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Effect of Si Addition on Microstructure and Tribological Properties of Al-0.1Mg-0.35Ni-(4, 6, 8, 10) wt %Si Alloy

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Abstract

The effect of Si addition on hardness, microstructure, and behavior of wear of Al-0.1Mg-0.35 Ni-(4, 6, 8, and 10) wt %Si alloy has been investigated. The alloy is melted in an electric furnace and Si added to the melt in a metal mold. The microstructure for samples and worn surfaces were analyzed and characterized using X-ray diffraction the residual voltage (XRD), energy dispersive spectroscopy (EDS), scanning of electron microscopy (SEM) and atomic force microscopy (AFM), respectively. The results have showed that the Si morphology remained particle shaped and an intermediate phase Al3Ni was observed. The hardness and tensile strength increased, wear rate decreases and the coefficient of friction CoF remained constant. Further, the impact of Si addition on the behaviour of the Al-0.1Mg-0.35Ni-(4, 6, 8, 10) wt %Si is also evaluated in this study. Finally, it is concluded that the Si addition significantly improves of tribological properties of the Al-0.1Mg-0.35Ni-(4, 6, 8, 10) wt %Si alloy.

Keywords: Aluminium; Silicon; Microstructure; Tensile strength

Introduction

(Al-Si) alloys are widely used in the automotive industry. Due to their low density, replacement of heavy cast iron components with lightweight cast aluminum alloys is a simple yet cost effective method [1]. However, the wear behavior of these alloys depends on a number of material-related mechanical properties (i.e., hardness, toughness and ductility), microstructure (i.e., shape, size, composition, type and distribution of micro constituents) in addition to the service conditions such as load, sliding speed, temperature. The most important alloying elements are used in Al-Si alloys in the engine piston of silicon (Si), copper (Cu), magnesium (Mg), iron (Fe), sodium (Na), manganese (Mn) and strontium (Sr), Nickel (Ni) as the corrosion resistance and excellent low thermal expansion [2].

The effect of Cr addition into as cast Al-Si-Fe alloy [1] and found an increase in the tensile strength. The author also observed Si particles which were distributed evenly in the microstructure of the modified alloy. The effect of Ni addition was investigated by Petrick [2], and observed an increase in the hardness. An increase in the hardness and tensile properties for the Ni added alloy [3]. The effect of Ni addition to the Al-Si alloy was studied by Li et al. [4] and found the formation of intermediate compound containing Ni. The effect of Ni addition to the as cast Al-Cu alloy [5] and found an increase in the hardness and tensile properties for the modified alloy after aging. The effect of Ni addition (2 wt %) on the Al-6Si-0.5Mg alloy and an increased tensile strength was observed after the alloy addition [6]. The effect of Co on the Al-Fe-Si alloy and found an increase in the hardness was observed after the Co addition [7]. The effect of Co addition on the Al-5Fe-25Si alloy by determining the micro hardness and an increase in the micro-hardness was observed after the Co addition upto 5 wt % [8]. The effect of Ti addition into Al-Mg alloy was studied [9] and they have observed an increased yield strength (YS) and tensile strength (UTS) for the alloy. The Ti additions into as cast Al-Mg alloy [10] and found increased UTS, YS and hardness. The effect of Ti addition into Al-Si alloys [11] and found an increase in the hardness due to the formation of the flake. The effect of Ti addition [12] and found an increase in UTS and the hardness after the addition whereas the percentage elongation remained a constant. The effect of Ti into Al-Si alloys [13] and found an increase in the hardness due to the formation of the flaky shaped Al_3Ti.

From the review of literature, it is observed that no study is carried out regarding the effect of varying Si content on the hardness, mechanical properties and wear rate of the Al-0.1Mg-0.35Ni-Si. Hence the present investigation is carried out to determine the effect of varying Si content on the following mechanical properties of Al-0.1Mg-0.35Ni-%Si alloy.

