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Analysis of Wear Rate and Tribological Behavior of Aluminum Cast Alloy A356 and Granite Composite at Different Speeds

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Abstract— Most of the machine elements have surface contacts with friction between them. The presence friction tends to wear off the surface leading to failure of the machinery. In today's world almost all material scientists are striving to develop materials with low wear rate to improve the life expectancy and performance efficiency of the components. In this paper, I have carried out a comparative analysis of the effect of presence of reinforcing granite particles on A356/LM25 cast alloy of aluminum. The wear rates of both the alloy and composite are analyzed at different speeds and pressures. The results are used to analyze the tribological behavior, of the alloy and the composite.

Keywords—Granite, LM 25, Tribology, Wear rate .

I. INTRODUCTION

In today's world we are all striving towards the development of environment friendly and energy efficient multiphase materials. The best part of using multiphase materials is that their properties can be predicted and the factors such as intrinsic properties, structural arrangement and the interaction between the constituents can be evaluated. The intrinsic properties of constituents determine the general order of properties that the composite will display. The interaction of constituents results in a new set of properties. The shape and size of the individual constituents, their structural arrangement and distribution and the relative amount of each, contribute to the overall performance of the composite. The factors that on which the properties of composites depend upon are volume fraction, microstructure, homogeneity and isotropy of the system and these are strongly influenced by proportions and properties of the matrix and the reinforcement [6,7]. The properties such as the Young's modulus, shear modulus, Poisson's ratio, coefficient of friction and coefficient of thermal expansion are predicted in terms of the properties and concentration and the most commonly used approach is based on the assumption that each phase component is subjected to either iso-stress or iso-strain condition [1,2]. There are many combinations of multiphase materials such as metal matrix Composites, Polymer matrix composites and ceramic matrix composites which can be tailor made according to the requirement of the application. In the field of automobile, MMCs are used for pistons, brake drum and cylinder block because of better corrosion resistance and wear resistance [13].

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Recent technological developments have led to the use Functionally graded materials instead of traditional composites in advanced mobility engineering applications [14]. The last 5 decades has seen a lot of work in the field of MMCs, especially Aluminium Matrix composites. This is because Aluminium is easily and cheaply available in almost all parts of the world. Aluminium with medium to high strength, good toughness, good surface finish and excellent corrosion resistance to atmospheric conditions, can be anodized and has good weldability, brazability and workability. AMCs, with naturally occurring minerals as reinforcement find wide applications in mobility engineering. In this work a comparative analysis of the properties of wear rate and tribological behaviour of the matrix cast alloy, A 356/ LM25 and composite by 10% by weight of A 356 and granite is carried out.

II. MATERIAL PROPERTIES

Among the various cast Aluminium cast alloys from LM series, LM 8, LM 13 and LM 25 show good wear resistant and anti-corrosion properties. They find many applications in marine and mining equipment [10]. LM25 is mainly used where good mechanical properties are required in castings of shape or dimensions requiring an alloy of excellent castability in order to achieve the desired standard of soundness. The alloy is also used where resistance to corrosion is an important consideration, particularly where high strength is also required. It has good weldability. Consequently, LM25 finds application in the food, chemical, marine, electrical and many other industries and, above all, in road transport vehicles where it is used for wheels, cylinder blocks and heads, and other engine and body castings. Its potential uses are increased by its availability in four conditions of heat treatment in both sand and chill castings. It is, in practice, the general purpose high strength casting alloy, whose range of uses is increased by its availability in the as-cast and partially heat-treated condition as well. It is used in nuclear energy installations and for aircraft pump parts. LM25 may be superior for castings, particularly in chill moulds, which are difficult to make to the required standard of soundness [15]. The Chemical composition of the matrix is given in Table 3.1 and the Physical and Mechanical Properties in Table 3.2. Natural Mineral namely granite was used as reinforcements in LM 25 matrix.

Table 3.1 Chemical Composition of LM25 Alloy

Element	Si	Fe	Cu	Mn	Mg	Zn	Al
Wt%	7.2	0.2	0.23	0.1	0.4	0.1	90.87

Table 3.2 Physical and Mechanical Properties of LM25 Al Alloy and Granite[10,12]

Material	Elastic Modulus (Gpa)	Density (g/cc)	Thermal Conductivity W/m-K	Hardness (HV)	Tensile Strength (MPa)
A 356/ LM 25	70 - 80	2.7	150	107	310
Granite	70	2.9	48	850	39
Compressive strength is 2200 MPa (Granite)					

The coarse-grained igneous rock granite consists of quartz, feldspar and mica in shapeless interlocking grains. It is composed of at least 65% silica [12]. The physical properties used for identifying minerals are cleavage or fracture, color, streak, and hardness. Apart from these properties some other physical descriptions are also given. Table 3.2 also gives the physical and mechanical properties of the reinforcing material used, i.e., granite. Cleavage is the tendency of minerals to break parallel to planes of weakness due to fewer or weaker chemical bonds. The lower bonding force usually leads to wider spacing between atoms, because the attractive force is not great enough to adjacent planes of ions closely together.

