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SYNTHESIS AND WEAR BEHAVIOUR OF Mg AZ91D MAGNESIUM ALLOY REINFORCED WITH SILICON CARBIDE (SiC) AND GRAPHITE (Gr) PARTICULATES

Mohammed Imran[1] , Prof Ravindra M Lathe [2]
[1]*PG Student of Production Engineering, PDA College Of Engineering, Kalaburagi*
[2]*Department of Mechanical Engineering, PDA College of Engineering, Kalaburagi*

Abstract— ***As the lightest structural material at present, magnesium alloy has a series of advantages like specific strength, good casting capability, machinability and are simple to reuse. As a result of these great properties, it has a wide application in numerous fields such as automobile industry, media transmission, aviation and so forth. An attempt is made to incorporate and examine the wear behaviour of Mg AZ91D fortified with Silicon carbide (SiC) and Graphite (Gr). The manufacture strategy utilized for fabrication was fluid metallurgy i.e stir casting by varying in the percentage of reinforcement. Machining of the samples was carried out as per ASTM test measures. Wear characteristics of Mg AZ91D-SiC-Gr composites have been studied under dry sliding wear. Dry sliding wear tests have been completed utilizing pin-on-disc wear analyzer at various speeds (200rpm, 400rpm, and 600rpm) and loads (20N & 30N). The tests were completed using different speeds and loads with each weight part of SiC-Gr.***

Keywords— Magnesium composite, Mg AZ91D alloy, Silicon carbide (SiC), Graphite (Gr), Stir Casting, Dry Sliding Wear.

INTRODUCTION

The use of natural composite material has been a part of man's technology since the first ancient builders used straw to reinforce mud bricks. Composite material is a material produced using at least two constituent materials with altogether unique physical or chemical properties that, when consolidated, deliver a material with attributes different from the individual. The individual components remain separate and distinct within the finished structure. The constituents are consolidated at macroscopic level and are not soluble in each other. One constituents is called matrix phase and the other is called reinforcing phase. Reinforcing phase is embedded in the matrix to give the desired characteristics. Reinforcing phase: Fibers, flakes, particulates, whiskers so forth. Matrix phase: Continuous phase. One commonly used classification of composite is based on matrix that can be partitioned into three primary group-1.Polymer matrix composites (PMCs) 2.Ceramic matrix composites (CMCs) 3.Metal Matrix Composites (MMCs). A metal matrix composite (MMCs) is composite material with no less than two constituent parts, one being a metal fundamentally, the other material might be an alternate metal or another material, for example, a ceramic or organic compound. When at least three materials are present, it is known as hybrid composite. MMCs are widely used because of specific characteristics such as their favorable mechanical properties, low densities, and electrical conductivities. Some important reinforcements for MMCs are Fibers, Whiskers and Particles.

Magnesium is an excellent metal as it is readily available commercially and it is the lightest structure at present having density of $1.73 g/cm^3$. Magnesium alloy has a series of advantages specific strength, good casting capability, machinability and simple to reuse. As a result of these great properties, it has a wide application in numerous fields such as automobile industry, aviation and so forth. Magnesium powder ignites effortlessly when heated in air and should be taken care of deliberately in a powder form. In request to be utilized as a part of assembling, it is alloyed with different metals, such as aluminium, zinc and so forth. Magnesium can likewise be alloyed with rare earth elements, which increment the quality of magnesium particularly at high temperatures. Magnesium AZ91D is portrayed by high specific strength and corrosion resistance sharply higher than pure magnesium. A represents aluminium (Al), Z represents zinc, 9 implies aluminium content is 9%, 1 in the interest of the zinc content is 1%, the last D as identification code.

Silicon carbide (SiC), also known as carborundum, is a semiconductor containing silicon and carbon. It occurs in nature as the extremely rare mineral moissanite. Grains of silicon carbide can be reinforced together by sintering to frame hard earthenware production that are broadly utilized as a part of applications requiring high endurance such as auto brakes, auto grasps and ceramic plates in bullet proof vests. Electronic uses of silicon carbide such as light emitting diodes (LEDs) and detectors. Silicon carbide is widely used as reinforcement because of its great properties, such as low density, high strength and high hardness, high elastic modulus and so forth.

Graphite archaically referred to as plumbago, is a crystalline allotrope of carbon, a semi metal, a native element mineral, and a type of coal. There are two principle sorts of graphite, natural and synthetic. Graphite gets its name from the Greek word “graphein” to write Graphite is the most stable form of carbon under standard conditions. In this way, it is utilized as a part of thermo-chemistry as the standard state for defining the heat formation of carbon compounds. The material is generally grayish dark, opaque and has a lustrous dark sheen. It is remarkable that it has properties of both metal and non metal Graphite is used as reinforcement because of its great properties such as it is flexible yet not elastic, and has a high thermal and electrical conductivity. It is highly refractory and chemically inert. It has high melting temperature, low density, low hardness, low friction and self lubrication and so forth.