1. Microstructure
2. Hardness
3. Tensile properties (UTS, YS, %EL)
4. Wear rate
5. Coefficient of friction CoF

Experimental Procedure

The melt was cast into metal mould to obtain specimens; test samples were homogenized about 545°C for 8 hours and cooled in air. The specimens were then aged at 145°C for 2 hrs. The electrical resistance of the furnace was used to melt the Al-0.1Mg-0.35Ni - (4, 6, 8, 10) wt % Si alloy and Si is added (% Si=4, 6, 8 and 10) was the composition of resultant alloy obtained. The effect of wear on the surface was analyzed using X-ray diffractometer (Philips PW 1710, USA) within 40 kV and 30 mA and characterized by scanning electron microscopy (SEM JSM-6010LV, USA) and Atomic Force Microscopy (AFM) (SPA 400, Seiko Instruments Inc., Japan). The microstructure was observed using an optical microscope. Vickers microhardness was used to measure hardness (ASTM E-384 Std) (Load: 90 g F, time 12 seconds). Wear test experiments were performed using pin-on disc. The specimen was 10 mm diameter; (load: 10 N, Speed: 300 rpm, diameter of track diameter: 90 mm, time: 15 minutes) (ASTM G-99 STD).

Results and Discussion

Microstructure

Figure 1 shows the microstructure of Al-0.1Mg-0.35Ni-4%Si alloy.

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The particle eutectic Si morphology is clearly visible in the Figure 1. Figure 2 shows the microstructure of Al-0.1Mg-0.35Ni -6%Si alloy. The eutectic Si morphology is found to be particle shaped in Figure 2. Similarly, in the microstructures of Al-0.1Mg-0.35Ni – (% Si =8 and 10) alloys, the eutectic Si morphology was found to be particle shaped. Hence it can be observed that the varying Si content has no effect on the particle shaped eutectic Si morphology of Al-8%Si alloy and Al-10%Si alloy.

Formation of intermediate phase

Figure 3 shown the SEM of alloy, the particles distributed in the images show the presence of an intermediate phase in the modified alloy. The EDS of the particle of Figure 3 is shown in Figure 4. It is observed from the EDS spectrum that Al and Ni are present in the white particle. The Al, Si, Ni, and the small relative areas of peaks are consistent with the scanning electron microscopy (SEM) images which give greater magnification and better depth. The composition analysis showed that the intermediate phase is Al_3Ni.

Similarly for the Al-0.1Mg-0.35Ni-(4, 6, 8, 10) wt %Si alloys also, the EDS analysis of the corresponding spectrums showed that Al_3Ni was the intermediate phase formed. The formation of Al_3Ni intermediate phase using EDS analysis, by the Ni addition into Al-6%Si-0.5Mg alloy [6]. Figure 5 shows the XRD result of Al-0.1Mg-0.35Ni-4%Si alloy. It is observed that the peaks correspond to Si, Al and Al_3Ni. The Al and Al_3Ni peaks were found similar as in the XRD pattern shown for Al-5Ni alloy. Similarly for the Al-0.1Mg-0.35Ni-(4, 6, 8, 10) wt %Si, XRD pattern was found to be similar and Al_3Ni was identified as the intermediate phase formed in all these alloys.

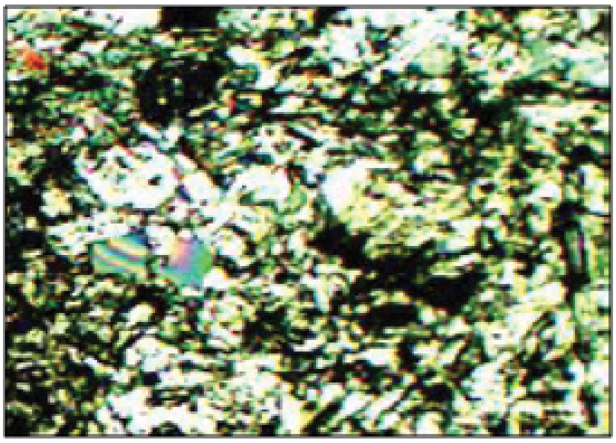

Figure 1: SEM microstructure of Al-0.1Mg-0.35Ni-4%Si alloy.

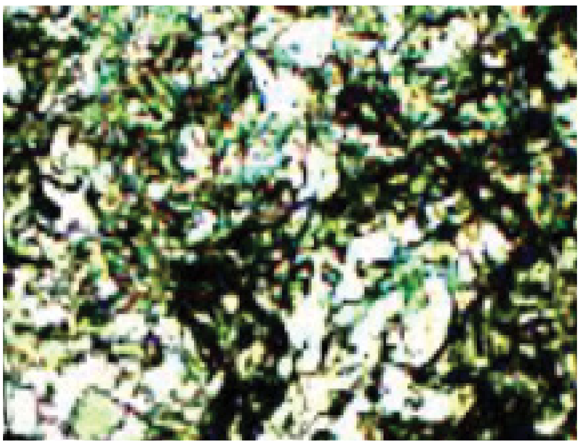

Figure 2: SEM microstructure of Al-0.1Mg-0.35Ni-6%Si alloy.

