fracture toughness ,Machinability, shear strength ,specific heat capacity and thermal conductivity of the material.
2. The composition of Al7075 95%, Gr 2.5% and TiO2 2.5% which improves the tensile strength, fatigue strength, fracture toughness, Machinability, shear strength ,specific heat capacity, thermal conductivity, melting point, boiling point and thermal expansion of the material.
3. The composition of Al7075 97.5%, Gr 2.5% and TiO2 0% which improves the tensile strength, fatigue strength, fracture toughness ,Machinability, shear strength ,specific heat capacity, thermal conductivity and thermal expansion of the material.
4. The composition of Al7075 97.5%, Gr 0% and TiO2 2.5% which improves the tensile strength, fatigue strength, fracture toughness, Machinability, shear strength , specific heat capacity and thermal conductivity of the material.

C. Microhardness

The micro hardness test is conducted on the square shaped Al7075, TiO2 and Pb sample by using IS: 1501-2002(RA 2007) test method by the micro hardness tester (Model- Matsuzawa, Japan/MMT-X7A) SI No. MMT 5421X. The microhardness is carried out under a 50 g load for 12 seconds dwell time and indentation speed of 25µm/sec. The microhardness tester is controlled by using touch-screen-based system, which is a part of the tester, and impressions of indentation are captured on a computer screen through digital camera. Average of three measurements is reported as a hardness value. The Table 4 shows the readings of the three values taken for microhardness.

***Table 4** test result*

LOCATION	HARDNESS HV0.5
1	119
2	117
3	117

D. Wear Morphology

The SEM analysis of the sample containing smallest spherulites shaped crystal at 28 magnification (Fig. 5 (A)).Thus SEM results also supports XRD results that addition of metal matrix composites did not bring any change in crystal morphology. Rod shaped crystals were still seen on further magnification upto 200(Fig. 5(B)). The magnification of 250 showed a small crystal linked together to form large shape crystals (Fig.5(C)). The scratch marks shown in the Fig. 5 (D), indicates the nature of wear is by pure adhesive wear.

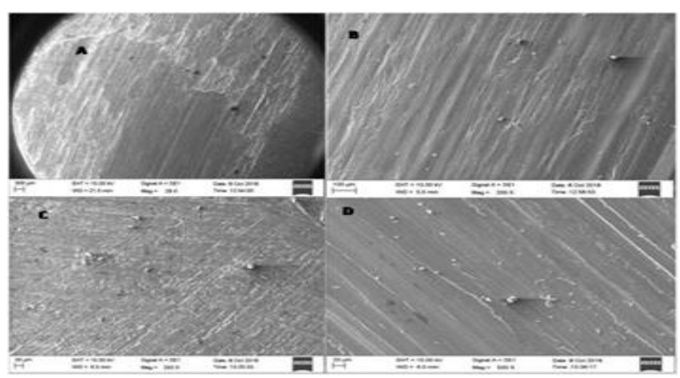

***Fig. 5**. Worn morphology of the composite material surface*

The quantitative analysis is acrried out on the worn surafce for the composition analysis. Fig. 6 shows the presence of Graphite and nano TiO2 particles along with Al. Table 5 shows the comsposition analysis carried out on the worn surafce.

***Table 5** composition table*

Element	Weight %	Atomic %
Al	99.06	99.72
Ti	0.37	0.21
Pb	0.57	0.07
Totals	100.00	100.00

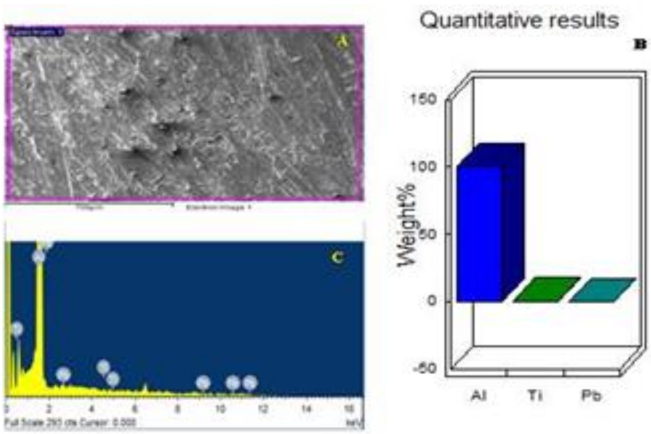

***Fig. 6** Quantitative analysis of the worn suraface.*

4. CONCLUSIONS

The present work concentrated on the preparation of Al 7075 Hybrid metal matrix composite in light of developing wear suit material. Hence, a hard nano TiO2 particles and self lubricating Gr particles are reinforced. The following conclusions are drawn from the experimental work:

- Fabrication of Al7075 and Nano particles were successfully done by the ECAP method which reduce the porosity for better performance.
- Morphology study reveals the presence of Gr and TiO2 in the composite material.
- Hardness of the aluminum metal matrix composite is 117.66 HV 0.5
- The wear morphology reveals the wear nature is by pure adhesive.

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