

EFFECT OF CONTACT TIME, SLIDING SPEED AND NORMAL PRESSURE ON

FRICITION OF AL-SI-MG-FE ALLOY

S. Madhava Reddy¹ and A. Chennakesava Reddy²

¹Associate Professor, Dept. of Mechanical Engineering, MGIT, Hyderabad, Telangana, India

² Professor, Dept. of Mechanical Engineering, JNTUH, College of Engineering, Kukapally, Hyderabad, Telangana, India

smrmech@gmail.com

Abstract

The wear characteristics of the Al-Si-Mg-Fe alloy depend upon material morphology such as composition, size, shape and distribution of micro constituents and the effect of normal pressure, contact time and speed on sliding friction coefficient was evaluated using a pin-on-disc wear testing machine. The conventional melting and casting procedures for AL-Si-Mg-Fe alloys result in massive nonmetallic precipitates and consequent casting defects causing deterioration of strength and toughness. Solution treated Al-Si-Mg-Fe alloys as a tribological component in recent years, has been expanding widely in aeronautical, automobile and general industries. Depending upon the applications, these alloys should be sand cast, investment cast and die cast. Experiments showed that the contact time, normal pressure and sliding speed affect the frictional force. The results conclude that the frictional force decreases with increasing of sliding speed for all the specimens. The frictional forces increase with increase in normal pressure. And also frictional force increases with increase in contact time upto 30 min and then decreases with further increase in the contact time.

Key Words: Frictional force, Normal pressure, Sliding speed, Contact time

1. Introduction

Various researchers have observed that variation of friction and wear rate depends on interfacial conditions such as normal load, geometry, relative surface motion, sliding speed, surface roughness of the rubbing surfaces, type of material, system rigidity, temperature, stick slip, relative humidity, lubrication and vibration. Among these factors sliding speed and normal load are the two major factors whose play significant role for the variation of friction and wear rate[1]. Fridmen and Levesque suggest that part of the observed friction reduction is due to negative slope of the dependence of the friction force upon velocity. The friction force is a function of velocity and time of contact. For most materials when the velocity increases, friction decreases and when duration of contact increases, friction increases. The dependence of friction on velocity may be explained in the following way. When velocity increases, momentum transfer in the normal direction increases producing an upward force on the upper surface. This results in an increased separation between the two surfaces which will decrease the real area of contact. Contributing to the increased separation is the fact that at higher speeds, the time during which opposite asperities compress each other is reduced increasing the level on which the top surfaces moves[2]. Aluminum alloys are attractive alternatives to ferrous materials for tribological applications due to their low density and high thermal conductivity. However, their uses have been limited by their inferior strength, rigidity and wear resistance [3]. Applications requiring enhanced friction and wear characteristics include brake rotors, engine blocks and cylinder liners, connecting rods and pistons, gears, valves, pulleys, suspension components, etc[4]. Aluminum alloys have been expanding widely used in aerospace, automotive and general industries because of their low weight and good mechanical and tribological properties[5]. The coefficient of friction effect

can be readily known but it is difficult to understand, although it has been used for a long time in engineering and scientific applications, because it is dependent on the type of grain, bulk density and roughness of the wall surface [6]. Ghajali [7] studied the effect of Al alloy composition on dry wear behaviour against a ferrous counterface. In particular, the effect of alloy composition on work hardening behaviour was investigated. The greatest wear resistance was exhibited by the A2124. This alloy showed the greatest initial hardness and the most surface hardening at all loads. The A6092 produced intermediate behaviour, with values of wear rates. As for the A5056, a lower specific wear rate at the highest load appeared to be associated with proportionately thinner surface damage accumulation. The A3004, being the softest alloy, exhibited the most substantial reduction in specific wear rate with load, being the highest at 23 N of all alloys by some margin, but similar to the other materials at 140 N[8]. The commercially important alloys contain copper as major addition and the phase reactions, which occur, are those between an aluminium solid solution and the intermetallic phases $CuAl_2$ and $CuMgAl_2$ [8]. AA6061 Al alloy, another commercial alloy, has a few Cu. It was reported that it showed relatively smooth worn surface [9,10]. The best wear resistance of 6061 Al alloy could be attributed to the highest hardness and the lowest coefficient of friction. In this work, effects of contact time, sliding speed and normal pressure on frictional force of Al-Si-Mg-Fe alloys on pin-on-disc has been investigated.