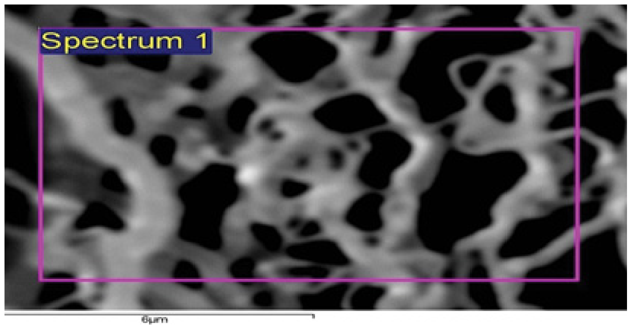

Figure 3: SEM micrograph of Si modified alloy.

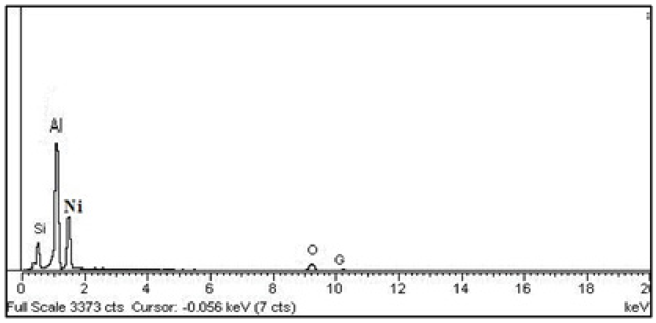

Figure 4: EDS of Si modified alloy (white area).

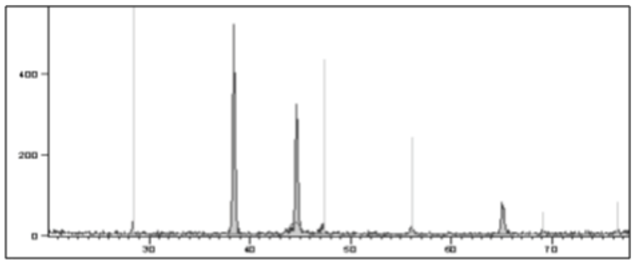

Figure 5: XRD of Al-0.1Mg-8%Si-35Ni alloy.

The SEM microstructure of Al-0.1Mg-0.35Ni-(4, 6, 8, 10) wt %Si alloys (SEM JSM-6010LV, USA). Al_3Ni phase has been marked in all the figures. The SEM (selected area electron diffraction) patterns for Al-0.1Mg-0.35Ni-(4, 6, 8, 10) wt %Si alloys. Al_3Ni data card (JCPDF no. 652418) showed peaks at these d-spacing values. Thus it was concluded that Al_3Ni is the intermediate phase forming in all these alloys (Figures 6-13).

Figure 14 shows the depth profiles , which was adopted in various regions of the wear tracks after 60 min, a load of 10 N and lubricated contact at 300 rpm, alloy (4%Si) comparison with (6, 8 and 10%Si) alloy. However, there is an improved hardness and wear resistance of effect of the silicon particles, generally accepted mechanism for the wear of Al-0.1Mg-0.35Ni-(4, 6, 8, 10) wt %Si alloy. Usually, the relationship between them is a little complicated, but the severity of damage on the sample surface at high loads. As known in terms of contact with the steel in the conditions of this study. In some cases, debris control

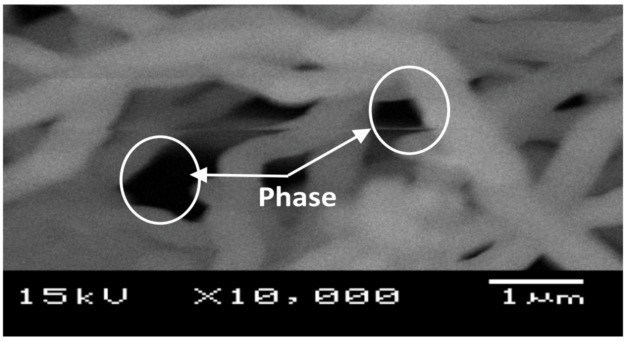

Figure 6: SEM microstructure of Al-4%Si-0.1Mg-0.35Ni alloy.

