DRY SLIDING WEAR BEHAVIOUR OF ALUMINIUM 7075/SiC/MoS_2 COMPOSITES AT ROOM TEMPERATURE

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Abstract: *Al7075 aluminium alloy is the most favored material used in aero space, defense, automobile and various engineering purposes due to its exceptional properties. Due to poor resistance to wear property, it is restricted to use at various engineering applications. The wear resistances of aluminium alloys are improved by adding of ceramic reinforcement particulates. In the present work Al7075 aluminium alloy is selected as a matrix material and silicon carbide (SiC) selected as primary renforcement which has good compatibility with aluminium alloy and posse's excellent mechanical properties, high electrical resistivity, and good thermal conductivity. On other hand molybdenum disulfide (MoS_2) also used as secondary reinforcement (solid lubricant) to enhance the wear properties of composite materials in dry sliding wear condition at room temperature. The Al7075-3%SiC – 3%MoS_2 composites are fabricated via stir-casting process with increasing of molybdenum disulfide (MoS_2) by 4% and 5% respectively. The dry sliding wear test was carried out for the fabricated composites on Pin-on-Disk apparatus to estimate the wear rate of composites by considering progression parameters as normal load, sliding distance and sliding velocity during experimentation. Further, the wear surface analysis was carried out by optical microscopy analysis. This experimental result reveals that, the effect of molybdenum disulfide (MoS_2) in dry sliding wear condition of fabricated composites.*

Keywords: **Hybrid Composites, Stir Casting Techniques, Micro Structures, Wear rate, Dry Sliding Wear**

1. INTRODUCTION

A innovative set of advanced materials entitled metal matrix composites(MMC) substitute traditional materials because of unusual wear resistance characteristics, strength to weight ratio and in several applications for instance as pistons, cylinder liners and other materials etc. MMCs have been an interesting and competitive field of scientific analysis and research more than the past two decades, with MMCs being practical engineering materials mainly in recent times[1]. Aluminum-based composites contribute to the overall share of commercially produced MMC[2]. Aluminum material is very light metal which is frequently used in various types of industrial appliances and having a density of approximately 2.7g / cc after that to magnesium. This type of metals is frequently applied as the stand material in various manufacturing due to high strength to weight ratio and fast storage. Products based on aluminum are typically combined with durable terracotta constituent parts to create compounds that enhance more suitability of these lightweight materials for use in quite a lot of applications wherever the biggest factor is wear [3]. Aluminum is armored with various kind of durable terracotta constituent parts similar to SiC [4,5,6,7,8], B_4C[9-10], Al_2O_3[11–13] and TiC [14] for the manufacture of composite materials for various applications. In addition to these normal ceramic particles, a

small number of supplementary materials just like mineral admixtures i.e. rock dust, fly ash, marble dust and bagasse ash have been examined by some researchers [15]. Mainly of the work spotlight on enhancing the wear resistance of the aluminum alloy and SiC is used with several materials among the specific ceramic particles, resulting in increased the main property which is resistance of wear. SiC improved AMCs are glowing acknowledged for their heavy strength and resistance to wear put side by side to conventional alloys [16]. Increasing SiC of volume and width diminishes Al6061/SiC composites ' common wear rate [17]. Al alloy's mechanical strength and wear resistance improve as SiC particulates increase. Other than the secondary augment in hardness build it hard to machine the material [18]. In addition to strong ceramic particles, the accumulation of solid lubricant constituent parts such as Gr or MoS_2 improves the wear characteristics of compounds [19–23]. It happens due to the mechanical characteristics are enhanced of bulk due to durable constituent parts and diminished abrasion coefficient due to the configuration of lubrication layer [24–26]. Additional amplify in the graphite (Gr) increases composite rupture strength which reduces wear resistance [27]. Furthermore, as the percentage of Gr reinforcement enhanced, the material's hardness decreases as a consequence of the compound's increased porosity [28]. Therefore, the quantity of unyielding lubricant added be supposed to contained by the maximum value and preserve be worn in combination in the midst of supplementary terracotta reinforcements like SiC and TiB_2. Furthermore, graphite is additional in a large amount revises as reinforcement owing to its enhanced self-lubricating characteristics to trim down friction and rate of wear. Nevertheless, very few attempts were made on MoS_2 alone as a reinforcing part of aluminum matrix compounds, which furthermore contain a self lubricating feature. The most crucial improvement of the MoS_2 in excess of Gr is that to show its strong lubricant nature, i.e., it does not necessitate any peripheral sustainable things i.e oxygen. Even in the vacuum environment, MoS_2 can show its solid lubricant property. However, MMC manufacturing faces many difficulties including similarities among medium and reinforced constituent parts, identical divisions of reinforcement constituent parts on more matrix material; it is very successfully resolved via an assortment of changes during manufacturing systems. Methods of in situ, liquid, solid state are widely utilized to incorporate ceramic particles into the techniques of matrix production. The MMCs were manufacture in liquid stir casting, among other things, incredibly inexpensive and effortless. The reinforced terracotta particles are unvaryingly disseminated and are accomplished of achieving a near net component and the production speed of the element [29, 30, 31].

