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Empirical impact of forging and T6 thermal treatment on the wear rate of an Al25Mg2Si3Cu4Ni alloy

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Abstract

In this work, a study of effect of forging and T6 heat treatment on wear rate of Al25Mg_2Si3Cu4Ni alloy, has been forged and homogenized for 5hr. In this study the wear test were conducted by varying load from 10-50N at a sliding velocity 1-3m/sec and a sliding distance of 1025m. It is observed that the Friction force and the volumetric wear rate are high at low sliding speed and reduce with increase in sliding speed. Whereas the interface temperature is low at low sliding speed and increases with the sliding speed. Results of SEM structure show rounded corners of Mg_2Si intermetallic blocks embedded with Ni in it due to the effect of homogenizing.

Keywords: flow stress, plastic deformation, wear rate, precipitates and friction coefficient.

1.0 Introduction

Aluminum alloyed with silicon (Si) is the material of tremendous industrial importance. The Al-Si alloys have a number of favorable characteristics including good wear resistance, low thermal expansion, ease of weld-ability, increase in the strength and stiffness without increasing the density. Various casting processes including high pressure die casting, permanent mold casting, sand casting and many other processes exhibit excellent productivity, mechanical and physical properties in these alloys. The strength and quality of Al-Si alloy castings are determined by the appropriateness of their microstructure, viz., the fineness, size and morphologies of the micro-constituents present there-in, as well as the amount of porosity produced in the casting.

2. Experimental Details

2.1 Material selection

In the present investigation, the hypereutectic alloys such as Al25Mg_2Si3Cu4Ni and Al25Mg_2Si with and without Cu, Mg and Ni as alloying additions are used to represent the light weight heat treatable Al-Mg_2Si-Cu alloys. Table 2.1 summarizes the nominal compositions of all the selected alloys. The as-cast ingots of different compositions, listed in the Table 1, are obtained from FENFE Metallurgical, Bangalore, India. The chemical composition of all the alloys is anlalysed by spark emission spectrometer [Make: PANalytical - XRD & XRF Instrumentation, Model QSN 750-II single or multi matrix system.]

The alloy used in the present work is Al25Mg_2Si3Cu4Ni its chemical composition as shown in the Table2.1.

Table 2.1 Chemical composition (wt %) of AlxxMg_2Si alloys

Sr. No	Alloy %	%Si	% Ni	%Cu	%Mg	%Al
1.	Al25Mg_2Si3Cu4Ni	9.3	3.85	3.25	18.25	Balance

2.2 Wear test

2.2.1 Dry sliding wear test

The wear test will be carried out using a pin-on-disc type wear-testing machine (DUCOM, Bangalore, India) according to ASTM: G99-05 (ASM, 1992) standard. The samples will be cleaned prior to and after each interval of wear test with acetone. The wear rates of the alloys are calculated by measuring the difference in weight of the specimens measured before and after the tests (measured with an analytical balance Mettler AJ100, Hightstown, NJ of 0.1 mg precision). Wear specimen of size 30 mm length and 10 mm diameter are machined from differently processed samples. The contact surface of the specimen are polished up to 1200 mm grit size and tested against a rotating EN-32 steel wear disc with a hardness value of HRC 65. The wear tests are carried out at sliding velocities for a fixed sliding distance of 5000 m at different normal loads. The frictional force induced on the specimen is recorded constantly during the wear test by a load cell. The worn surfaces of pins after the test are examined using (SEM) Scanning Electron Microscope - EDAX, TEM, and XRD tests.

Wear tests will be conducted on all the alloy specimens on a pin-on-disc wear testing machine as shown in the figure 3.2 (Model: TR-20, DUCOM) as per ASTM: G99 - 05. The counterpart disc is madeup of quenched and tempered EN-32 steel having a surface hardness of 65HRC. Wear specimens of size Ø10×30 mm will be machined out from the alloys. The specimens are polished and then cleaned with acetone before conducting the wear test. The wear tests are conducted by varying the load from 10–50 N at a sliding velocity of 1-3 m/s and a sliding distance of 1025 m. All the experiments will be carried out under dry sliding conditions and data will be recorded at higher working/ operating temperatures

Figure 2.2 Pin-on-disc wear testing machine

2.3 Microstructural study

2.3.1 Metallographic sample preparation

The samples from as cast, as cast and hot pressed and as-cast alloys are machined from the center portion of the preform. The samples are prepared using standard metallographic techniques of grinding on emery paper with 1/0, 2/0, 3/0 and 4/0 specifications. Final polishing is done on a wheel cloth using brasso and kerosene. The polished samples are etched with Keller's reagent (1% vol. hydrofluoric acid, 1.5% vol. hydrochloric acid, 2.5% vol. nitric acid and rest water).