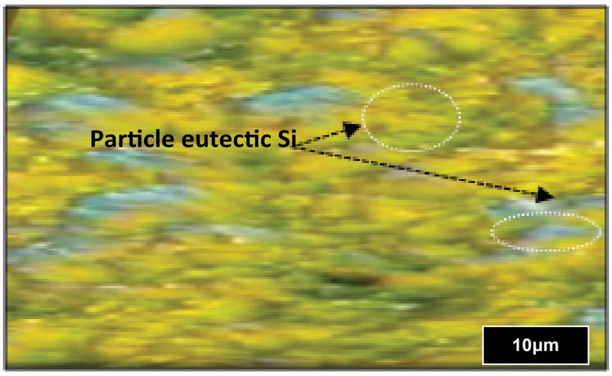

Figure 7: 2D Optical image AFM of Al-4%Si-0.1Mg-0.35Ni alloy.

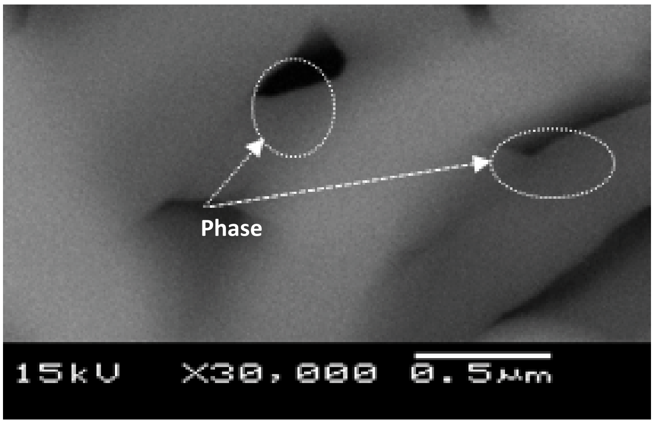

Figure 8: SEM microstructure of Al-6%Si-0.1Mg-0.35Ni alloy.

transfers from the sample surface on the disc surface due to a difference in hardness.

Hardness results

Figure 15 shows the hardness vs. wt % Si plot for Al-0.1Mg-0.35Ni-(4, 6, 8, 10) wt %Si alloys in the aged condition. It is observed that the hardness increases linearly with an increase in the Si content. This increase in the hardness in the aged condition is due to the presence of Al3Ni intermediate phase. Thus it can be concluded that the hardness increases with increasing Si content in Al-0.1Mg-0.35Ni-(4, 6, 8, 10) wt %Si alloy.

Tensile test results

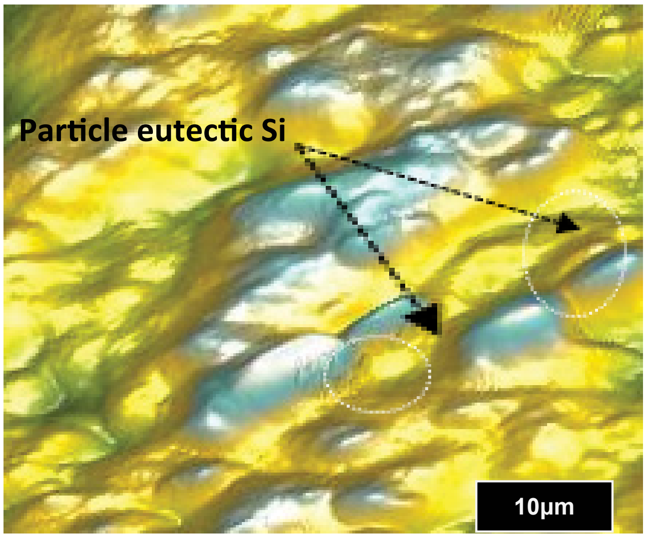

Figure 9: 2D Optical image AFM of Al-6%Si-0.1Mg-0.35Ni alloy.