A. Literature Survey

[1] I.Aatthisugan et al., conducted an experimental study on mechanical and wear behaviour of Mg AZ91D magnesium matrix hybrid composite reinforced with boron carbide (B_4C) and graphite (Gr) particle which were manufactured by stir casting. The results of the tests revealed that the graphite reinforced hybrid composites exhibited a lower wear loss compared to the unreinforced AZ91D alloy and AZ91D-B_4C composites. It was found that with an increase in B_4C content, the wear resistance increased monotonically with hardness and ultimate tensile strength decreased. This study revealed that the addition of both a hard reinforcement B_4C and soft reinforcement Gr significantly improves the wear resistance of magnesium composites.

[2] K. Soorya Prakash et al., worked on the development and characterization of Mg-SiC-Gr hybrid composites through powder metallurgy route. The results showed that the developed composite exhibit increased hardness when compared to base material, could be attributed to the presence of hard SiC. Furthermore, a slight decrease in hardness is observed for the hybrid composite when compared to Mg-SiC composite due to the presence of soft Gr particles. The wear resistance of the developed composites improved significantly than that of the magnesium matrix due to the upright effect offered by both of the reinforcements.

[3] B. Selvam et al., presented a work on investigation of the dry sliding wear behaviour of a Mg matrix composite reinforced with zinc nano-particles was prepared using powder metallurgy and was hot extruded to eliminate pores. The wear behaviour of the Mg/Zno nano composite was investigated dry sliding test on a pin-on-disc apparatus. Wear tests were conducted for normal loads of 5, 7.5 and 10N at sliding velocities of 0.6, 0.9, 1.2 m/s at room temperature. the variations of the friction coefficient and wear rate with the sliding distances (500m, 1000m, 1600m) for different normal loads and sliding velocities were plotted and analyzed. The results show that the wear rate was found to increase with the load and sliding velocity.

[4] Muhammed Rashad et al., investigated the effect of micron-sized titanium and aluminium addition on the micro-structural, mechanical and work-hardening behaviour of pure Mg. Pure Mg was reinforced with 10%Ti and 10% Ti and 1%Al particulates which were synthesized through semi-powder metallurgy route followed by hot extrusion. Tensile results indicate that the direct addition of micron-sized 10wt% Ti particulates to pure Mg caused an improvement in elastic modulus, 0.2% yield strength, ultimate tensile strength, and failure strain. The addition of micron-sized 10wt% Ti particulates along with 1wt% Al particles to pure Mg, resulted in an enhancement in elastic modulus, 0.2% yield strength, ultimate tensile strength, and failure strain.

[5] Karthick et al., showed that magnesium alloy (AZ31) is used as base metal matrix. Alumina (Al_2O_3) with 5%wt and silicon carbide (SiC) with varying 0-8% is used as the reinforcing ceramic materials. The compacted green samples were sintered at 450˚C for 20min. The prepared (MMC) samples were subjected to characterization and mechanical studies. Results showed that magnesium metal matrix composites hardness increased from 64.52 to 75.16 HV, which was mainly due to the presence of reinforcements Al_2O_3 and SiC along with precipitates. Addition of alumina and silicon carbide on magnesium alloy influenced the hardness of MMC.

B. Gaps Found From Literature & Objective

The extensive review of literature carried out for present study reveals that lot of work has been reported to upgrade properties of magnesium metal matrix through stir casting or by any other process.

To develop the new material utilizing magnesium alloy composites, with the goal that it ought to be lighter in its weight and has higher wear resistance which can be utilized for industrial purpose, for example, automobile and aviation industries.

The work carried out by various researches can be sorted into following wide classes.

1. Some studies have been done which clarifies the factor affecting wear properties of Magnesium metal matrix composite.

2. Very constrained measure of work has been done on consolidated impact of Silicon carbide (SiC) and Graphite (Gr) with magnesium metal matrix.

METHODOLOGY

A.Preparation of samples by stir casting

The base matrix material used in the present experimental investigation is Mg AZ91D and Silicon Carbide (SiC) and Graphite (Gr) as the reinforcement to form a hybrid metal matrix composite.