Figure 3.4 Disc type wet polishing machine

4 Results and discussions

4.1 Optical Microscopy

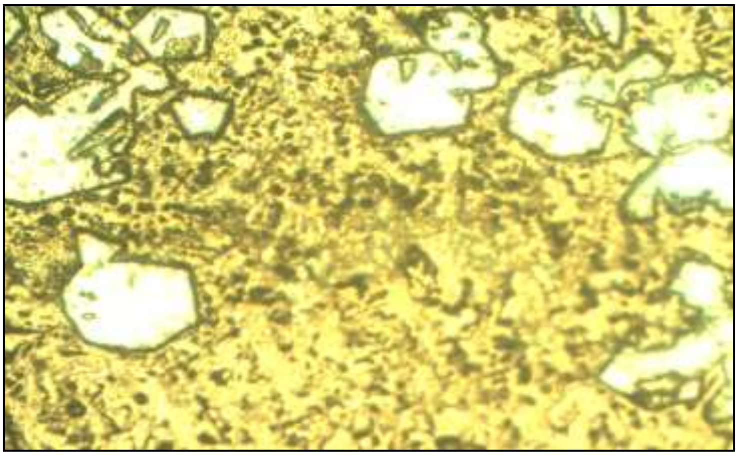

Fig 4.1 homogenized optical microscopy

Results

1. Mg_2Si blocks getting fragmentedof Al_2Cu

2. Formation of chinese script shaped precipitates **Fig SEM** image of Al25Mg_2Si3Cu4Ni, hours of homogenized

4.2 Wear test results

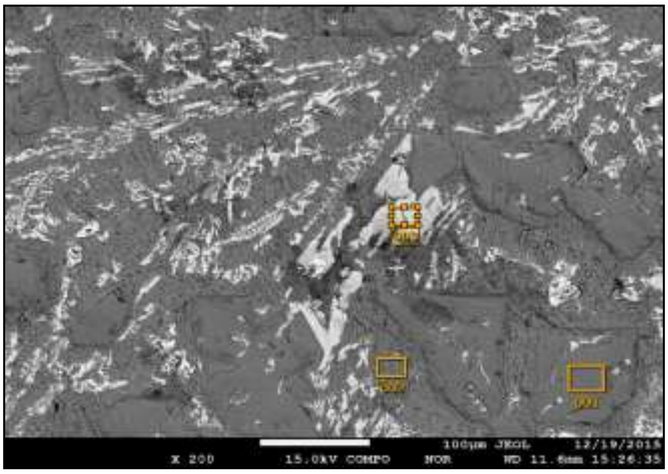

Fig 4.2 Wear SEM surface

Results

1. Ni plates have broken.

2. Precipitates of Al_2Cu formed

3. Mg_2Si blocks have broken.

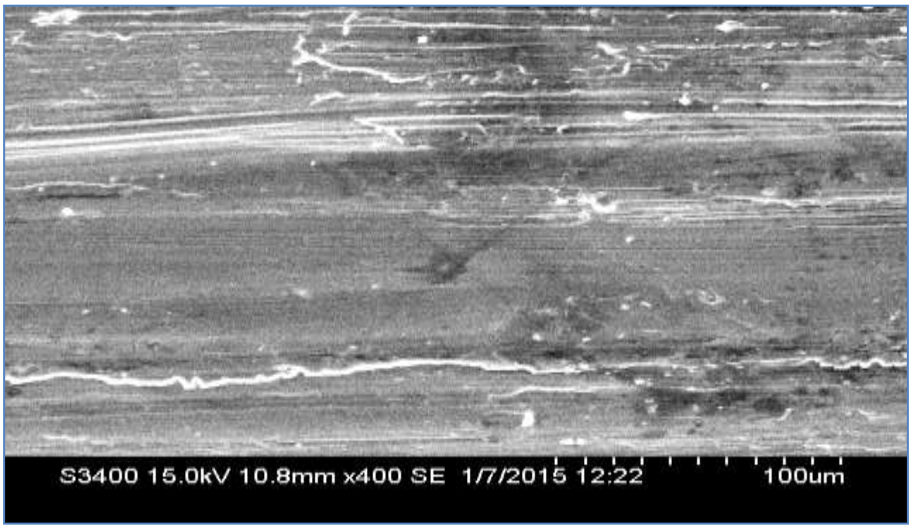

Fig 4.3 SEM wear surface

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Results

1. Wear test surface show minimum wear due to precipitation of intermetallics such as Al_2Cu

Conclusions: Overall trend is increase in the volumetric wear rate with increase in the load at lower sliding speeds.

4.3 Load v/s friction coefficient

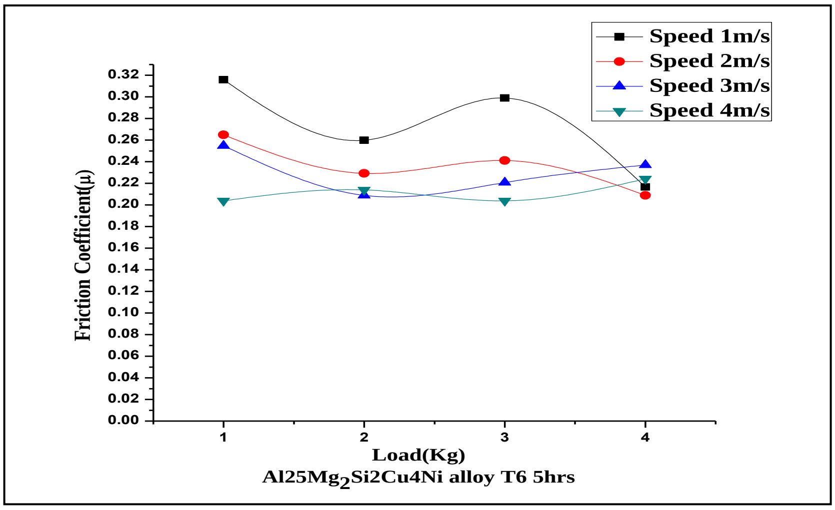

Fig 4.1 Load v/s friction coefficient

Result:

a. **For 1 m/s sliding speed :** As load increases from 1 to 2 kg friction coefficient decreases then from 2 to 3 kg of load friction coefficient Increase later it decreases again.