2. EXPERIMENTAL PROCEDURE

2.1 Raw Materials

For this work, the base matrix selected was Al7075 alloy and procured in the form of ingots from Vision Castings, Hyderabad. Table 1 illustrates the chemical composition of the Al7075 alloy. For this work, The chosen reinforcement material was Silicon Carbide (SiC) and MoS_2 (molybdenum disulfide) from M/s Vision Castings & Pvt. Ltd., Telangana, Hyderabad.

Table 1. Al7075 Chemical Composition (Weight percentage)

Chemical composition	Si	Fe	Cu	Mn	Mg	Cr	Zn	T
Al7075	0.4	0.5	1.6	0.3	2.5	0.15	5.5	0

2.2 Fabrication of Composites

Composites are prepared using stir casting technique through the liquid metallurgy route. Upon successful degassing with solid degassing hexachloroethane tablet, preheated SiC fine particles and MoS_2 of lab-grade spotlessness were additional into the eddy of the molten alloy. A ceramic-coated steel impeller was used for a period of 10 minutes, to achieve molten alloy by mechanical stirring. It achieved a frequency of 400 rpm. A 710^0C pouring temperature was continued and the fused metal used in preheated cast iron molds.

Table 2. Composition and code of prepared materials

S.No	Composition	Code
1	Al alloy	Al
2	Al 7075 + 3% by wt Sic + 3% by wt MoS_2	
3	Al 7075 + 3% by wt Sic + 4% by wt MoS_2	
4	Al 7075 + 3% by wt Sic + 5% by wt MoS_2	

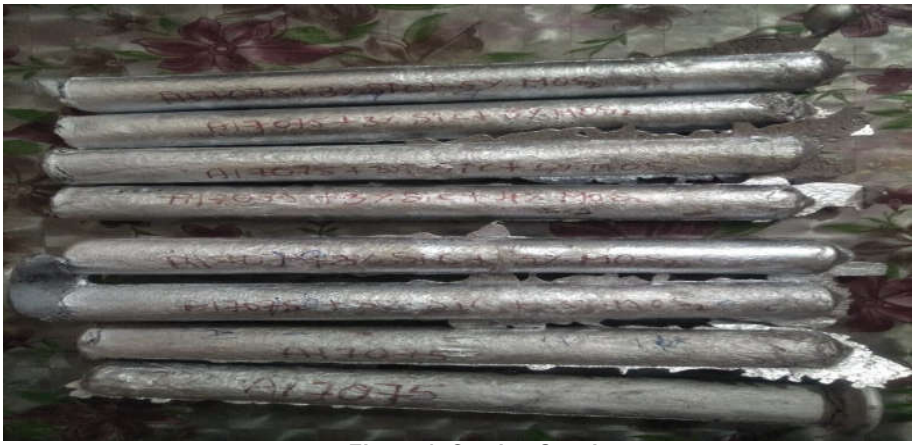

Figure 1. Casting Specimens

3. PHYSICAL AND MECHNICAL PROPERTIES

3.1 Hardness Test

Bulk hardness measurements are performed using standard Rockwell hardness testing machine scheduled to the base metal & composite specimens. The sections were machined at room temperature and load using 500 kg as per ASTM E10-07a. The test showed that the composite specimen's hardness had progressively amplified through an enhancement of up to 5% wt of MoS_2 fine particles in the metal matrix.