III. Composite Fabrication

Fabrication of AMCs has several challenges like porosity formation, poor wettability and improper distribution of reinforcement. Achieving uniform distribution of reinforcement is the foremost important work. The raw materials used for the synthesis of the composites is LM25 alloy and 10%(wt) granite. The LM 25 and granite composite was fabricated using stir casting for three different percentages of reinforcement. Synthesis of composites requires various additions other than the actual raw materials such as flux and die coat are required for synthesizing and casting of metal matrix composites. The (Si-7.2%), A 356/ LM 25 matrix alloy, has the following chemical composition (in weight percent) is listed in Table 3.1. This alloy conforms to BS1490. Table 3.2 gives the mechanical properties of A356 alloy. The LM 25 aluminium alloy ingot pieces were melted in a preheated graphite crucible in an induction furnace. After the complete melting of the matrix material at around 800° C the melt surface was covered by a fluxing agent “COVERAL-11”[13] in order to minimize the oxidation of molten metal. For each melting 3-4Kgs of alloy was used. The superheated molten metal was degassed at a temperature of 780°C by passing dry Nitrogen gas in the melt for 5 minutes. The reinforcing particles of granite were preheated to around 750°C for 4 hours and then were added to the molten matrix alloy and stirred continuously by using mechanical stirrer at 720□C. The stirring time was maintained between 5 – 10 minutes at an impeller speed of 600 rpm. During stirring, Magnesium (1Wt %) was added in small quantities to increase the wettability of the dispersoid particles. To ensure uniform distribution of dispersoid in the matrix alloy, stirring was continued at 350 rpm for 4-5 minutes after addition of particles in the melt. The melt temperature during mixing of reinforcing particles was maintained in the range of 700°C-800°C. The dispersion of the preheated particulates was achieved in accordance with the vortex method. The melt with the reinforced particulates were poured into the dried, coated, cylindrical permanent metallic moulds of size of diameter of 25mm, 50mm, 75mm and height 200mm. The pouring temperature was maintained at 680□C. The same molten mixture was poured into strip and spiral fluidity dies for **fluidity measurements**. The total length of the metal that has flown inside the mould cavity is taken as a fluidity measure. The melt was allowed to solidify in the moulds. For the purpose of comparison, the base alloy was cast under similar processing conditions as described. In each case about 10Wt% of reinforcing particles of size 50-150µ were used to synthesize two set of composites.

IV. Experimental Analysis

Two body sliding wear tests were carried out on prepared composite specimens. Pin-on-disc wear test machine (DUCOM, Bangalore, India Make, Model: TR-20 LE) was used for these tests. The tangential friction force and wear in microns were monitored with the help of electronic sensors. These two parameters were measured as a function of load, sliding velocity and % of dispersoid. For each type of material, tests were conducted at three different speeds (1.95,3.95 and 5.55 m/s). All the tests were conducted for a maximum sliding distance of 5000m under varying load up to 8 Kg in steps of 0.5 Kg A cylindrical pin of size 8mm diameter and 40 mm length prepared from composite casting was loaded through a vertical specimen holder against horizontal rotating EN32 disc of steel with hardness 65 HRC and diameter 50 mm. Before testing, the flat surface of the specimens was abraded by using 2000 grit paper. Wear tests were carried out at room temperature without lubrication for about 2Hrs and 20 min. Temperature rise near the mating surface of the specimen was measured as a function of test duration using a Chromel Alumel thermocouple. Inserted in the hole of the pin specimen 1.5 mm away from the sliding surface. The seizure of the specimen was indicated by a relatively higher rate of temperature rise of test pin and followed by vibrational and abnormal noise from the mating surface. Both the alloy matrix and the composites were tested under identical conditions. The specimen were cleaned thoroughly by acetone before and after the test for measuring the weight loss. The wear rate was calculated as the volume loss per unit sliding distance.

V. Results

The effect of wear pressure on applied wear rate has been studied at different sliding speeds for the matrix alloy LM25 and the composite containing granite particles.

