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Effect of Ni on Wear Behavior of Al25Mg2Si2Cu4Ni Alloy

M.D. Harlapur[1a*], D.G.Sondur[2b,] , Altaf Hussain. M.H.[3c]

[1*]Department of Mechancial Engineering, R.T.E.Society's, Rural Engineering College, Hulkoti, 582205, Karnataka, India.
[2]Department of Mechancial Engineering, R.T.E.Society's, Rural Engineering College, Hulkoti, 582205, Karnataka, India.
[2]Department of Mechancial Engineering, R.T.E.Society's, Rural Engineering College, Hulkoti, 582205, Karnataka, India.

[a]mdhrechulkoti@gmail.com, [b] dgsondur_tce@yahoo.co.in.[c]altaf.hussain867@gmail.com

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

Abstract

In the present work,the effect of Ni on the wear behaviour of as cast and cast aged Al25Mg_2Si2Cu4Ni has been investigated.Microstructure , SEM and EDS results confirm the presence of different intermetallics and their effects on wear properties of Al25Mg_2Si2Cu4Ni alloy in as cast as well as aged condition. The main alloying elements Si, Cu, Mg and Ni partly dissolve in the primary α-Al matrix and to some extent present in the form of intermetallic phases. SEM structure of as cast alloy shows blocks of Mg_2Si which are randomly distributed in the aluminium matrix. Precipitates of Al_2Cu in the form of Chinese script are also observed. Also 'Q' phase (Al-Si-Cu-Mg) are distributed uniformly in the aluminium matrix. Few coarsened platelets of Ni are seen. In case of homogenized samples blocks of Mg_2Si get rounded at the corners, Platelets of Ni get fragmented and distributed uniformly in the aluminium matrix. Results show improved volumetric wear resistance and reduced coefficient of friction after homogenizing heat treatment.

1 Introduction

Al-Si alloys are widely used in different fields of industry. Various additives are usually used to modify industrial alloys. Recently, much attention has been given to unmodified cast alloys especially to hyper- eutectic Al-Si alloy. Aluminium silicon alloys with greater than 12% Silicon have outstanding wear resistance, a lower thermal expansion coefficient, and very good casting characteristics, fluidity and excellent machinability in terms of surface finish and chip characteristics. The structural and mechanical properties of hypereutectic unmodified cast alloys have been studied mainly for Si content upto 19 %. It is only known that increasing the Si content results in an increase in the strength of hypoeutectic alloys and a decrease in the strength of hypereutectic alloys [1, 2]. Effect of nickel on hot hardness of aluminium alloys can be utilized to improve the hot hardness (up to 600 F) of aluminium-silicon (10 to 16 per cent silicon) casting and forging alloys. The maximum benefits are realized by developing a large volume and favourable distribution of nickel aluminide. The addition of more than the eutectic amount of silicon was not particularly helpful in improving hot hardness. While the addition of more than the eutectic amount of nickel did improve hot hardness [3].The effect of Nickel addition on microstructure and mechanical properties of aluminium-based alloys. Alloys were produced by powder metallurgy. Characterization results indicate that the microstructure of the aluminium-nickel alloys present a thin and homogeneous distribution of an intermetallic compound in the aluminium matrix, identified as Al_3Ni. Furthermore, it was observed that the amount of intermetallic Al_3Ni increases as the nickel content in the alloy is increased. Evaluation of mechanical properties proved that the hardness, compression and flexural strength also improves due to the presence of the intermetallic compound [4].

