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Study of Wear Behaviour of Cast Al25Mg2Si2Cu4Ni Alloy Forged with T6 Heat Treatment at Constant Speed For 3 Hours

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Abstract
In this study, the hypereutectic Al–Si alloys were synthesized by spray atomization and deposition technique. The microstructures of spray-deposited alloys were studied using scanning electron microscopy (SEM) and X-ray diffraction (XRD). The dry sliding wear behavior of the alloys was investigated under the applied load of 8.9–35.6 N. The wear behavior of the alloys was dependent on the morphology of the intermetallics in microstructure and applied load. At lower load (8.9 and 17.8N), the Fe-containing alloy showed higher wear rate compared with the binary alloy due to the tendency for embrittlement brought about by needle-like intermetallics. At higher load (35.6 N), Ni- and Mn containing alloy exhibited inferior wear resistance than the binary alloy due to the fragmentation of the intermetallics, thus leading to easier crack nucleation and propagation.

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

1.0 Introduction

The hypereutectic Al-Si alloys with alloying elements such as, Mg, Cu, Fe 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.

Alloying with Cu leads to further increase in strength by age hardening. Cu and Mg can also be added in combination to increase the strength of the alloy. The coarse phases which may form during solidification are Al_2Cu phase and the Q-$Al_5Mg_8Si_6Cu_2$ phase in Al-Si-Cu-Mg alloys, while the π-$A_{18}Mg_3FeSi_6$ and β-Mg_2Si phase form in Al-Si-Mg alloys. These coarse phases do not contribute to strength and their degree of influence on ductility depends on their distribution and size relative to Si particles. Addition of Cu and Mg also leads to the formation of bands of coarse Si particles and an increased risk for shrinkage porosity due to an increased solidification interval. Alloying of Al with high content of Mg and Si (>20 mass %Mg_2Si) offer the possibility of significant decrease in density (density of Mg_2Si - 1.99gmcm^{-3}) and an increase in stiffness (Young's modulus of Mg_2Si is 120 GPa) at the same time. A fine and uniform distribution of Mg_2Si in the Al- matrix leads to a further increase in the strength.

2.0 Experimental Details

2.1 Material selection

In the present investigation, the hypereutectic alloys such as Al-25Mg_2Si with and without Cu, Mg and Fe 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. 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.]

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The alloy used in the present work is Al25Mg_2Si2Cu4Ni its chemical composition as shown in the Table 2.1.

Table 2.1 Chemical composition (wt %) of AlxxMg_2Si alloys

Sr. No	Alloy %	%Si	% Ni	%Cu	%Mg	%Al
1.	Al25Mg_2Si3Cu2Ni	9.3	2.53	2.89	18.6	Balance

3.0 Methodology

4 Results and discussions

4.1 Optical microscopy

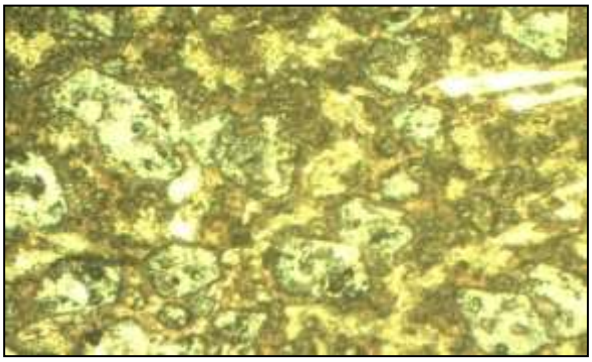

Fig 4.1 Microstructural results (3 hour homogenized)

Results

- Fragmentation of Mg_2Si chinese script is observed
- Plates of Ni are seen
- Precipitates of Al_2Cu distributed uniformly in the aluminium matrix.