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The effect of speed on the seizure pressure is presented in this section. Studies were carried out on the variation of wear rate for the matrix alloy and the composite containing granite reinforcement as a function of applied pressure at different sliding speeds of 1.95, 3.95 and 5.55 m/sec respectively which is represented in figures 5.1, 5.2 & 5.3 respectively. It should be noted from the figures that the wear rate increases with the increase in applied pressure and reaches a seizure point denoted by S. It is also noticed that the wear rate of the matrix alloy is significantly more than that of the composite containing granite particles. At all the sliding speeds slope of the curve for the base alloy is very sharp indicating substantial increase in the wear rate with increase in the applied pressure. In the case of the composite containing granite particles the wear rate in general increases with the applied pressure irrespective of the speed. At low speed of 1.89 m/sec in initial and final stage rate of increase in wear rate is high with increasing applied pressure as shown in Fig 5.9. At the intermediate speed of 3.95 m/sec the wear rate increases uniformly with the applied pressure. However it is seen that the increase in wear rate is insignificant at higher speed range of 5.5 m/sec and applied pressure of 0.4 MPa (Fig 5.3).

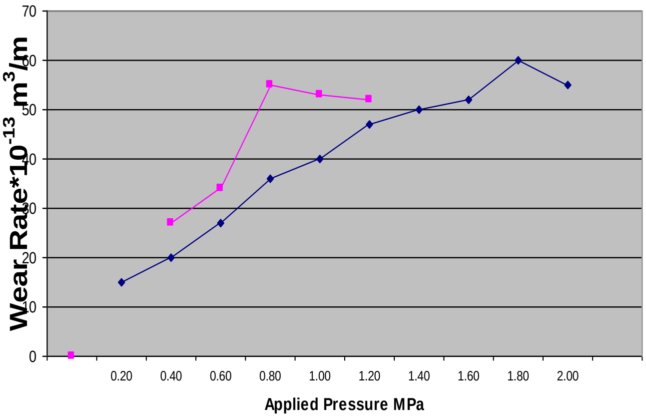

Figure 5.1: Applied Pressure verses Wear rate for the A 356 alloy and composite with 10% Granite at sliding speed of 1.95 m/sec

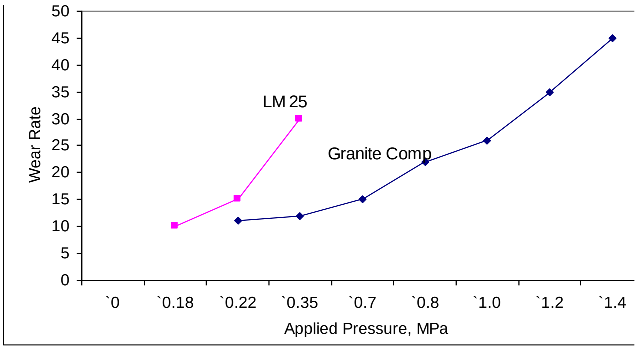

Figure 5.2: Applied Pressure verses Wear rate for the A 356 alloy and composite with 10% Granite at sliding speed of 3.95 m/sec

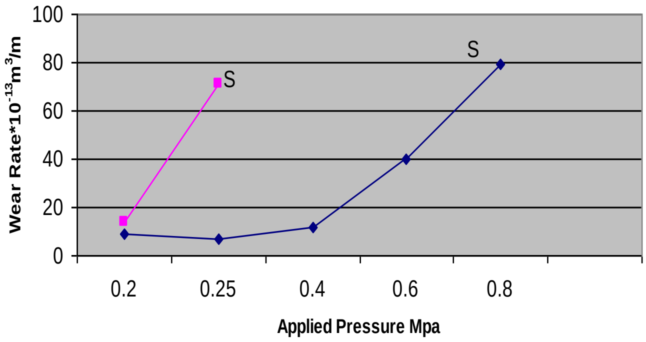

Figure 5.3: Applied Pressure verses Wear rate for the A 356 alloy and composite with 10% Granite at sliding speed of 5.5 m/sec

The effect of sliding speed on the wear rate has been studied and is shown in fig 5.4. It is evident from the figure that the wear rate of the composite decreases with increase in sliding speed irrespective of applied pressure. But, for the matrix alloy the variation in wear rate does not follow any specific trend with the sliding speed. The wear rate of the alloy initially decreases with speed and reaches to minimum at the critical speed of 4m/sec and after that it starts increasing and reaches seizure point at the applied pressure of 0.3 Mpa. On the other hand at the higher pressure of 0.4 Mpa or above the wear rate of the alloy increases monotonically with the sliding speed and reaches seizure.