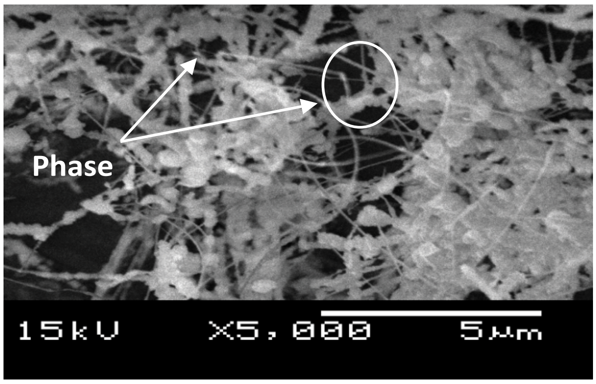

Figure 10: SEM microstructure of Al-8%Si-0.1Mg-0.35Ni alloy.

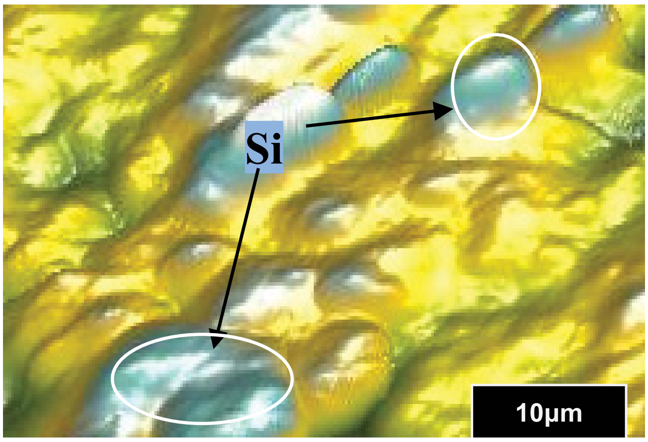

Figure 11: 2D Optical image AFM of Al-8%Si-0.1Mg-0.35Ni alloy.

Figure 16 shows the tensile strength of Al-0.1Mg-0.35Ni-(4, 6, 8, 10) wt %Si alloys. With the increasing Si content it is observed that the UTS increase linearly. The increasing UTS with the increasing Si content in the aged condition are due to the presence of intermediate phase Al_3Ni. Figure 17 shows the yield strength results of Al-0.1Mg-0.35Ni-(4, 6, 8, 10) wt %Si alloys in the aged condition. It is observed

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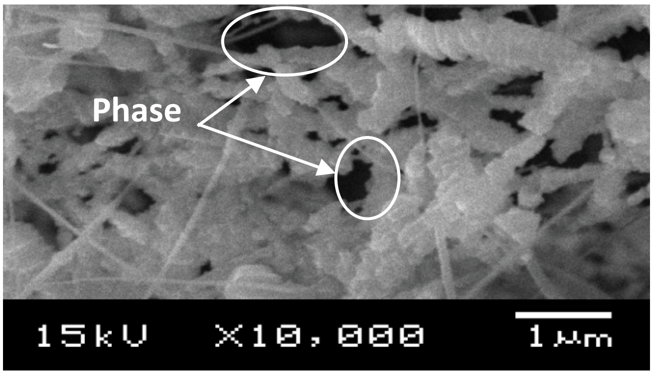

Figure 12: SEM microstructure of Al-10%Si-0.1Mg-0.35Ni alloy.

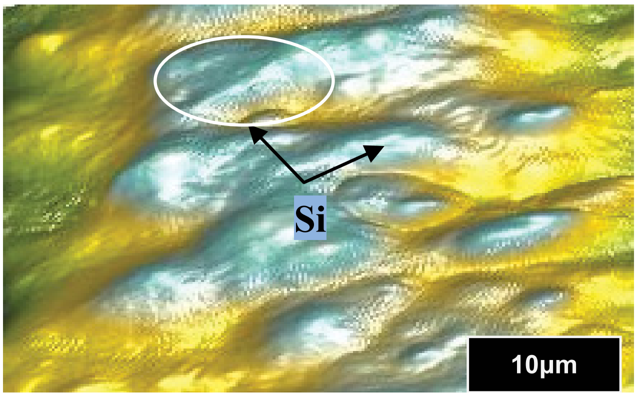

Figure 13: 2D Optical image AFM of Al-10%Si-0.1Mg-0.35Ni alloy.