4.2 SEM figure

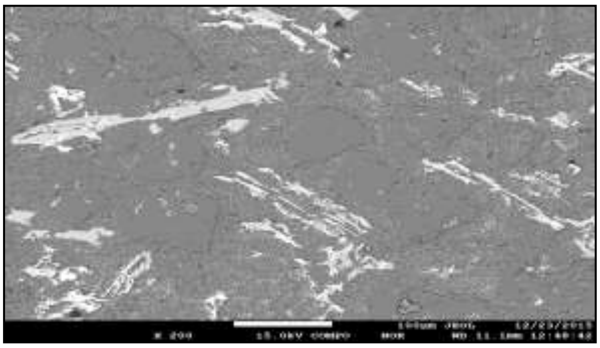

Fig 4.2 SEM figure Al25Mg_2Si2Cu3Ni for 3 hr homogenization

Results

1. Mg_2Si blocks are rounded off at the edges and are getting broken.

2. Chinese scripts like structure are also found precipitated.

Discussion:

It is the result of T6 heat treatment that the structure shows increased quantity of Al2Cu precipitates. This improves the wear resistance.

4.3 Wear test results

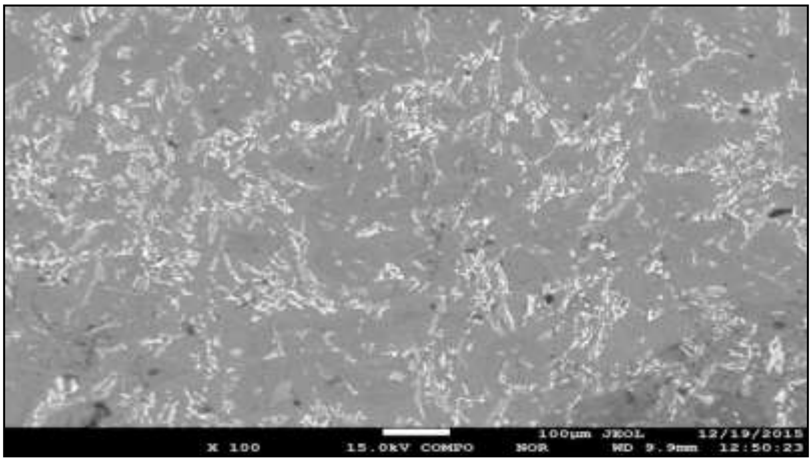

Fig 4.3 SEM Figure wear results 100X (Speed 4m/s,4 Kg load, H.T.3 Hr),

Results: As seen from figure 4 (a) volumetric wear rate increase steadily for all the sliding speed values, except at 3 m/s sliding speed.
As seen from the figure 4 (b) volumetric wear rate is negligible or constant at 1 kg load. At higher loads volumetric wear rate reaches the peak values for 2 and 4 kg loads at 2 m/s

Conclusions: Overall volumetric wear rate is observed to be lower at 3 hour homogenizing heat treatment compared to those unheat-treated samples. However, an increasing trend is observed for constant load with increase in the sliding speed.