In stir casting procedure, stainless steel rod and cast iron mould were preheated to 175˚C for 30 minutes to eliminate moisture and gases from the surface area of the particles and parts before casting. The essential amount of AZ91D Mg ingot is weighed and placed into the mild steel crucible and heated to 750°C in the induction furnace. Manual stirring was done constantly with the assistance of steel stir (rod). Silicon carbide (SiC) and Graphite (Gr) powder was weighed according to the weight percentage. Then Silicon carbide (SiC) and Graphite (Gr) powder was added according to the percentage in the molten slurry of Mg AZ91D and stirring was done around 15 to 20 minutes. After stirring, the molten slurry was poured into the preheated die of 20mm diameter and 170mm length to get the desired shape of samples as shown in fig below. Same methodology was completed for getting ready distinctive organization of Silicon Carbide (SiC) and Graphite (Gr) powder.

TABLE I

CHEMICAL COMPOSITION OF Mg AZ91D ALLOY

Material identification	*Al*	*Cu*	*Mn*	*Fe*	*Ni*	*Zn*	*Si*	*Other metallic*
Magnesium AZ91 Alloy	*83-97*	*0.03 max*	*Bal.*	*0.005*	*0.002*	*0.35-0.5*	*0.1 max*	*0.02 max*

Fig 2.2: Die mould

Fig 2.3 Magnesium Ingot

Fig 2.4 Silicon carbide (SiC)

Fig 2.5 Graphite (Gr)

Fig 2.6 Casted cylindrical specimens with different weight percentage of reinforcements

TABLE II
SAMPLE SPECIFICATION

Samples	***Hybrid Composition***
Pure	Pure Mg AZ91D
1.1	Mg AZ91D+14% SiC+1.5% Gr
1.2	Mg AZ91D+14% SiC+2.5% Gr
1.3	Mg AZ91D+14% SiC+3.5% Gr
2.1	Mg AZ91D+16% SiC+1.5% Gr
2.2	Mg AZ91D+16% SiC+2.5% Gr
2.3	Mg AZ91D+16% SiC+3.5% Gr
3.1	Mg AZ91D+18% SiC+1.5% Gr
3.2	Mg AZ91D+18% SiC+2.5% Gr
3.3	Mg AZ91D+18% SiC+3.5% Gr
4.1	Mg AZ91D+20% SiC+1.5% Gr
4.2	Mg AZ91D+20% SiC+2.5% Gr
4.3	Mg AZ91D+20% SiC+3.5% Gr

B. Wear Testing

Wear is a procedure of removal of material from either of two solid surfaces in solid state contact. When two surfaces with a relative motion associate with each other, it brings about the progressive loss of material from contacting surfaces in relative motion. As the wear is a surface removal phenomenon and occurs mostly at external surfaces, it is more appropriate and practical to make surface modification of existing alloy than utilizing the wear resistant alloys. The prepared specimens were subjected to wear against a rotating EN-32 pin on disc under dry sliding wear testing machine. The tests were carried at room temperature without lubrication for 5 minutes.

Fig. 2.5 (a) Pin on disc wear testing machine *(b) Display unit*

Fig 2.6 Wear test samples

Basic specification

Specimen Standard Dimensions

Length = 32mm

Diameter = 10mm

In this test

Track Diameter = 60mm

Time = 300seconds

Speeds = 200rpm, 400rpm, 600rpm

Load = 20N and 30N.

III RESULT AND DISCUSSION

Wear is a process of material expulsion phenomena. When two surfaces with a relative motion interface with each other, because of friction it brings about the dynamic loss of material from the contacting surfaces in relative motion. The prepared specimens were subjected to wear against a rotating EN-32 pin on disc under dry sliding wear testing machine. The tests were carried out at room temperature without lubrication for 300sec. In this test, track Dia = 60mm and time = 300sec are kept consistent while load and speed are varied. The characteristics are determined by the comparison of the Magnesium AZ91D alloys for varying percentage of SiC and Gr.

TABLE III
Speeds and loads for wear test

Speeds	200rpm	400rpm	600rpm	400rpm
Loads	20N	20N	20N	30N

Fig 3.1 & 3.2 shows that with pure Mg AZ91D, it was observed that the wear rate is less when the speed & load are less. As the speed increases the wear rate increases.

Fig 3.3 shows that for hybrid composition i.e., Mg AZ91D+16% SiC+1.5%,2.5% and 3.5% Gr at speed 400rpm and load 20N. When compared with pure Mg AZ91D, it showed that as the graphite content increased the wear rate was significantly reduced.

Fig 3.4 shows that with reinforcement of 14%SiC and 1.5% Gr the lowest wear rate were recorded, even at higher speed of 600rpm.

Fig 3.5 & 3.6 shows that upon further increasing the amount of Gr with the same composition of SiC, does not have a good wear rate at higher speeds but lesser wear rates at lower speeds at the same loads.

Fig 3.7 & 3.8 shows that the same behaviour trend was observed with different samples i.e., 16%SiC, 18%SiC with varying amounts of Gr, showed a slow wear rate at lower speeds.