2. Material and experimental study

The following raw materials were used to evaluate the friction and machining characteristics Al-Si-Mg-Fe alloy

samples:

- Al-Si alloy
- Pure magnesium
- Pure aluminum
- Pure iron
- Sand mould, investment shell, and cast iron mould (die)
- Fluxing agent
- Degasifier

The alloy was prepared and chemical analysis of their ingredients was done. The chemical composition of alloy is given in Table 1. The sand mould, investment shell, and cast iron mould were employed to prepare the samples for wear tests. The melts were degasified with tetrachlorethane tablets.

Table-1: Chemical composition of alloys

Alloy	Composition on determined spectrographically, %						
Element	Al	Si	Mg	Fe	Cu	M _n	Cr
%	85.2 2	9.0	2.0	3. 5	0.0 1	0.2 5	0.0 2

An Al-Si-Mg-Fe alloys were melted in an oil-fired furnace. The melting losses of aluminum and magnesium were taken into account while preparing the charge. During melting, the charge was fluxed with coveral-11 (a Fosco company product) to prevent dressing. The molten metal was then degasified by tetrachlorethane (in solid form) using a plunger ending in a small inverted crucible. The melt was also modified with sodium and refined with Al-Ti master alloy in the crucible before pouring. The crucibles were made of graphite. The dross removed melt was finally gravity poured into the preheated sand mould, investment shell, and metal die. The cavity shape is cylindrical in all the methods of casting. The pin specimens were prepared from Al-Si-Mg-Fe alloys. The dimensions of the specimens was 6 mm diameter and 20mm length.

A pin on disc type friction and wear monitor (ASTM G99) was used to evaluate the wear behaviour of Al-Si-Mg-Fe alloys against hardened ground steel (En32) disc having hardness of RC 62 and surface roughness (R_a) 0.6 μm (Fig.1). Load was applied on pin by dead weight through pulley string arrangement. All the test samples were solution heat treated under T6 conditions. The mechanical behavior of the Al-Si-Mg-Fe alloy specimens was evaluated in terms of tensile strength, ductility (in terms of tensile elongation), and hardness. The microstructural examination of the test samples was carried out to reveal and study the grain structure, the interfaces, and the formation of intermetallics in the test samples. The sliding behavior of the specimens under the dry frictional conditions was evaluated (fig.1).

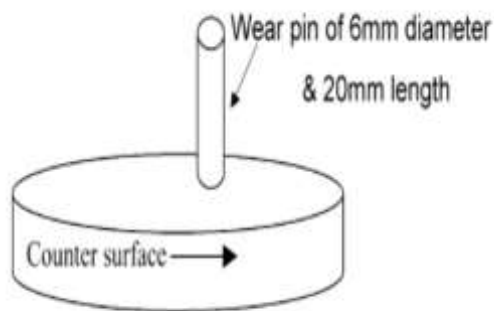
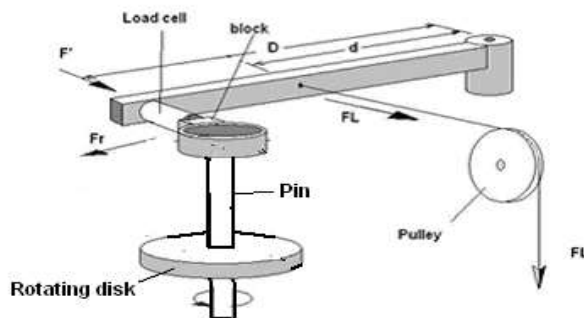


Fig.1. Schematic representation of the sliding wear experiment

Wear tests include the measurement of:

- Temperature of pin using thermocouple, and
- Friction force with data acquisition system

An investigation has been carried out to study the effects of sliding speed, contact time, normal pressure, and casting procedure of Al-Si-Mg-Fe alloys on the wear characteristics. The mechanical properties and metallurgical morphology were investigated to evaluate the frictional coefficient of these alloys. EDX analysis was also carried out to find the major elements present in the worn surface of the wear specimens. Each experiment was repeated twice and the average values of wear characteristics were plotted against the process variables.