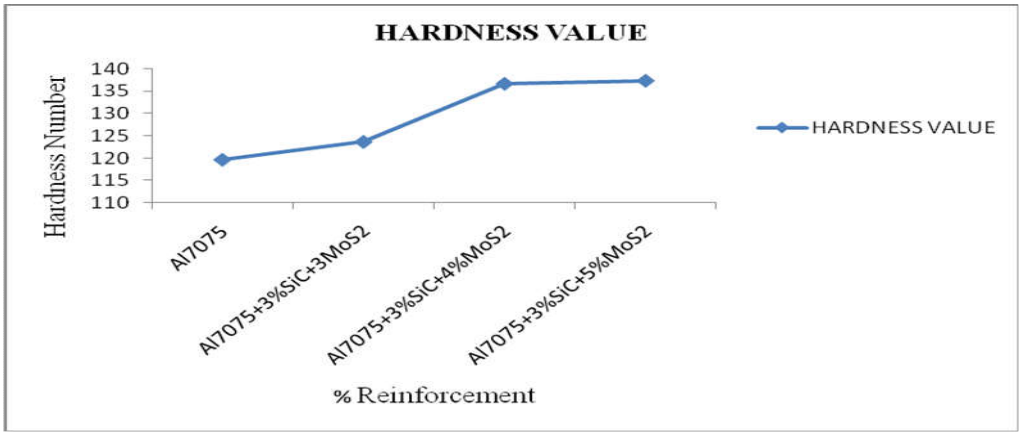

Figure 2. Change in Hardness of the material with percentage reinforcement in hardness

3.2 Tensile Strength Test

The specimens were a machine for obtaining dog boned structure as per ASTM–UTM carried out the standard E8 experiment. All the samples of the tensile test are publicized in Figure 4. The test showed that the ultimate tensile strength improved slowly by rising the percentage of reinforcement applied to the steel matrix by wt. The peak tensile strength of 5% MoS_2 was observed. The ultimate tensile strength pattern is shown in the Figure 3.