Fig 3.9 shows that at a moderate speed of 400rpm and higher load of 30N, sample shows moderate wear rate compared to other sample.

The results of the wear test are as shown below with the following graphs:

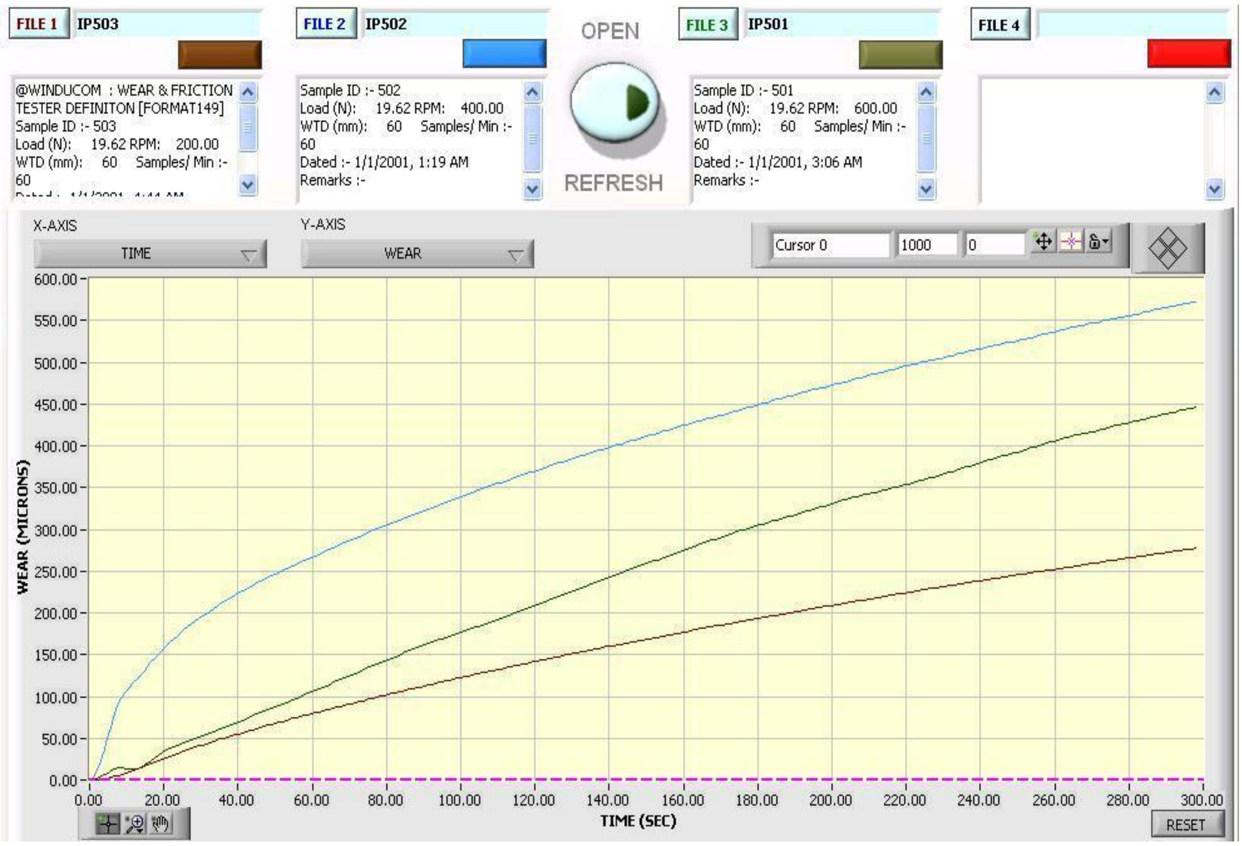

Fig 3.1 Comparison graph of pure Magnesium AZ91D Alloy for different speeds at 20N load.