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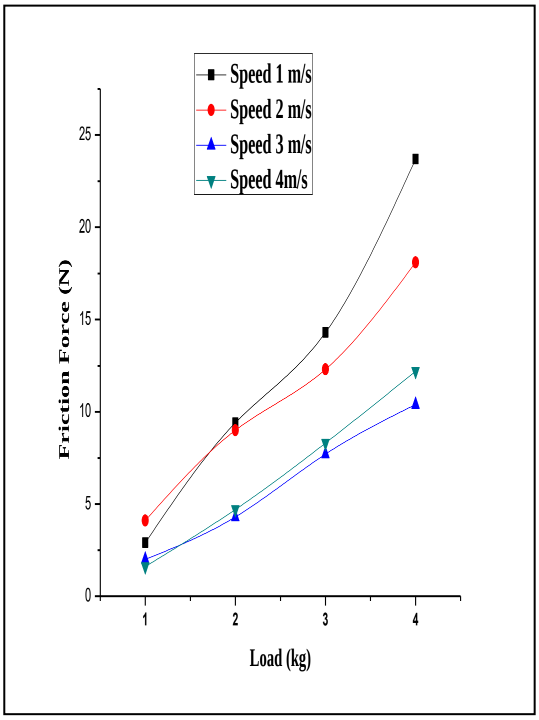
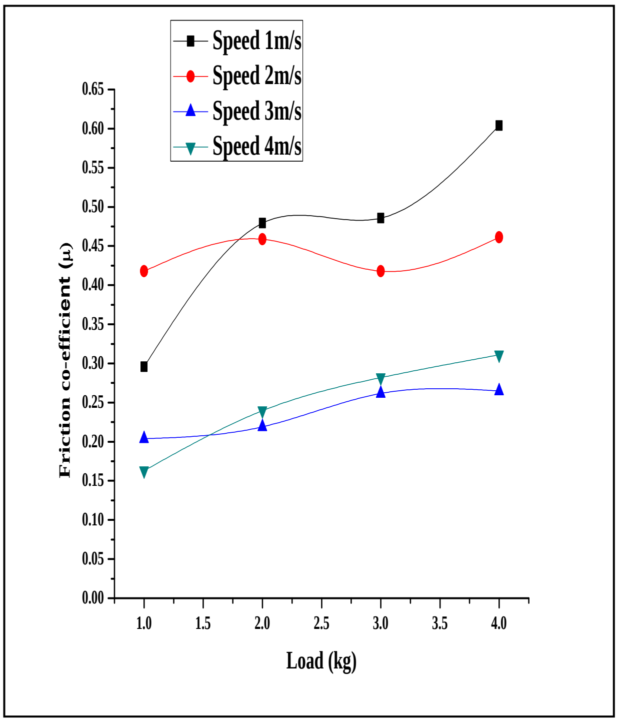
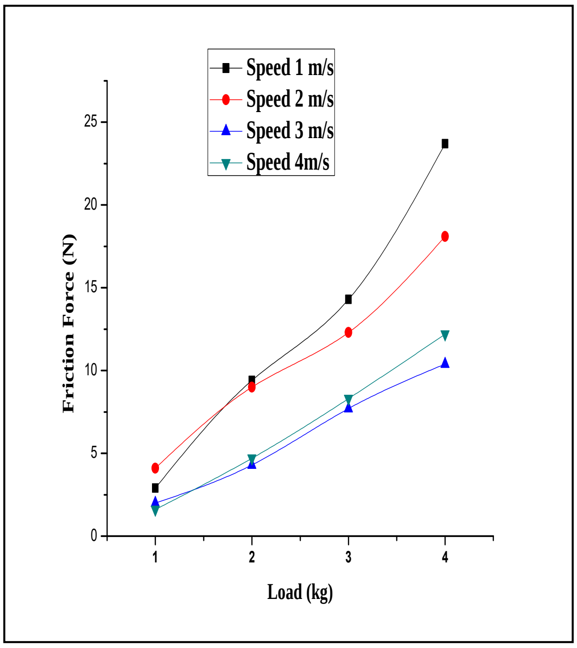
4.4 Wear Graphs

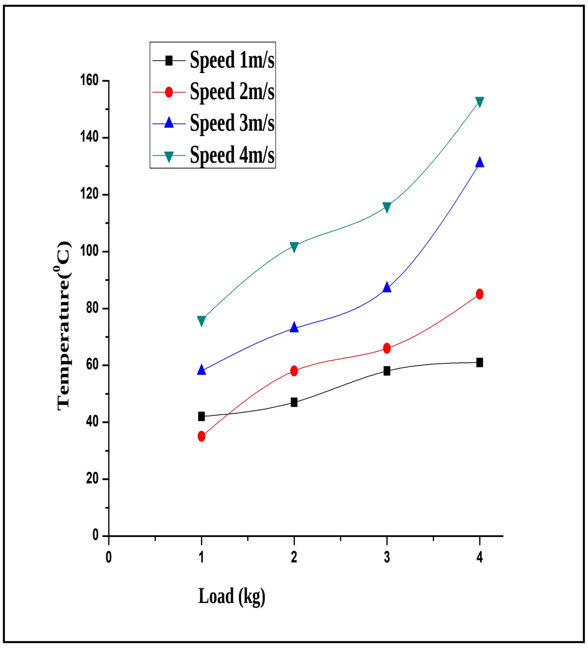
Al25Mg2Si-3Cu-2Ni Alloy T6 (3hrs)