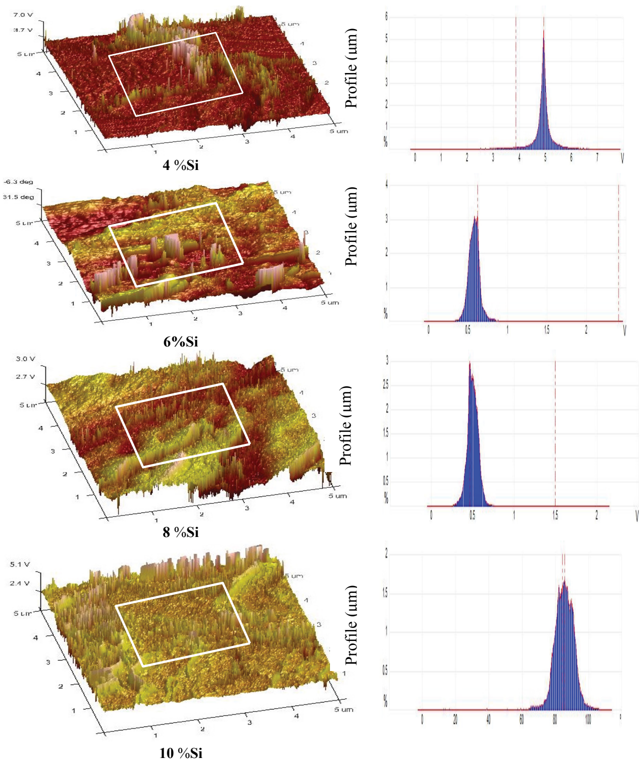

Figure 14: 3D Optical image AFM and depth profiles of Al-0.1Mg-0.35Ni-(4, 6, 8, 10) wt %Si alloys.

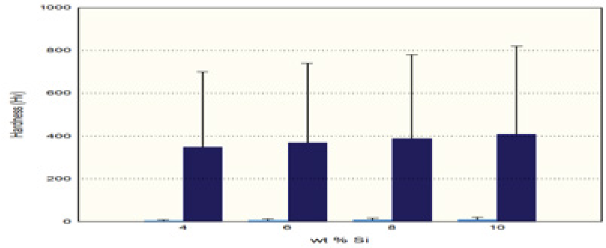

Figure 15: Hardness vs. Wt % Si.

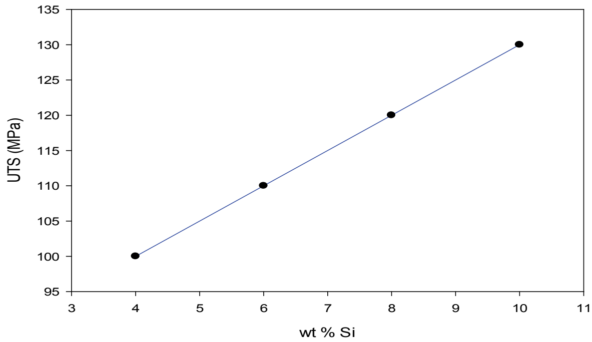

Figure 16: Tensile strength vs. wt % Si.

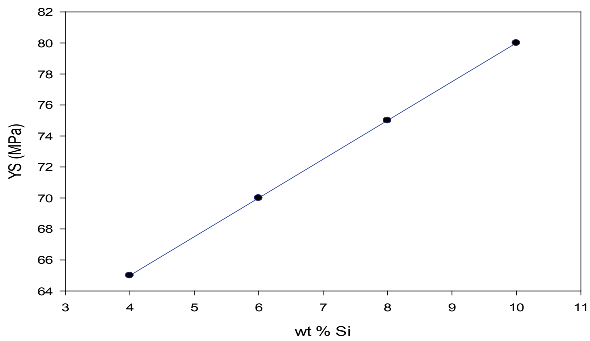

Figure 17: Yield strength vs. wt% Si.

that the YS increase linearly with the increasing Si content. The increasing YS with the increasing Si content in the aged condition are also due to the presence of intermediate phase Al_3Ni. Figure 18 shows the %elongation vs. wt % Si plot for the Al-0.1Mg-0.35Ni-(4, 6, 8, 10) wt %Si alloy combination in the aged condition. The %elongation does not vary significantly with the increasing Si content as observed from the Figure 18. Thus it can be observed that the Si addition has no detrimental effect on the % elongation.