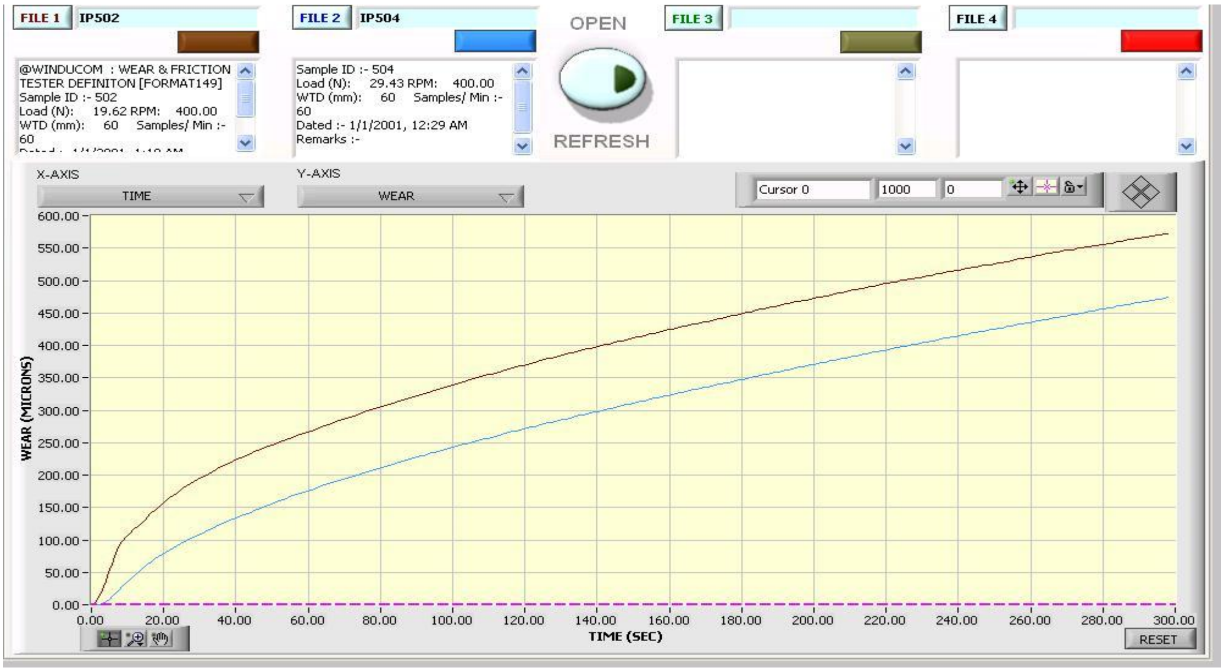

Fig 3.2 Comparison of pure Magnesium AZ91D for different loads at 400rpm speed

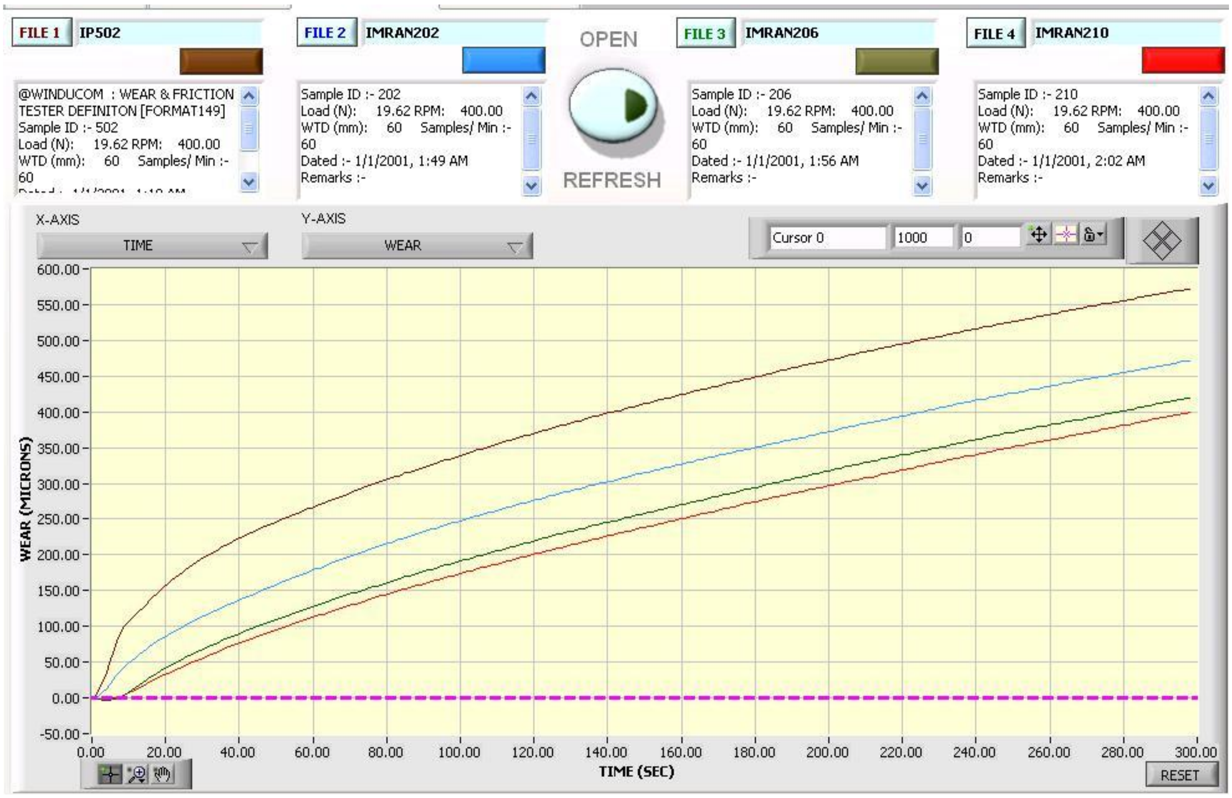

Fig 3.3 Comparison of pure Magnesium AZ91D with 16% SiC+1.5%Gr+2.5%Gr+3.5%Gr at speed 400rpm and 20N load.