1.1 Heat Treatment

The incipient melting tends to lower the mechanical properties at temperatures of 495°C or less, however, is not capable of maximizing the dissolution of the copper-rich phases, nor is it able to modify the silicon particle morphology sufficiently [5].In a study of Al-Si-Cu-Mg alloys having a low magnesium content (0.5 wt.%) solution temperature of 500ºC was used because, at 505ºC, fusion of low melting point phases can occur [6].The effect of heat treatment on the alloy properties suggested that silicon content and the aging time significantly affected the wear resistance. It was observed that there was an increase in the wear resistance with the aging time [7]. Hypereutectic alloys show better wear resistance than the eutectic alloys under the same conditions [8]. Hypereutectic alloy wear behaviour suggested that fine grain structure tends to improve the wear resistance of Al-Si alloys. Needle like microstructures in the alloy tend to reduce the wear resistance by promoting micro-cracking [9]. Improvements in the mechanical and tribological properties are observed as the microstructure changes from coarse columnar to fine equiaxed dendrites accompanied by the morphological change of plate like Si to finer structure by addition of Ti-B as refiner and Sr as modifier respectively, which was also substantiated later on in a publication by the same author [10].The hypereutectic alloys are likely to dominate because of their wear resistance, combined with low coefficient to thermal expansion (CTE) and fluidity properties, allows thinner walled castings to be manufactured [11]. Further, studies on the effect of addition of Ni on the mechanical and wear properties of as cast, cast aged Al25Mg_2Si2Cu4Nihas been investigated.

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2 Experimental details

2.1 Material selection

In the present investigation, the hypereutectic alloy such as Al25Mg_2Si 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 composition of the selected alloy. The as-cast ingots of the alloy is obtained from FENFE Metallurgical, Bangalore, India. The chemical composition of all the alloys is analysed by sparkemission spectrometer [Make: PANalytical - XRDand XRF Instrumentation, Model QSN 750-II single or multi matrix system.] Chemical composition of the alloy is given in table. Alloy was formed by casting an ingot by melting process. Sample pins for as cast samples were prepared by machining and cast aged samples were prepared by first solutionizing the ingot and then homogenizing the pins. . As cast and cast aged samples were examined by optical microscopy, SEM attached with energy dispersive X-ray analysis.

2.2 Metallographic studies

Before the wear test, samples were prepared for metallographic examination by polishing, using polish papers of grade 4/0, 6/0 and then wet polishing was carried out using wet alumina paste of sub- micron grade. Specimens were etched with 2% Nital solution and analyzed under optical microscope. After the wear test, worn out pin samples were coated with gold oxide to overcome the effect of oxidation and then studied under the optical and SEM microscopes. Hardness of the wear tested samples will be measured on Brinell hardness testing machine. As cast and cast aged samples were examined by optical microscopy, SEM attached with energy dispersive X-ray analysis.

2.3 Heat treatment

All the heat treatment experiments were carried out in a muffle resistance furnace with a temperature accuracy of ±3ºC.

2.3.1 Solutionizing and aging heat-treatment

The samples of as cast Al-Mg_2Si2Cu4Ni alloyis subjected to age hardening heat treatment. The age hardening treatment is accomplished following the procedures as per ASM handbook (ASM, 1997).Solutionizing at 500^{o}C for 1 hour and homogenizing at 210^{0}Cfor 1,3,5 and 7 hour.

2.4 Wear test

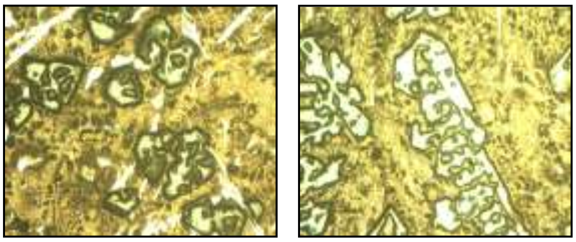
Alloy was formed into ingot by casting process. Samplepins for as cast samples were prepared by machining and cast aged samples were prepared by first solutionizing the ingot and then homogenizing the pins. As cast and cast aged samples were examined by optical microscopy, SEM attached with energy dispersive x-ray analysis. All the pin samples were tested on pin-on-disc wear testing machine supplied by DUCOM instruments, Bangalore, India. Wear tests were carried out with polished pins and rounded at the edges. Weight losses of pin were recorded using an electronic balance having an accuracy of 10^{-7} Kg at different interval of time.