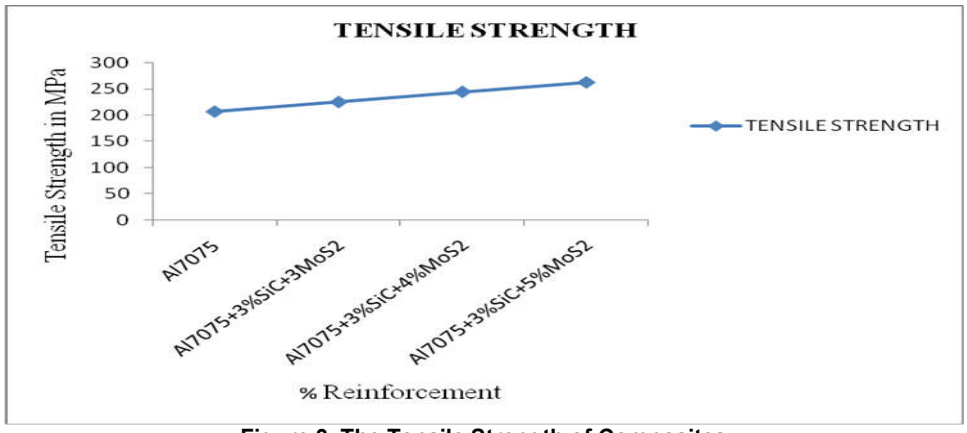

Figure 3. The Tensile Strength of Composites

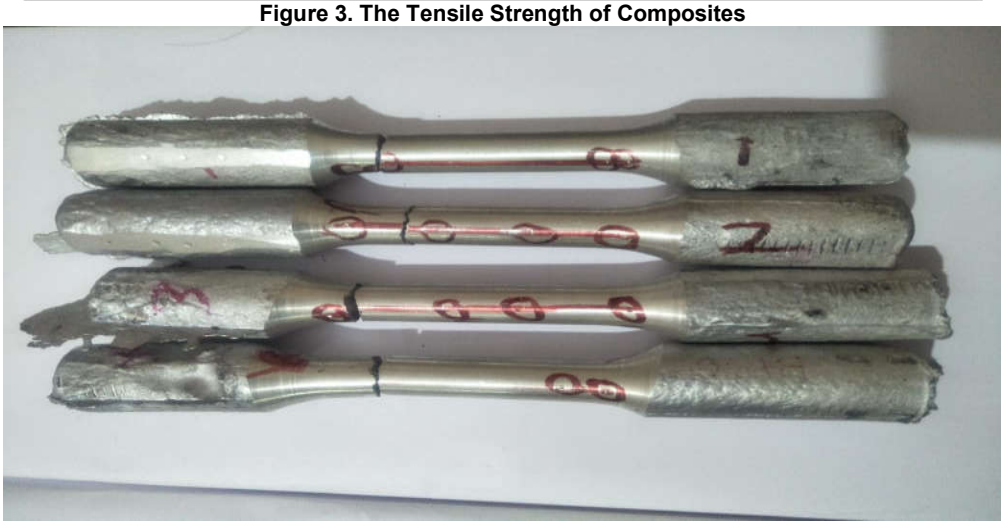

Figure 4. Tensile Test Specimens

3.3 Elongation

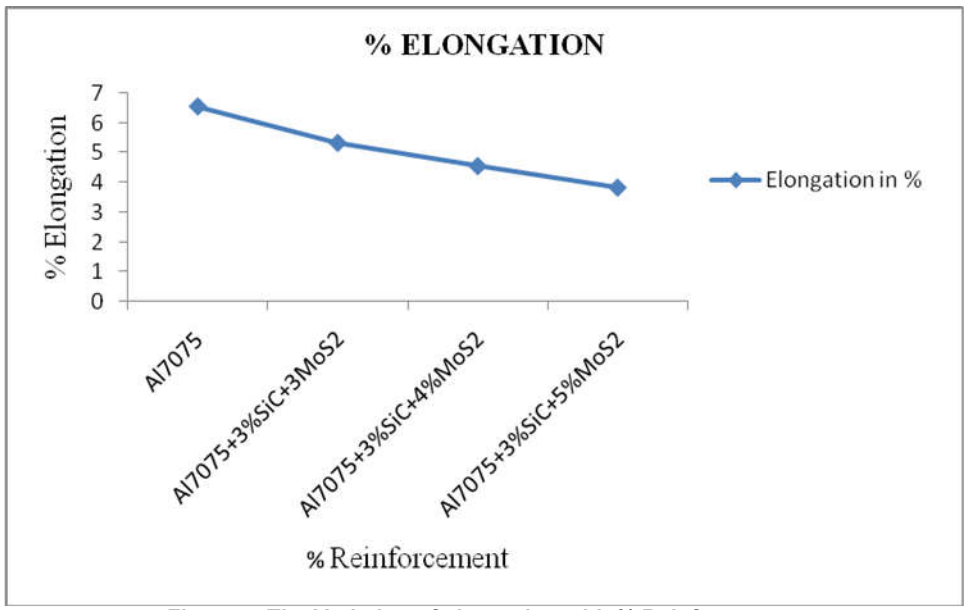

Figure 5. The Variation of elongation with % Reinforcement

Figure 5. Shows the difference of elongation among SiC & MoS_2, the measurement of Ductility of composites by using % elongation. The Ductility of Al alloy is high as evaluate to prepared composites. The elongation of the composites drastically condensed due to raise in weight percentage of reinforcement. The decrease in the ductility due to development voids nucleation by increasing % of MoS_2. At the tip of cracked particles stress concentration is very high, this forms lower ductility as compared to un reinforced composites (Al alloy).

3.4 Density

A rule of mixture is used to determine the potential density values of base alloy and composites. We used Electronic specific gravity balancer to measure the density of alloy and composites. Figure. 6 shows electronic specific gravity balancer.



Figure 6. Electronic specific gravity balancer

The typical theoretical and measured density values of the AA-7075 alloy and its relevant composites were shown in Table 6. Adding Sic and MoS_2 into the base material in such a

case density of the composites was increased evaluate to the base material AA 7075 alloy. This is the reason of high density of AA 7075 alloy.

Table 3. Theoretical and measured densities of AA-7075 and Composites

Samples	Measured Density (g/cm^3)	Theoretical Density (g/cm^3)
AA-7075	2.81	2.82
AA-7075+3%SiC +3%MoS_2	2.86	2.88
AA-7075+3%SiC+ 4%MoS_2	2.89	2.91
AA-7075+3%SiC+ 5%MoS_2	2.9	2.93

