Effect of Ni at constant loading on the wear behavior of 5H homogenized $Al25Mg_2Si2Cu4Ni$ alloy

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Abstract- *In this work, we have made a study of wear behaviour of as cast aluminium (Al25Mg2Si2Cu4Ni) alloy, which has been homogenized for 5hr with T6 Heat treatment. In this study we have come across various parameters like Friction force, Friction co-efficient, Speed and Volumetric wear rate and their relationship. 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 Mg2Si intermetallic blocks embedded with Ni in it due to the effect of 5 hour homogenizing.*

Keywords: Volumetric wear rate, coefficient of friction, solutionizing, Interface temperature.

1. INTRODUCTION

Aluminium 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.

6000 series aluminium alloys are being used for applications in automotive industries for their light weight and strength. This strength comes mainly from their ability to age artificially. Copper is added to these aluminium alloys in different proportions which leads to the formation of different phases as well as precipitates with unique properties. In case of Al-Mg-Si alloys the hardening phases are beta' and beta" whereas in case of Al-Mg-Si-Cu alloys more number of hardening phases appear that makes the response to the artificial aging process more complex. Among all the phases present in these alloys 'Q' phase is an important one which forms as an equilibrium phase. In this paper the thermodynamic stability of the 'Q' phase is discussed against other coexisting phases. A meta stable type of this phase has been reported to exist at the peak age temper that may be useful in understanding the overall precipitation hardening mechanism. This phase is documented by using TEM micrographs and diffraction patterns which helps in differentiating this 'Q' phase from the β'phase.

As shown in Figure 1 commercial aluminium alloys of Al-Mg-Si have ternary equilibrium phases such as theta, beta and Si . When Cu is added Al and 'Q' phases which are common are formed along with theta, beta and Si based phases. As seen in the figure 1 addition of silicon in the ternary Al-Cu-Mg alloys the three phase field consisting of Al, theta and Si expand into tetrahedron phase field consisting Al, theta, S and beta phase at low silicon addition. At higher addition of silicon 'Q' phase replaces the 'S' phase. This replacement of 'S' phase with 'Q' phase results in abrupt changes in the phase combinations.

The hypereutectic Al-Si alloys with alloying elements such as, Mg, Cu, Ni and Mn have been successfully produced by modern processing technologies to improve strength-to-weight ratio, mechanical properties and wear behavior. They are ideal candidates for several automotive applications, such as engine blocks and piston heads. Alloying of Al with high content of Mg and Si (> 20 mass % Mg_2Si) results in the formation of Mg_2Si phase and eutectic Al-Mg-Si and offers the possibility of significant decrease in density (density of Mg_2Si 1.99 gcm^{-3}) and increase in stiffness compared to other Al alloys. This makes them superior material for the light weight automotive applications. However, hypereutectic Al-Si alloys with high content of Mg is difficult to be processed by conventional casting routes due to excessive slag formation, high porosity caused by the high solubility of hydrogen in such melts. Further, low solidification rate in the casting leads to a coarse microstructure.

For the improvement of mechanical and wear properties of hypereutectic Al-Si alloys, a modification in composition is necessarily made by adding alloying elements like Cu, Mg, Ni, Mn etc. to these alloys. Addition of Cu and Mg increases the strength of the alloy through formation of intermetallic phases. However, this also leads to reduction in ductility of the cast materials. Recently, focus has been shifted to the continuous improvement in elevated temperature strength of hypereutectic Al-Si alloys. This is mainly due to the fact that the alloys are needed in various high temperature applications, such as in automotive engines. Addition of Fe to Al-Si alloy enhances the strength at elevated temperature through the precipitation of multi-component thermally stable intermetallic compounds that result in considerable improvement in the high temperature performance. The microstructure of these alloys processed through conventional casting methods, however, consists of long plates and needle like intermetallic compounds. The intermetallic phases act as stress raiser, thereby reducing the mechanical and wear properties of the as-cast alloys. Furthermore, the brittle and hard natures of intermetallic make the machining of cast parts difficult.