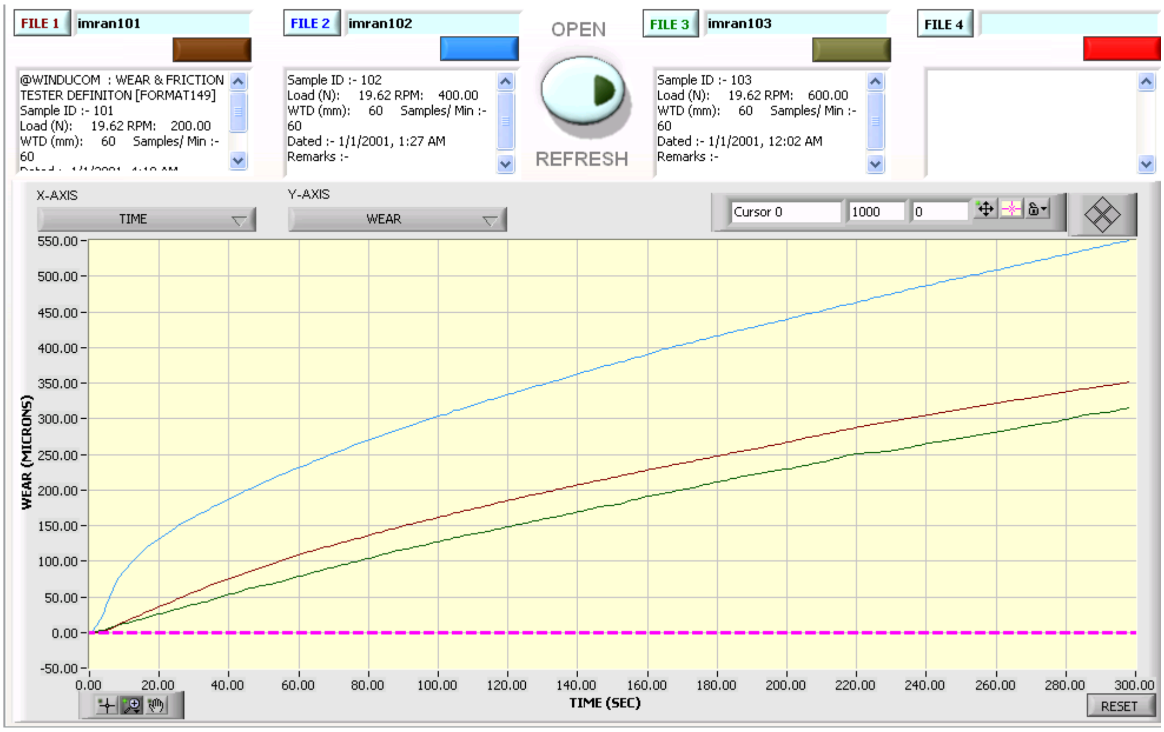

Fig 3.4 Comparison of hybrid composition Mg AZ91D+14% SiC+ 1.5% Gr at different speeds.

Fig 3.5 Comparison of hybrid composition Mg AZ91D+14% SiC for 1.5% Gr, 2.5% Gr & 3.5% Gr at speed 200rpm.

Fig 3.6 Comparison of hybrid composition Mg AZ91D+14% SiC for 1.5% Gr, 2.5% Gr & 3.5% Gr at speed 600rpm.