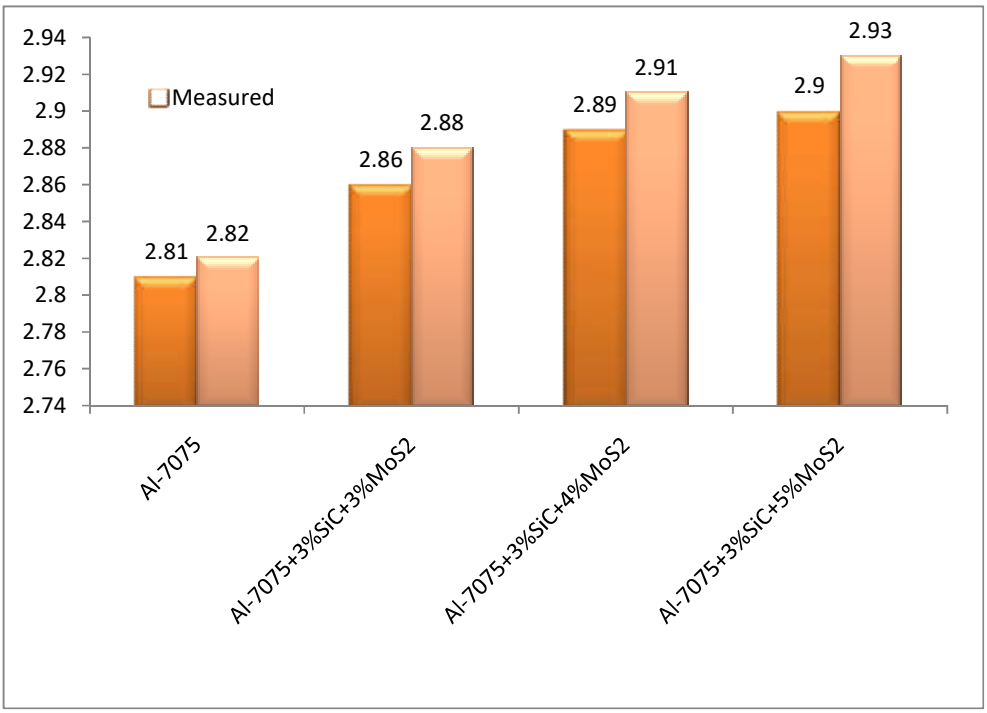

Figure 7. Variation of Density Vs % of Reinforcement

4. WEAR PROPERTIES

In this work we used specimens as per the ASTM G99 and experiments conducted using a computerized wear test machine (pin on disc) as illustrated in the figure 9. Disc of the material is steel. The disc surface was cleaned with high garde emery paper before testing. Figure 8 reveals the dimensions of the wear test samples were 8mm ϕ and 30mm length and Figure 10 shows wear test samples. In this wear test we used different types of paremeters such as load is varied 10N, 15N and 20N, sliding distance is 950 m and sliding velocity is 2.5 m/s. In this test pin was kept stationary perpendicular to the disc and disc was roated.

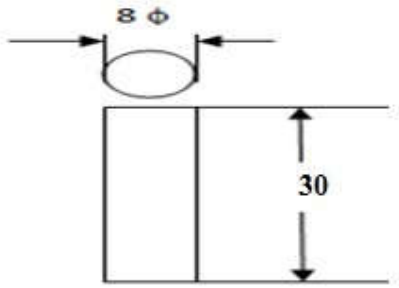

Figure 8. Dimensions of Wear test sample



Figure 9. Pin on Disc Setup

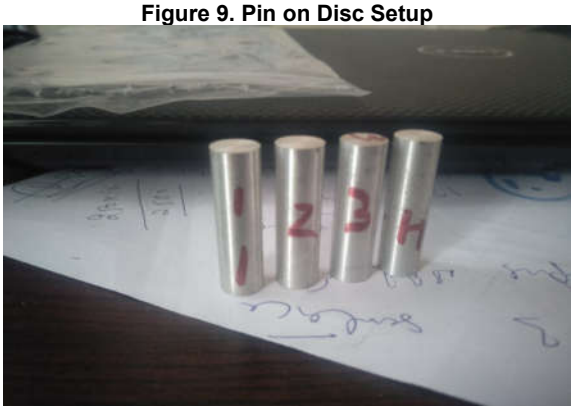

Figure 10. Wear test specimens



Figure 11. Wear test specimens

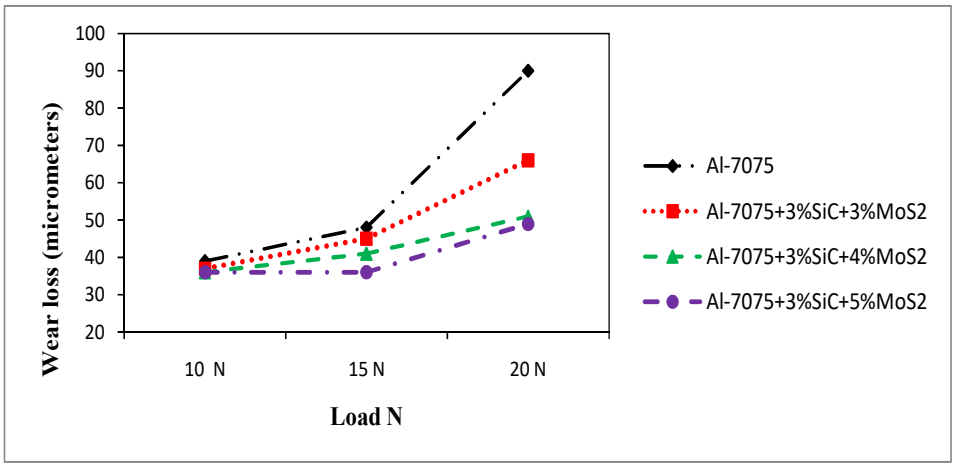

Figure 12. Variation of Wear rate with load at sliding velocity 2.5 m/sec and constant sliding distance 950m