b. **For 2 m/s sliding speed:** There is slight changes in friction coefficient.

c. **For 3 m/s sliding speed:** Between 1 to 2 kg of load friction coefficient decreases then it is increases gradually.

d. **For 4 m/s sliding speed:** There is small changes in friction coefficient.

Discussion: For small value of load friction coefficient is high and as load increases Friction coefficient varies with smaller value and becomes stable. By this we can conclude that for 1 kg of load friction coefficient is high.

4.4 Load v/s friction force

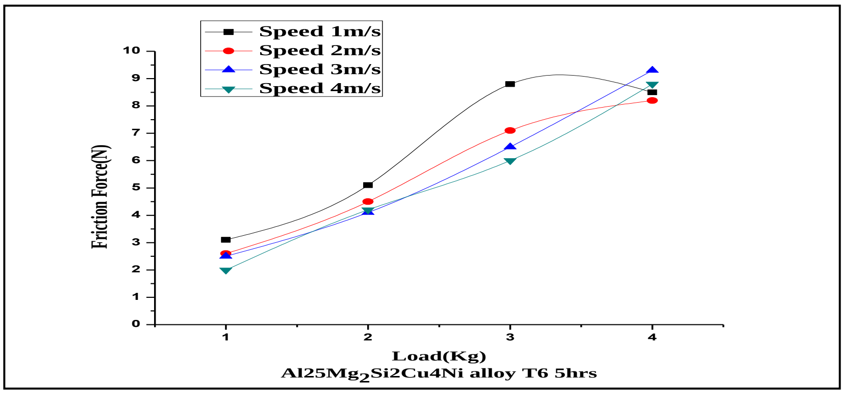

Fig 4.2 Load v/s friction force

Result:

a. **For 1 m/s sliding speed:** As load increases the friction force gradually increases up to 3 kg then it decreases.

b. **For 2 m/s sliding speed:** As load increases the friction force gradually increases.

c. **For 3 m/s sliding speed:** As load increases the friction force simultaneously increases.

d. **For 4 m/s sliding speed:** As load increases the friction force similarly increases.