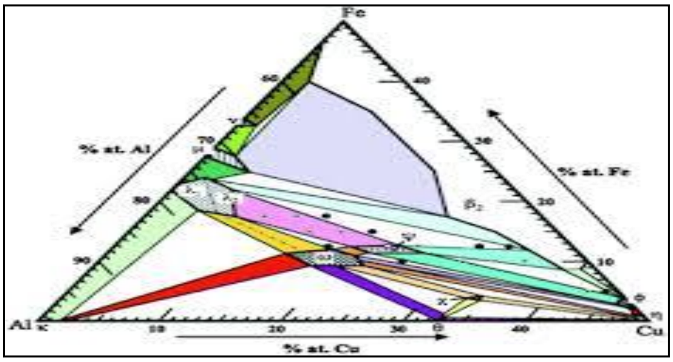


Fig. 1: Line diagram of stable equilibrium phase fields in Al-Mg-Si-Cu system at normal aging temperatures

2. Experimental details

2.1 Material selection

In the present investigation, hypereutectic alloys such as Al25Mg2Si with Cu, Mg and Ni as alloying additions are used to represent the light weight heat treatable Al-Mg_2Si-Cu alloys. Table 1 summarizes the nominal compositions of all the selected alloys.

Table 1: Chemical composition (wt %) of the alloy

Sr. No.	Alloy	%Si	% Ni	%Cu	%Mg	%Al
1	Al25Mg_2Si2Cu4Ni	8.51	2.34	1.8	14	73.835

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. The alloy used in the present work is Al25Mg_2Si2Cu4Ni its chemical composition as shown in the Table 1.

2.2 Heat treatment

2.2.1 Solutionizing and aging heat –treatment

The samples of as cast Al25Mg_2Si2Cu4Ni alloys are subjected to age hardening heat treatment after forging. The age hardening treatment was accomplished following the procedures as per ASM handbook. All the heat treatment experiments were carried out in a muffle resistance furnace with a temperature accuracy of ±3ºC. The alloy will be subjected to T6 heat treatment in a muffle heat treatment furnace. T6 process consists of solutionizing followed by artificial ageing. The samples will be solutionized at 525 °C for 5 hr and quenched in water at ambient temperature. Ageing will be carried out at 210 °C for 1, 3, 5 and 7 hours respectively. The aged samples will be cooled in air till room temperature is reached.

2.3 Wear test

2.3.1 Operating conditions

Table-2: Operating conditions

Sr. No	Sliding speed (m/s)	Load (Kg)
1	1	1
2	2	2
3	3	3
4	4	4

Note: Sliding distance is 2000 meters

2.3.2 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 Meter 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 2000 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.

3. RESULTS AND DISCUSSIONS

3.1 Microstructure results

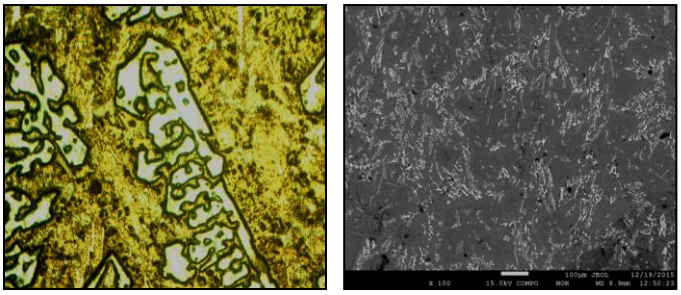


Fig-2: 5 hour homogenized (a) (optical) and (b) (SEM) 100X

Discussion: Fig 2(a) shows Chinese script like structure of Mg_2Si. Plates of Ni get converted into dispersed structure & are distributed uniformly in the Aluminum matrix. Fig-2(b) shows modification of Ni plates which get dispersed in the aluminium matrix.