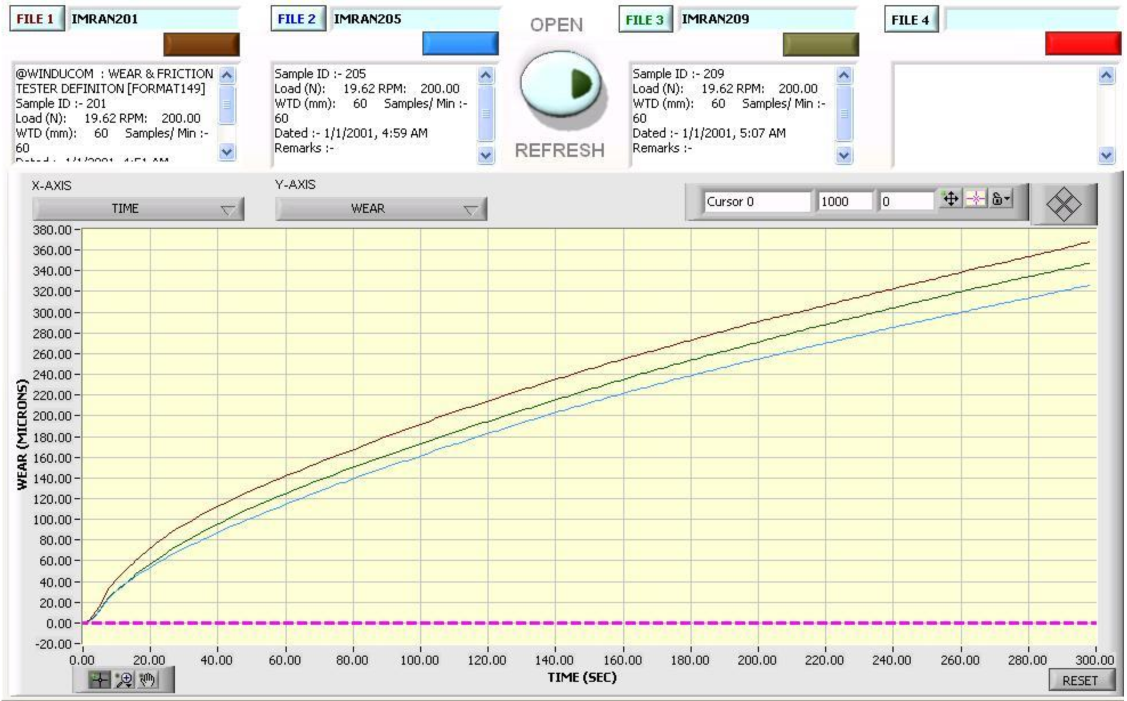

Fig 3.7 Comparison of hybrid composition Mg AZ91D+16% SiC for 1.5% Gr, 2.5% Gr & 3.5% Gr at speed 200rpm.

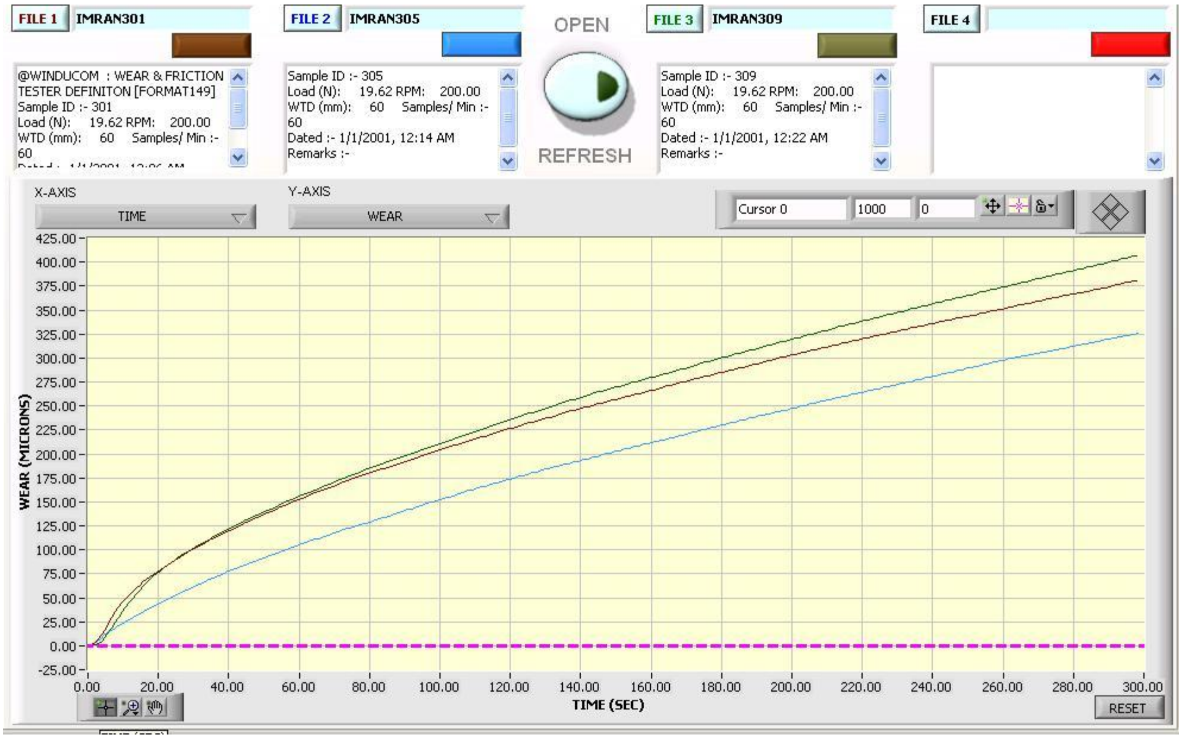

Fig 3.8 Comparison of hybrid composition Mg AZ91D+18% SiC for 1.5% Gr, 2.5% Gr & 3.5% Gr at speed 200rpm.