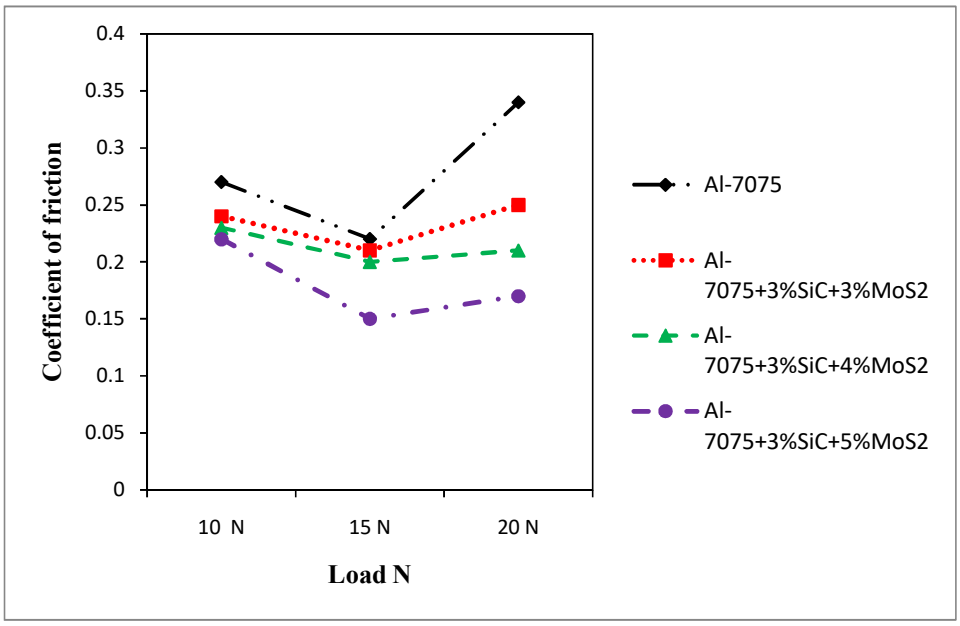

Figure 13. Variation of Coefficient of friction with load

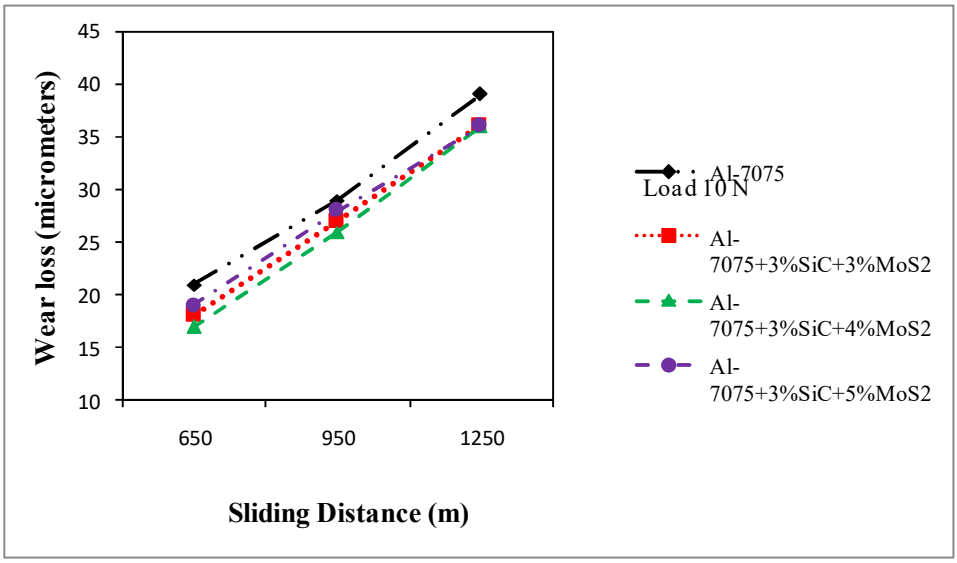

Figure 14. Variation of Wear rate with Sliding distance at sliding velocity 2.5m/sec and at constant load 10N in room temperature condition