Discussion: From above graph we observe that as load increases friction force increases. By this we can conclude that at the higher load friction force reaches maximum value.

4.5 Load v/s Interface temperature

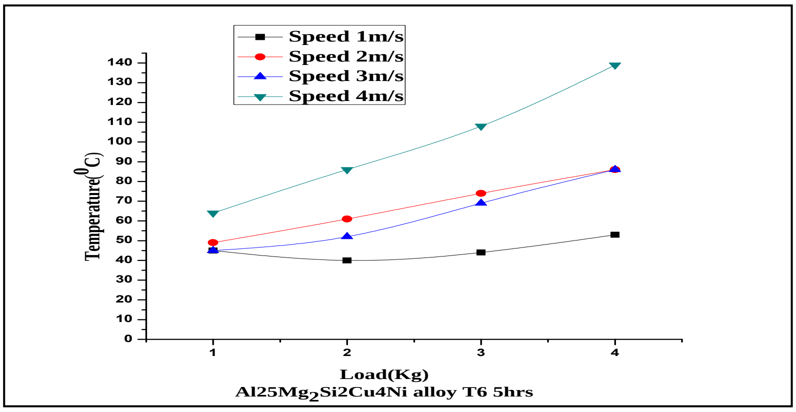

Fig 4.3 Load v/s Interface temperature

Result:

a. **For 1 m/s sliding speed:** As load increases interface temperature remains constant.

b. **For 2 m/s sliding speed:** As load increases, there is a small changes in interface temperature.

c. **For 3 m/s sliding speed**: As load increases again there is small change in interface temperature.

d. **For 4 m/s sliding speed:** As load increases interface temperature gradually increases.

Discussion: For sliding speed of 1 m/s as load increases the interface temperature remains Constant. Between sliding speed of 2 to 3 m/s the interface temperature increases gradually. The interface temperature is high for 4 m/s because of higher load and increase in friction Force.

4.6 Load v/s volumetric wear rate

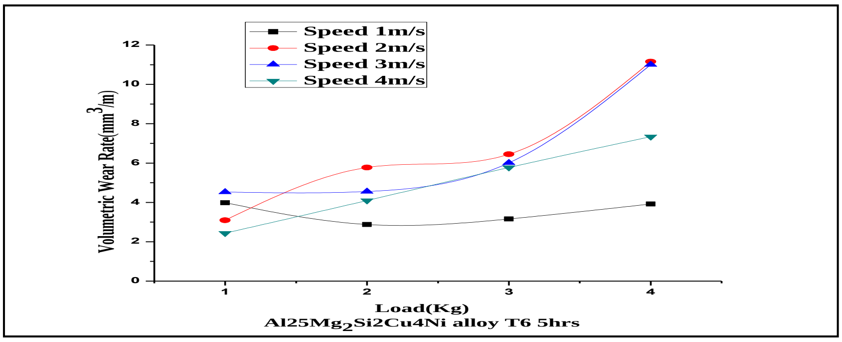

Fig 4.4 Load v/s volumetric wear rate

Result:

a. **For 1 m/s sliding speed:** As load increases volumetric wear rate remains constant.

b. **For 2 m/s sliding speed:** Between 1 to 3 kg of load volumetric wear rate increases slightly then increases rapidly.

c. **For 3 m/s sliding speed:** Between 1 to 2 kg of load volumetric wear rate remains constant hen it increases rapidly.

d. **For 4 m/s sliding speed:** As load increases the volumetric wear rate gradually increases.

Discussion: At 1 m/s of sliding speed with increase in load volumetric wear rate gradually increases. Between sliding speed of 2 and 3 m/s volumetric wear rate remains constant and suddenly increase at higher load. For higher speed volumetric wear rate shows a straight line.

5. Conclusions

1. The friction coefficient is independent of increase in load further it decreases at lower sliding speed.
2. For load of 1kg the friction force remains constant and is directly proportional to load.
3. At higher speeds due to higher friction force the interface temperature increases. For lower sliding speed there is slight increase in interface temperature.
4. At lower sliding speed volumetric wear rate is independent of increase in load. With increase in sliding speed the volumetric wear rate also increases because of higher temperature.

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