Wear rate results

Figure 19 shows the wear rate vs. wt % Si plot for Al-0.1Mg-0.35Ni-(4, 6, 8, 10) wt %Si alloys in the aged condition. The wear rate was found to decrease with the increasing Si content and this behaviour was attributed to the formation of an intermediate phase Al_3Ni. Figure 20 shows the wear rate vs hardness plot for the Al-0.1Mg-0.35Ni-(4, 6, 8, 10) wt %Si alloys in the aged condition. The wear rate is found to decrease with the increasing hardness and this result is found to be consistent with the Archard's theory [14]. Generally results in higher

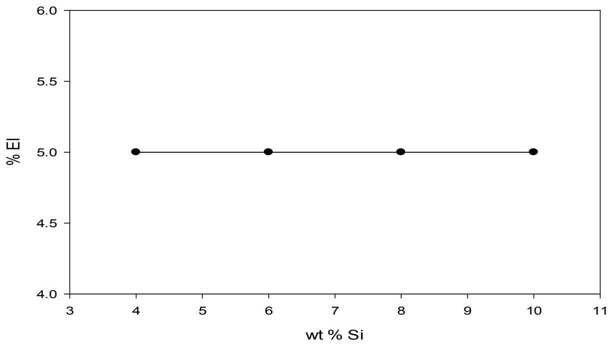

Figure 18: % El vs. wt% Si.

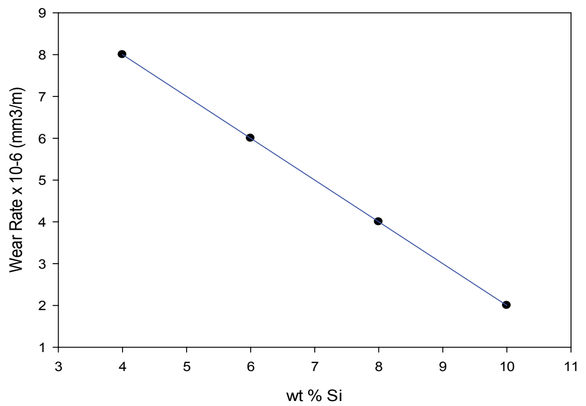

Figure 19: Wear rate vs. wt%Si.

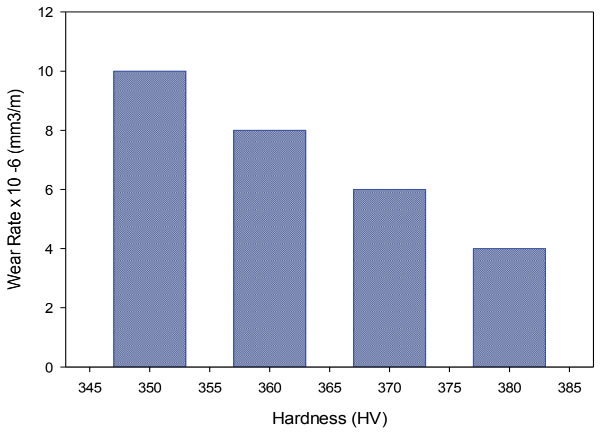

Figure 20: Wear rate vs. hardness.

wear but longer distances, at lower load, abrasion were the dominant mechanism of wear for alloy. Hence it can be concluded from the above observations that the increasing Si addition leads to a reduction in the wear rate of the Al-0.1Mg-0.35Ni-(4, 6, 8, 10) wt %Si alloy [15].

Coefficient of friction (CoF) results

Figure 21 shows the coefficient of friction vs wt % Si plot for the Al-0.1Mg-0.35Ni-(4, 6, 8, 10) wt %Si alloys in the aged condition. It is observed that the coefficient of friction CoF does not vary significantly

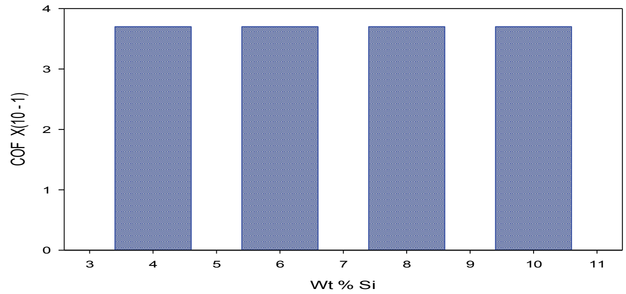

Figure 21: Coefficient of friction CoF vs. wt% Si.

with the increasing Si content. This decrease in value occurs likely as a result of particulate standing above the surface making contacting area of the specimen smaller [16]. Thus it can be inferred that the Si addition has no significant influence on the CoF of Al-0.1Mg-0.35Ni-(4, 6, 8, 10) wt %Si alloy.