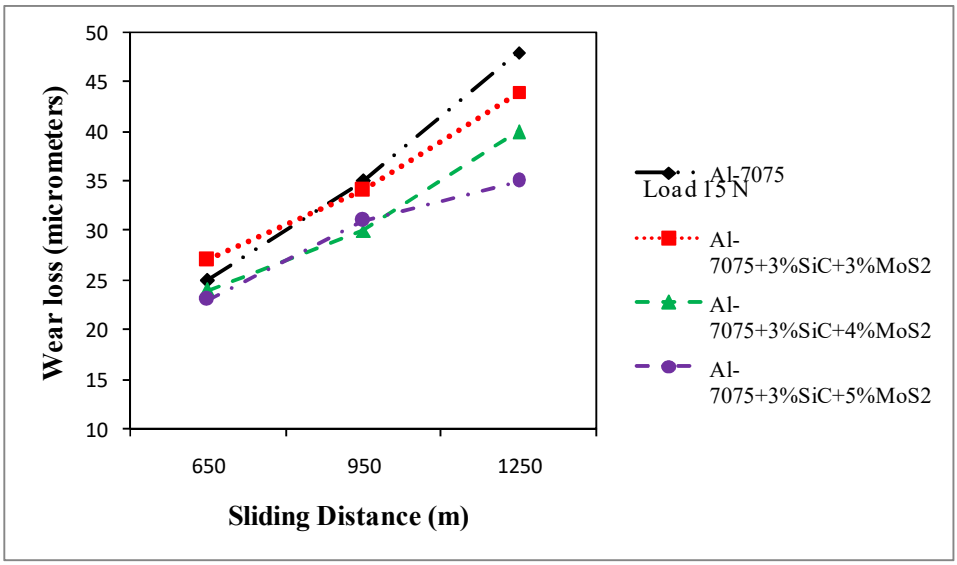

Figure 15. Variation of Wear rate with Sliding distance at sliding velocity 2.5m/sec and at constant load 15N in room temperature condition

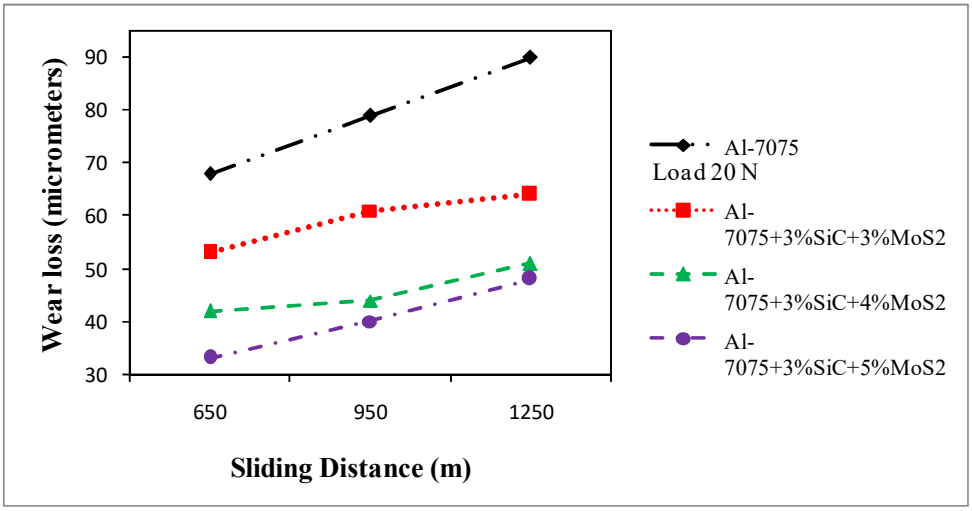

Figure 16. Variation of Wear rate with Sliding distance at sliding velocity 2.5m/sec and at constant load 20N in room temperature condition

The above figures clearly show the difference in wear rate for different loads viz 10N, 15N, 20N with accumulation of wt percent reinforcement to Aluminium alloy. From the statistics above, we can clearly identify that the wear rate decreased in every part of different loads by adding wt percent of reinforcement, as the load rises the wear level often enhanced in all situations. The stress also amplified proportionately at the pin-disk boundary when the load is raised, whereas Al7075 as a lighter material endure very high wear and SiC elements & MoS_2 soild lubricant withdraws the weight functioned after that the boundary connection among Al, SiC and MoS_2 decreases the rate of wear in the abrasive wear system.