3. Results and Discussions

3.1 Microstructure results

As seen from figure 1(a) shows optical microstructure of as cast Al-25Mg_2Si2Cu4Ni alloy having blocks of Mg_2Si with sharp corners. Also Mg_2Si blocks show Ni particles embedded in it.

Plates of Ni are also observed in the aluminium matrix. Figure1 (b**)** shows the microstructure of 1 hour homogenized alloy. Chinese script like structure of Mg_2Si is seen. The plates of Ni get converted into dispersed structure distributed uniformly in the aluminium matrix. Also seen are the precipitates of Al_2Cu distributed uniformly in the aluminium matrix.



(a) **(b)**

Fig.1 (a-b) As cast structure and 1 hour homogenized structure.

Comparing between the two structures we find that the heat treatment reduces the stress and increases the wear resistance of the alloy.Formation of precipitates and the intermetallic compounds further improve the properties. In as cast condition Mg_2Si blocks formed are having sharp corners giving high volumetric wear rate. After homogenizing for 1 hour Mg_2Si structure gets converted into the chinese scripts which are clearly evident.

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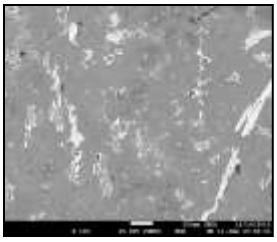
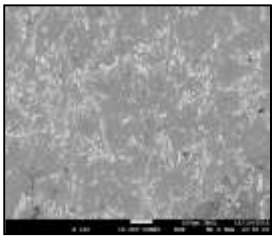
3.2. SEM results

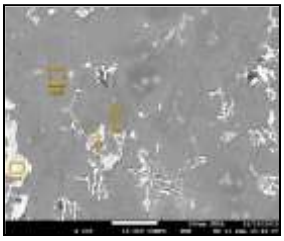
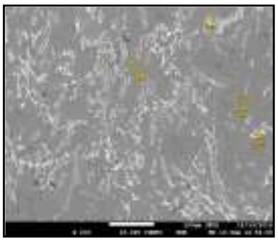



(a) (b)

Fig. 2 (a-b) as cast and 1h homogenized samples (100X)

As seen from figure 2(a)the SEM figure shows plates of Ni distributed non-uniformly in the aluminium matrix. Blocks of Mg_2Si are seen with sharp corners and ranging in size from 50 to 150µm distributed randomly. Figure2(b) shows modification of Ni plates into dispersed Ni particles in the aluminium matrix.

3.3 EDS Results.

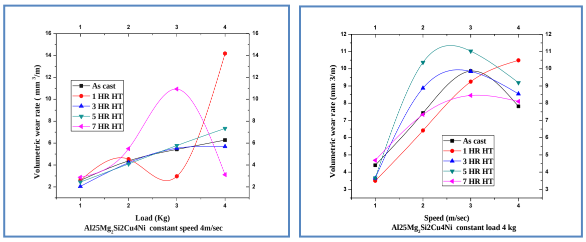



(a) (b)

Figure 3 EDS results (a) As cast, (b) 1 hour homogenized.

As seen from figure 3(a) EDS results show Mg_2Si blocks coarse in size ranging from 75 to 150µm with sharp corners, raising stress points in the aluminium matrix. Also seen are coarse plates of Ni distributed randomly in the matrix. Spot no. 2, 3 and 4 show particles of Cu and nickel. Spot 3 shows multiphase component such as 'Q' phase containing Al, Mg, Cu, Si, Ni and Fe possibly the phase $Al_{20}Fe_3Ni_9$(Mg,Si,Cu).Mg_2Si is the hardening precipitate. Cu and Mg increase strength. Ni increases the strength. figure3(b) shows conversion of coarse Ni plates into finely dispersed particles. Also precipitates of Al_2Cu are formed that are distributed in the matrix non-uniformly. Blocks of Mg_2Si get modified with rounding off of the sharp corners. In Al-Cu-Ni-Mg-Si system containing more than 1-1.5% by wt. of Cu solidification is by eutectic reaction.