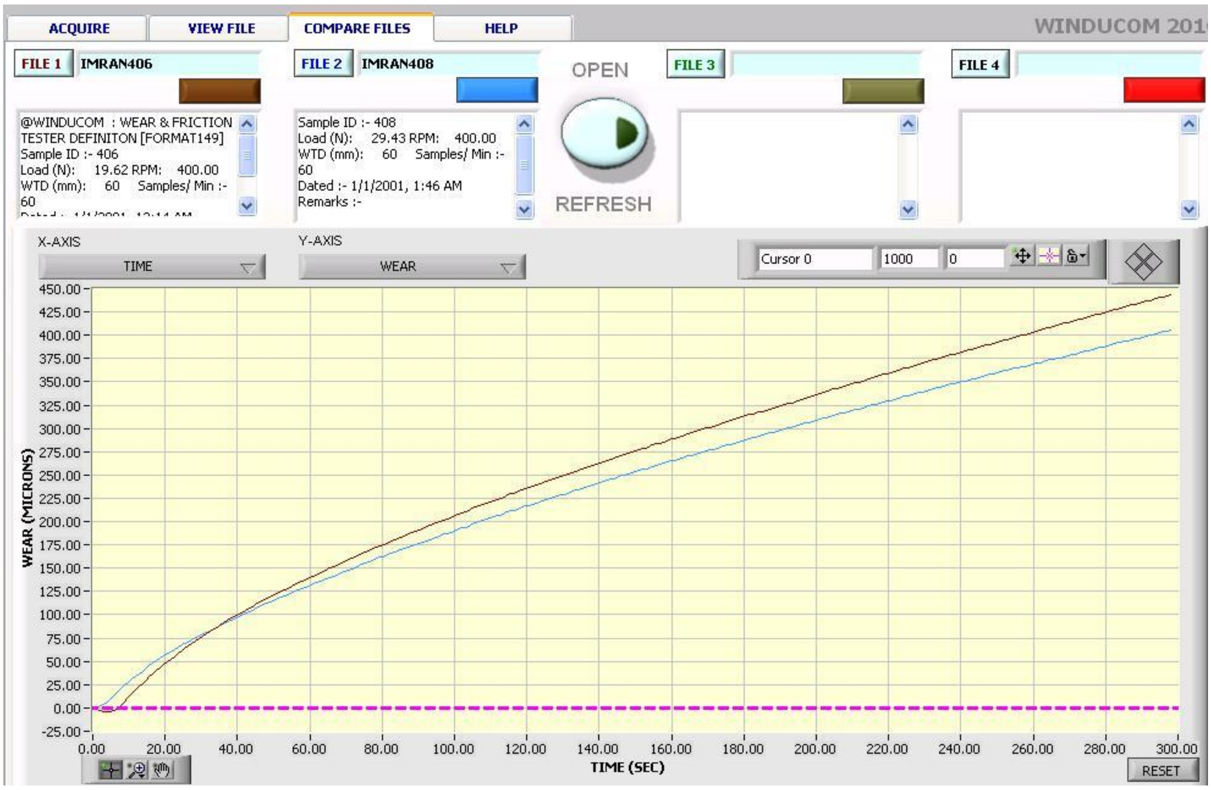

Fig 3.9 Comparison of hybrid composition Mg AZ91D+20%SiC+2.5%Gr at speed 400rpm and different loads i.e., 20N & 30N.

IV CONCLUSION

From the present work on the wear behaviour of Magnesium based hybrid metal matrix composites the following conclusions have been derived:

1. At lower speeds, the wear rate is reduced.
2. As the speed increases, the wear rate also increases.
3. The addition of varying percentages of SiC and Gr in the composites produced good wear rates only at lower speeds, wear rate increases as the speed increases.
4. At moderate speeds and higher load (30N) samples exhibited a moderate wear rate.

Finally from the work, we can conclude that there is no marked effect on the wear rate of hybrid composites as compared to pure Mg AZ91D.

SCOPE FOR FUTURE WORK

The above work has been completed in view based on the literature already available. By applying Design of experiments (Tagauchi Technique) the optimization of number of samples can be carried out, yielding better results. In this work only random composition (based on the literature available) was taken and the results were analyzed, discussed and documented. In the future work Design of experiments can be effectively used to study the wear behaviour of the hybrid composites.

Also instead of only dry sliding wear studies, we can go for wet sliding wear.

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