5. MICROSTRUCTURE

Morphology, thickness, size and distribution of reinforcing particles have a foremost impact on the properties of particulate composites. The samples were prepared by rigorous buffing and engraving for microstructure analysis, and the specimens were then examined beneath an optical microscope to examine the microstructure. Figures 17-19 display the optical micrograph, which illustrate the even scattering of the matrix reinforcement.

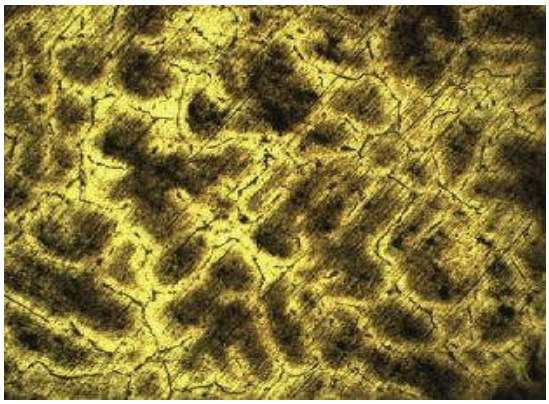

Figure 17. Al7075+ 3% SiC+3%MoS_2

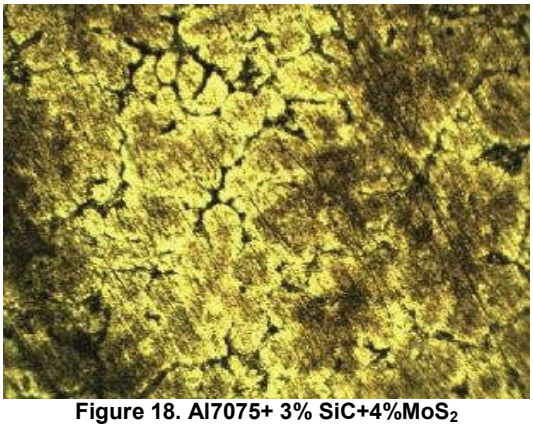

Figure 18. Al7075+ 3% SiC+4%MoS_2

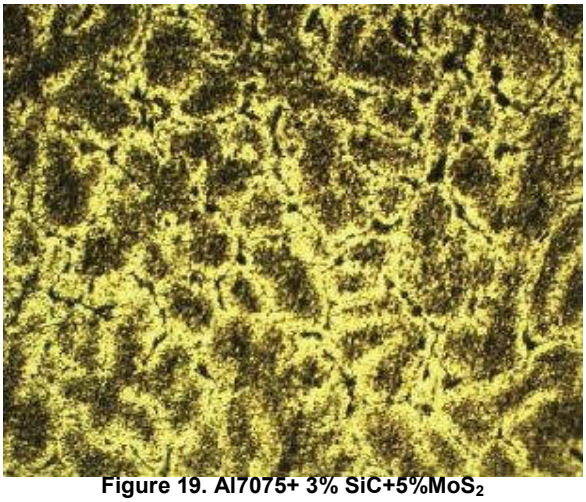

Figure 19. Al7075+ 3% SiC+5%MoS_2

6. CONCLUSIONS

1. Through increasing the percentage of SiC & MoS_2 reinforcement content, density increases. There are not much more variations among the experimental and the theoretical density values and this designate the aptness of the stir casting system for composite preparation..

2. The composites are arranged using the technique of liquid metallurgy (stir casting). in the midst of an amplify in the percentage of reinforcement, the micro hardness increases; this is due to the SiC particle and secondary MoS_2 reinforcement distributed in the soft matrix material. As the reinforcement percentage increases the hardness value when compared to the alloy.

3. By increasing the secondary MoS_2 reinforcement, the tensile strength increases. Due to the addition of 3%, 4% and 5% by mass MoS_2, the tensile strength increases significantly. The composite elongation rate dropped drastically thanks to weight percentage increase in reinforcement.

4. At first, the rate of wear was greater in the nonappearance of SiC & MoS_2 particle asperities. The SiC & MoS_2 elements outlined a protective stratum among the pin and offset face exterior as the sliding distance and load increases, thereby increasing the wear speed. When the pin-disk interface raises the load. As a softer material, Al 7075 endure higher wear, but the Sic particle & stronger lubricant MoS_2 resists the load functional and the bonding crossing point among Al. SiC & MoS_2 in the abrasive wear system decreases wear rates.

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