3. Results and discussion

3.1 Mechanical Properties

The mechanical properties of Al-Si-Mg-Fe alloys are given in Table-2. The mechanical properties of die cast alloy are superior to investment cast and sand alloys. The reason could be the fine grain structure in the die cast alloys. The grain structure in the casting is influenced by the solidification process. The sand casting resulted with coarse grain structure in the castings due to slow solidification process. The castings produced by the investment casting have intermediate grain size having the lower limit of sand castings and the upper limit of die castings.

Table-2: Mechanical Properties of Al-Si-Mg-Fe alloys

Mechanical properties	Sand cast	Investment cast	Die cast
Tensile strength, N/mm ²	199.52	213.64	234.11
% Elongation	9.1	9.8	10.2
Hardness (surface), BHN	71	75	87

The solubility of Mn in aluminium is reduced by the presence of Fe and Si leading the formation of intermetallic compounds. Fig.2 shows the EDX analysis of the Al-Si-Mg-Fe alloy castings. The EDX analysis of worn surfaces of Al-Si-Mg-Fe alloy. EDX analysis showed that the worn surfaces contain Al, Si, Mg, Fe, O, and indicating the presence of Fe₂O₃, Al₂O₃, and MgO. This confirms that the wear mechanism also consists of oxidative phenomena.

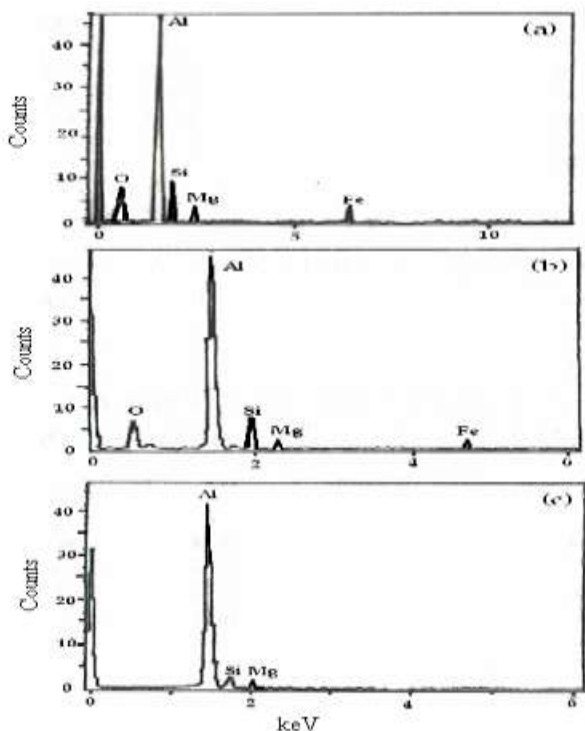


Fig.2: EDX analysis of Al-Si-Mg-Fe alloy worn surfaces (a) sand cast, (b) investment cast, and (c) die cast

The sand casting resulted with coarse grain structure in the castings due to slow solidification process. The castings produced by the investment casting have intermediate grain size having the lower limit of sand castings and the upper limit of die castings (fig.3).