(1)Load v/s Friction Force **(2)Load v/s Friction Coe-efficient**





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(3)Load v/s Friction Force **(4)Load v/s Temperature**

(1) Load v/s Friction Force

Result:

a. Speed 1m/s : The Load increases simultaneously Friction force will be increases.

b. Speed 2m/s : As the Load increases the Friction force gradually increases.

c. Speed 3m/s :As the Load increases the Friction force increases

d. Speed 4m/s: In this Load increases the friction force also increases.

Discussion: For all speeds friction force values remain low at low loads. However with increase in the load friction force values go on increasing, as load increases the friction force also increases

1. Conclusion: As the load increases the friction force values also goes on increasing at different loads.

(2) Load v/s Friction Coefficient

Result:

a. Speed 1m/s : Between 1kg-3kgof load friction co-efficient gradualy increases then suddenly increases.

b. Speed 2m/s : As the load increases the friction co-efficient gradually increases and for higher load it slightly decreases

c. Speed 3m/s : As the load increases friction co-efficient gradually increases.

d. Speed 4m/s : As load increases friction co-efficient almost remains constant.

Discussion: As seen from the graph for the speed of 1m/s and 2m/s the coefficient of friction values remains low at 1 kg of load, which the value of coefficient of friction increases up to 2 kg of load and slightly decreases up to the 3 kg of load and finally coefficient of friction value increases up to the 4 kg of load. And for the 3m/s,4m/s the coefficient of friction value remains low at low load and increases as the load increases up to the 4 kg of load.

2. Conclusion: for the low speeds the friction coefficient values increases as the load increases but for the high speeds friction coefficient values increases slightly, Compared to low speeds the raising values of coefficient of friction at high speeds is lesser than the raising values of coefficient of friction at low speeds for the different loads.

(3)Load v/s Volumetric wear rate

Result:

a. Speed 1m/s : As the load increases the volumetric wear rate gradually decreases.

b. Speed 2m/s : As the load increases up to 2kg volumetric wear rate decreases after that volumetric wear rate gradually increases.

c. Speed 3m/s : As the load increases volumetric wear rate gradually increases

d. Speed 4m/s: As the load increases volumetric wear rate increases.

Discussion: As seen from graph the volumetric wear rate which will be decreases as increase in load for speed of 1m/s but for the speed of 2m/s the volumetric wear rate will decreases up to the 2kg of load and suddenly increases up to the 3kg of load finally slightly decrease in volumetric wear rate up to 4 kg of load and for the high speed of 3&4m/s.the volumetric wear rate which will increases as load increases.

3. Conclusion: For the low speeds the volumetric wear rate decreasing & increasing at different loads but for high speeds the volumetric wear rate goes on increasing as the load increases.

(4)Load v/s Temperature

Result:

a. Speed 1m/s : As the load increases the temperature gradually increases.

b. Speed 2m/s : As the load increases temperature gradually increases.

c. Speed 3m/s : As the load increases temperature gradually increases.

d. Speed 4m/s :As the load increases the temperature also increases

Discussion: As seen from graph the value of temperature which will be low at low loads & increases as the load increases but for the high speeds the value of temperature is more than the value of temperature of low speed at low load & the temperature of high speed is goes on increases at increasing in the load.

4. Conclusion: The temperature increases as increase in the load at all speed & temperature values are different for different speeds at low & high loads.

5. Conclusions

1. As the load increases the friction force values also goes on increasing at different loads.

2. For the low speeds the friction coefficient values increases as the load increases but for the high speeds friction coefficient values increases slightly, Compared to low speeds the raising values of coefficient of friction at high speeds is lesser than the raising values of coefficient of friction at low speeds for the different loads.

3. For the low speeds the volumetric wear rate decreasing & increasing at different loads but for high speeds the volumetric wear rate goes on increasing as the load increases.

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