3.2 Wear test results.

3.2.1 Wear Surface SEM

As seen from the Figure 3 volumetric wear rate has reduced. Number of wear tracks formed are also less. This may be due to the disintegration of Ni needles and precipitation of Mg_2Si precipitates in the matrix.

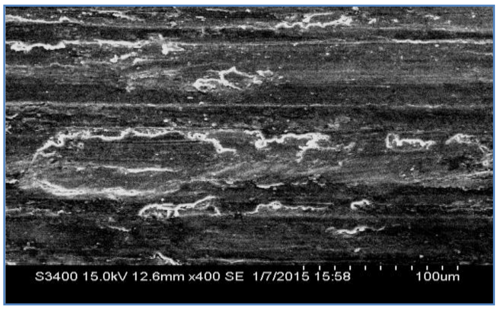
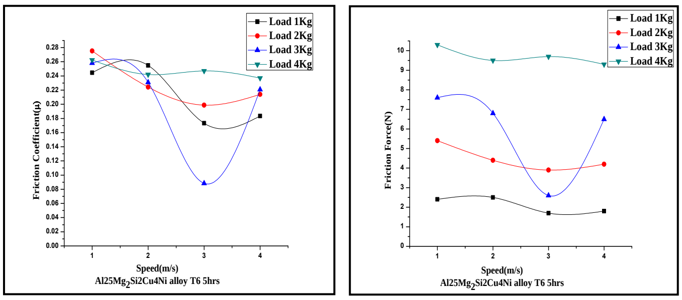


Fig-3: SEM for Speed 4 m/s, 4Kg load and H.T.5Hr (200X)

3.2.2 Speed v/s Friction coefficient and Friction Force

Discussion: As seen from Figure 4(a) for all loads friction coefficient values remain high at low sliding speed. However with increase in the sliding speed coefficient of friction values go on decreasing, beyond this sliding speed friction coefficient values become

Discussion: As seen from Figure 4(b) friction force values are low at low load of 1kg and higher for higher loads i.e. 2, 3 and 4 kg respectively. With increase in the sliding speed, friction force values decreases and becomes stable after 3m/s sliding speed is reached.

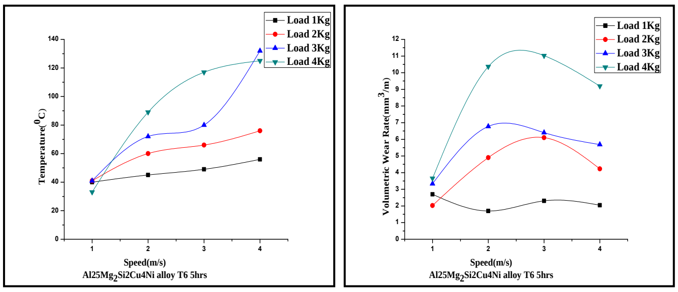


(a) (b)

Fig-4: (a) Speed v/s Friction coefficient (b) Speed v/s Friction force

3.2.3 Speed v/s Volumetric wear rate (mm^3/m) and interface temperature.

Discussion: As seen from Figure 5(a) interface temperature is less at low sliding speed and goes on increasing with increase in sliding speed. Thus we may conclude that the interface temperature is a function of sliding speed, i.e. temperature is directly proportional to sliding speed.



(a) (b)

Fig-5: (a) Speed v/s Volumetric wear rate (mm^3/m) and (b) Interface temperature.

Discussion: As seen from Figure 5(b) for load 1kg the volumetric wear rate remains constant for increase in speed. But as load increases volumetric wear rate increases for low sliding speed. But as the sliding speed reaches maximum value and the volumetric wear rate starts decreasing.

4. CONCLUSIONS

1. As the sliding speed increases the friction coefficient decreases for constant load.
2. We can conclude by saying that sliding speed and Friction forces are inversely proportional to each other.
3. As the speed increases temperature increases for constant load.
4. As speed increases volumetric wear rate increases at constant load.

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