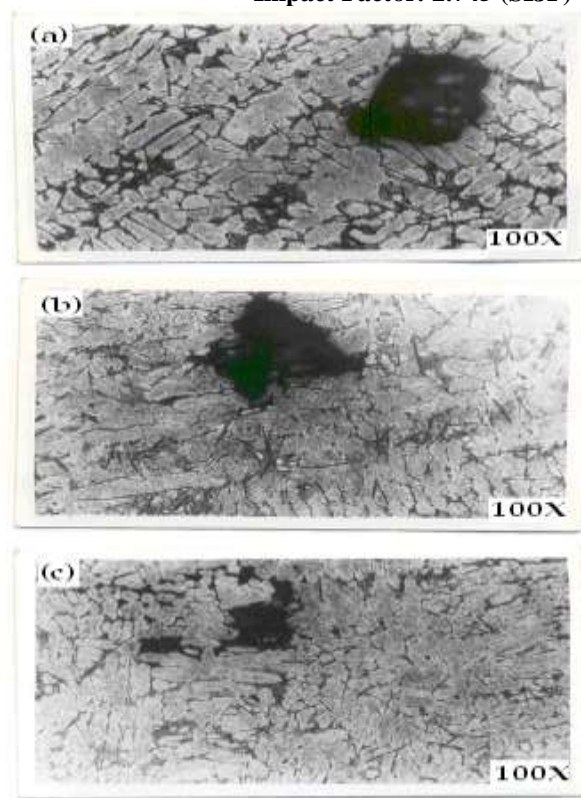
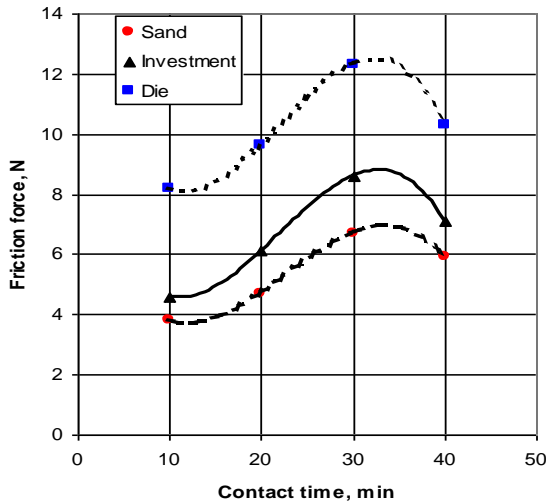


Fig.3 Microstructures of Al-Si-Mg-Fe alloys produced by (a) sand cast (b) investment cast, and (c) die cast processes.

4. Effect of contact time, sliding speed, and normal pressure on frictional force

The influence of contact time on the frictional force is shown in figure 4. The frictional force increases with increasing of contact time up to 30 min and then decreases with further increase in the contact time for all the specimens. The increase in the frictional force may be attributed to the dominant role of abrasive mechanism, which is responsible for dry wear up to 30 min of contact time. The decrease in the frictional force may be ascribed to the dominant role of adhesive mechanism, which is accountable for the formation of viscous layer between the pin and abrasive disc. The viscous layer reduces the coefficient of friction and subsequently reduces the frictional force developed during the long contact periods. The frictional force is higher for die cast specimens than that for sand cast specimens. The reason could be due to the presence of fine grain structure in the die cast specimens and the coarse grain structure in the sand cast specimens. The fine grains have greater surface area per unit volume than the large and irregular grains. The frictional force generated in the investment cast specimens is intermediate to the sand cast and die cast specimens. The influence of sliding speed on frictional force is shown in figure 5. The frictional force decreases with increasing of sliding speed for all the specimens.

Fig.4 Influence of contact time on frictional force. The normal pressure and sliding speed respectively, 0.75MPa and 2 m/s This is in fact, a general phenomenon because the dynamic coefficient of friction is lower than the static coefficient of friction. Furthermore, the slip phenomena appearing between the pin and the abrasive disc lowers the



frictional force.

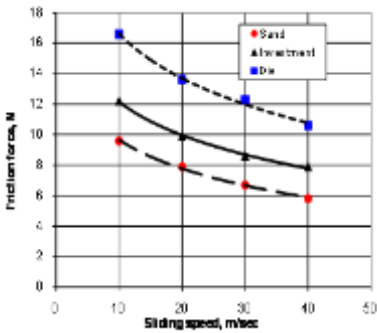


Fig. 5 Influence of sliding speed on frictional force. The normal pressure and contact time are respectively, 0.75MPa and 30min.

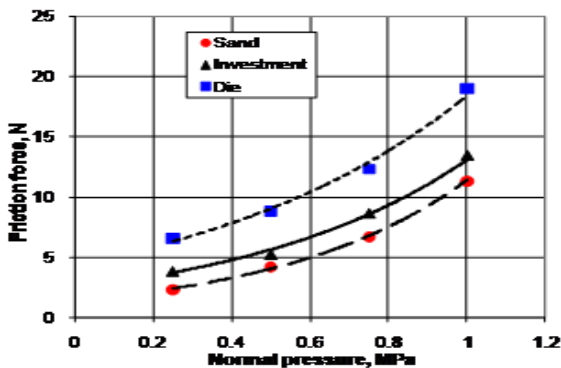


Fig. 6 Influence of normal pressure on frictional force. The contact time and sliding speed are respectively, 30min and 2m/sec.