Conclusion

The effect of Si addition on microstructure and various mechanical properties have tested. And behavior of wear of Al-0.1Mg-0.35Ni-%Si alloy is investigated that contributed more understanding of the tribological properties by friction and wear tests. With the addition of Si to the Al-0.1Mg-0.35Ni-%Si alloy, the following results are observed (in the aged condition):

1. Eutectic Si morphology remained particle shaped.

2. Ultimate tensile strength has increased with increase in silicon content. The hardness of the samples increases with the increase in silicon content.

3. UTS and YS increased and % EL remained a constant.

4. The eutectic Si phase and hence improves the mechanical properties of the alloy.

5. Wear rate decreases and the coefficient of friction CoF remained constant. The Si addition significantly improves the tribological properties of the Al-0.1Mg-0.35Ni-(4, 6, 8, 10) wt %Si alloy.

References

1. Hong SJ, Kim TH, Kim WT, Chun BS (1997) Effects of Cr and Zr addition on the microstructure and mechanical properties of rapidly solidified Al-20Si-5Fe alloy. Mat Sci Engg A226-228: 878-882.
2. Petrik J (2009) Application of Ni for improvement of Al-Si-Fe alloy. Materials Engineering 16: 78-85.
3. Naeem TH, Mohammed SK (2014) Influence of Ni and Sn additives on the microstructural and mechanical properties of Al-Zn-Mg-Cu alloys. Adv in Mat Sci Engg 686474: 79-88.
4. Li C, Wu Y, Li H, Yuying W, Liu X (2010) Effect of Ni on eutectic structural evolution in hypereutectic Al-M_{g2}Si cast alloys. Mat Sci Engg A528: 573-577.
5. Naeem TH, Mohammed SK (2013) Microstructural evolution and mechanical properties of Al-Zn-Mg-Cu alloy after addition of Ni under RRA conditions. Mat Sci Appl 4: 704-711.
6. Hossain A, Kurny ASW (2014) The effects of Ni on tensile properties of Al-6Si-0.5Mg alloy during precipitation hardening. Chem Mat Engg 2: 9-13.
7. Kilicaslan MF, Yilmaz F, Hong SJ, Uzun O (2012) Effect of Co on Si and Fe containing IMCs in Al-20Si-5Fe alloys. Mat Sci Engg A556: 716-721.
8. Kilicaslan MF, Yilmaz F, Hong SJ, Uzun O, Ergen S (2013) Microstructure and microhardness of melt spun Al-25Si-5Fe-XCo (X=0, 1, 3, 5) alloys. Materials Characterization 77: 15-22.

9. Elhadari HA, Patel HA, Chen D, Kasprzak W (2011) Tensile and fatigue properties of a cast Al alloy with Ti, Zr and V additions. Mat Sci Engg A528: 8128-8138.

10. Liu Z, Li Z Mingxing W, Yonggang W (2008) Effect of complex alloying of Sc, Zr and Ti on the microstructure and mechanical properties of Al-5Mg alloys. Mat Sci Engg 2: 120-122.

11. Zeren M, Karakulak E (2008) Influence of Ti addition on microstructure and hardness properties of near eutectic Al-Si alloys. Journal of alloy & composition 450: 255-259.

12. Kamali H, Emamy, Razaghian MA (2014) Influence of Ti on microstructure and tensile properties of Al4.5Cu0.3 Mg alloy. Mat Sci Engg A590: 161-167.

13. Saheb N, Laoui T, Daud AR, Yahaya R (2001) Influence of Ti addition on wear properties of AlSi eutectic alloys. Wear 249: 656-662.

14. Archard JF (1953) Contact and rubbing of flat surfaces. J Appl Physics 24: 981-988.

15. Afonso C, Spinelli JE (2012) Rapid solidification of an Al-5Ni alloy processed by spray forming. Mat Res 15: 34-42.

16. Wang SQ, Wei MX, Zhao YT (2010) Effects of the tribo-oxide and matrix on dry sliding wear characteristics and mechanisms of cast steel. Wear 269: 424–434.