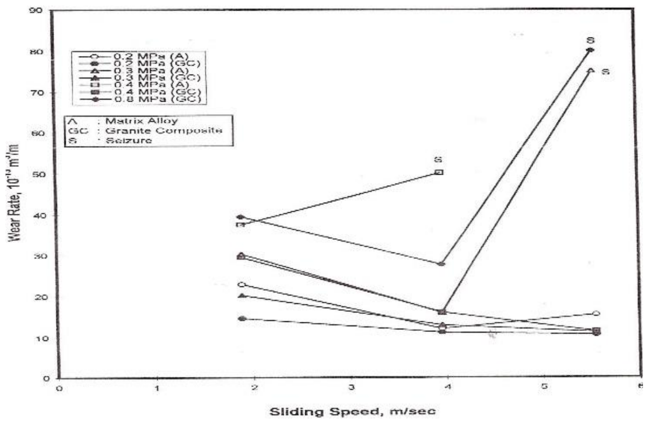

Figure 5.4: Wear Rate as function of Sliding Speed for the matrix alloy and Granite Composite at different applied pressures

It is also observed that the seizure pressure of the matrix alloy is less than of the composite due to the presence of reinforcing particles. There is a variation noticed in the seizure pressure of the matrix alloy and the composite with respect to the sliding speed, as can be seen from Figure 5.5. It is also noticed that for the alloy and the composite, the seizure pressure decreases linearly with the speed. The seizure pressure of the alloy at the speeds 1.93, 3.95, and 5.5 m/sec are 0.6, 0.4 and 0.3 Mpa respectively. For the granite reinforced LM25 matrix composite the seizure pressures for speeds of 1.93 m/sec, 3.95 m/sec and 5.5 m/sec are 1.6, 1.2 and 0.8 Mpa respectively. It is also noticed that the difference in the seizure pressure between the composite and the alloy decreases with increase in the sliding speed.

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Even at the higher speed the difference in pressure is quite significant (fig 5.5). In fact the seizure pressure for the granite composite is almost 2.5 times more than that of the base alloy at the sliding speed of 5.55 m/sec.

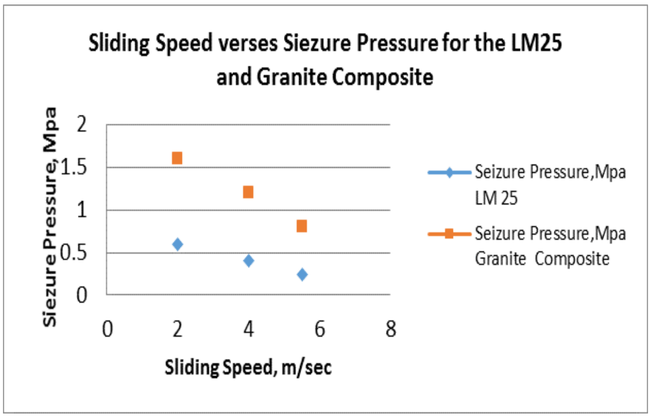

Figure 5.5: Sliding Speed versus Seizure Pressure for the matrix alloy LM25 and the Granite Composite

VI. Conclusion

It is evident from experiment that at low sliding speed (1.95 m/s) the worn pin surface predominantly reveals fine and shallow grooves in the sliding direction. Such features are characteristics of abrasive wear, in which hard asperities of the counterface plough into the hybrid composite pin, causing wear by the removal of small fragments of material. The granite particles effectively act as load carrying members and coupled with the formation of lubricating graphite film, the overall wear rate is low The fractured granite particles and sharp asperities on the counter face easily penetrate the graphite film and coarser and deeper grooves are formed and the wear rate increases. As speed increases the particulates undergo less fracture, this helps in retaining the amount of granite particulates. It is obvious from figure3.4, the wear rate of both unreinforced LM 25 alloy and the Aluminium matrix composites decreases as the sliding speed increases up to 5.5 m/s. At a speed of 3.95 m/s, only the wear trend of the unreinforced alloy changes from mild to severe, while the composites continue to show the same trend. At a speed of 5.5 m/s, the composite wear rate curve pattern changes to severe wear. The unreinforced alloy shows seizure at 5.5 m/s, whereas the composite does not. Further, the wear rate of the composite decreases as the amount of reinforcement. Heavy noise and vibration were observed during the process and transfer of the pin material to the disc was also observed. The effect of applied load is directly proportional to wear rate, i.e., as applied load increases, wear rate also increases. The positive coefficient of load indicates that dry sliding wear rate of the composite increases by increasing load. This is because, the temperature at the interface between the disc and the pin increases with increase in the applied load and the same has been observed in A356 Al composites. Abrasive wear is possible at low loads, where the reinforcing hard alumina particles remain intact without fracture during wear and thus act as load bearing elements. Thus at low loads, the abrasion wear mechanism becomes dominant and as the load increases, the induced stresses exceed the fracture strength of the particles causing their fracture. Thus, reinforcing the virgin alloy with ceramic particles of granite improves the wear rate of the material, thus making it suitable for tribological applications.

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