The influence of normal pressure on frictional force is shown in figure 6. It can be seen that a general trend of

increase in frictional force with increase in normal pressure. The frictional force is directly proportional to the normal pressure applied on the pin. The die cast specimens have higher frictional forces developed than the sand cast specimens. The frictional force developed is proportional to the hardness value of the material and is inversely proportional to the material loss. The material loss is more for the sand cast specimens. The frictional force is exponential to the normal pressure applied on the specimen. The worn specimens are not length enough for tensile testing to evaluate tensile strength and %elongation.

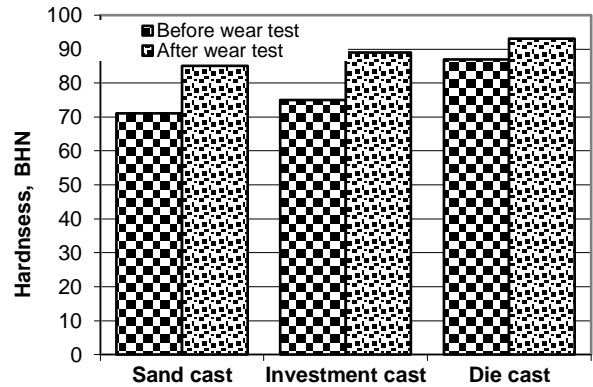


Fig.7 Hardness values of worn specimens

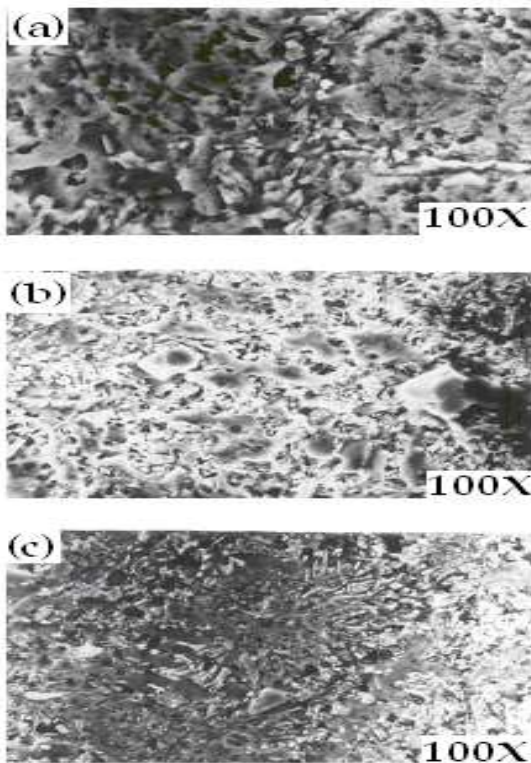
Therefore, the worn specimens were tested for hardness only. The change in hardness of the worn specimens is shown in figure 7. It can be seen that the hardness values increase after wear test. The increase in hardness in the worn specimens may be attributed to the work (strain) hardening and the frictional temperature.

Fig.8: Microstructures of Al-Si-Mg-Fe alloy worn specimens (a) sand cast, (b) investment cast, and (c) die cast.

The microstructures of worn specimens are revealed in figure 8. The grains become finer owing to the work hardening. There is also diffusion across the grain boundaries due to the frictional temperatures and strain hardening. The frictional temperatures rise in the worn specimens on account of increased conversion of frictional energy into heat energy. The frictional temperatures and plastic deformations of the wearing surface result in the movement of dislocation in the wearing layers. The frictional temperatures also result in tempering which in turn soften the structure. The increase in hardness values of worn specimens indicates that the work hardening effect dominates the softening effect. The softening of structure in the wearing specimens aids in the diffusion across the grain boundaries

5. Conclusions

The normal pressure, contact time and sliding speed affect the amount of frictional force. The results conclude that the frictional force is reduced with the increasing of sliding speed. The higher frictional force is noticed when the contact pressure increases. And also frictional force increases with increase in contact time upto 30 min and then decreases



with further increase in the contact time. The frictional force is higher for die cast specimens than that for sand cast specimens. Frictional force depends on the material properties such as hardness, strain rate, modulus of elasticity and ultimate tensile strength.

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