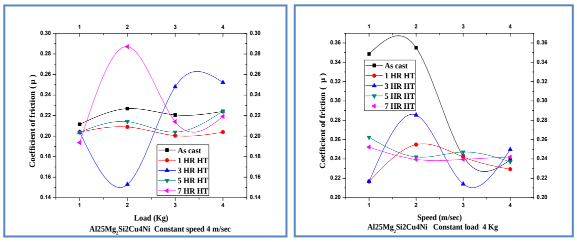
3.4. Wear test



(a) (b)

Fig.4 Volumetric wear rate at (a) constant speed 4m/s, (b) constant load 4kg

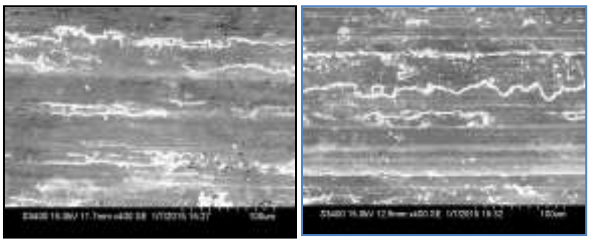
As seen from thefigure4(a) the graph ofvolumetric wear rate of as cast, 3 and 5 hour heat treated alloy show similar trends i.e volumetric wear rate increases steadily with increase in the load at high speed of 4 m/s. figure 4(b) shows minimum volumetric wear rate compared to other conditions. At 1, 3, 5 and 7hours heat treatment conditions volumetric wear rate increases, reaches maximum at 3m/s speed and then decreases.



(a) (b)

Fig.5(a-b) Coefficient of friction at (a) constant speed 4m/s, (b) constant load 4kg

Results:figure5(a) shows coefficient of friction values are low and constant for as cast condition. Whereas coefficient of friction values for 1, 3, 5and 7hours heat treated condition alloy remain very high.Figure5(b) shows coefficient of friction values for 1, 3, 5 and 7hours heat treated conditions show high value initially and then decrease with increase in the speed. Whereas, for as- cast condition, coefficient of friction value remains high at all the speeds.



(a) (b)

Fig. 6(a-b) SEM Figures as cast (a) 100X, (b) 200X)

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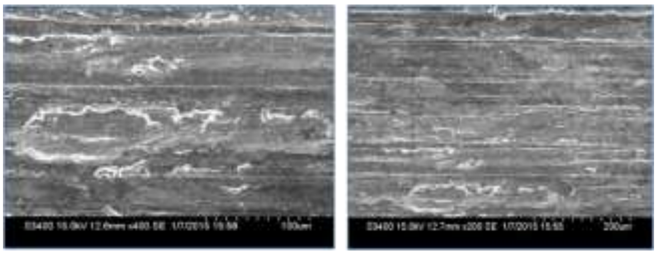
Results: For constant high speed and high load condition. For volumetric wear rate at constant speed 4m/s and high load of 4kg, in as cast condition SEMfigure 6 shows small adhesive wear with cracks formed all along the wear tracks.Figure 4(a-b) shows that volumetric wear rate increases steadily with increase in the load, and values are high at low load and low at high load of 4kg.Figure 6(a-b) shows low coefficient of frictionvalues at constant speed of 4m/s and high load of 4kg.For constant high speed and high load condition.For volumetric wear rate at constant speed of 4m/s and high load of 4kg, 1h homogenizedcondition.



(a) (b)

Fig 7(a-b) Speed 4m/s,4Kg load, H.T.1 Hr(a) 100X (b) 200X

SEM Figure 7 shows wear with small cracks formed all along the wear tracks. Figures 5(a-b) show that coefficient of friction values are lowest at high load of 4kg and high speed of 4m/s. Also there is no significant wear taking place.

Conclusion

1.Volumetric wear rate are low for high load and high speed conditions for both as cast and 1 hour homogenized conditions.

2. Coefficient of friction values are steady at both the constant load and constant speed conditions in case of both as cast and 1 hour homogenized conditionsplace.

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