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Wear Behavior of Hypereutectic Al-Si Alloys at Elevated Temperatures

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ABSTRACT

The wear behavior of hypereutectic Al-Si alloys has been investigated using a Pin-On-Disc machine. Parameters such as alloy composition & normal pressure were studied on the hypereutectic Al–Si alloys at elevated temperatures. The worn surfaces were then characterized by SEM/EDS microanalysis. The results suggest that the wear resistance increases as the temperature increases due to the oxide layer formation which prevents direct metal to metal contact of sliding surfaces. The EDS microanalysis shows that there is almost 15% to 20% increase in oxygen content when temperature increases from 60ºC to 180ºC. The results also suggest that the wear resistance decreases as the silicon content increases.

Keywords: ***Al-Si alloys, wear, Elevated Temperature.***

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1. INTRODUCTION

Al–Si alloys are widely used in different fields of industry. High wear resistance, high strength-to-weight ratio, low coefficient of thermal expansion, high thermal conductivity, high corrosion resistance, excellent cast ability, hot tearing resistance, good weld ability etc. make hypereutectic aluminum silicon alloys very attractive candidate in aerospace and other engineering sectors. These applications demand the study of techniques to improve the wear properties of these alloys. For this purpose, many researches had been done to enhance their wear properties. Most common applications of aluminum silicon alloys are components like connecting rods, pistons, engine blocks, cylinder liners, air conditioner compressors, brake drums etc. The improvement in the tribological properties depends on number of material-related properties like shape, size and size distribution of the second-phase particles in the matrix and microstructures in addition to the operating conditions such as sliding speed, sliding distance, temperature, load etc. With the development of automobile industry, the need of hypereutectic Al-Si alloys is increasing greatly.

Wear is major problem in industry and its direct cost is estimated to vary between 1 to 4% of gross national product . Therefore many efforts have been made to produce durable materials and techniques to reduce the wear of the tools and engineering components. Over the last few years many efforts have been made to understand the behavior of the surface in sliding contact and the mechanism , which leads to wear.

A.D. Sarkar[13] studied the wear of aluminum-silicon alloys against hardened steel and grey cast iron using a pin-bush machine. The hypereutectic alloy wears more than the hypoeutectic alloy; overaging gives a higher wear rate and underaging a lower wear rate than the optimum aged alloy. Optical and scanning electron microscopical investigation of tested specimens was carried out to aid the elucidation of the wear mechanisms.

H.R. Manohara et al. [9] studied the addition of Inter metallic particles of Al_3Ti, TiB_2, AlB_2 and Al_4Sr to A_41_3alloy and sliding wear tests were carried out under dry sliding conditions to room temperature as well as at high temperatures of 60ºC, 120ºC and 180ºC. The results demonstrate that contacting surfaces at high temperature conditions are susceptible to oxidation and the wear rate of reinforced alloys is reduced. This is due to the formation of glazing layer that offers protection.

S.A. Kori et al.[2] studied the effect of grain refiner and or modifier on the wear behavior of hypoeutectic (Al–0.2, 2, 3, 4, 5 and 7Si) and eutectic (Al–12Si) alloys and investigated the same using a Pin-On-Disc machine. Various parameters such as alloy composition, normal pressure, sliding speed and sliding distance were studied on the hypoeutectic and eutectic Al–Si alloys. The cast master alloys (Al–5Ti–1B, Al–1Ti–3B and Al–10Sr) and worn surfaces were then characterized by SEM/EDX microanalysis. The results suggest that the wear resistance of hypoeutectic and eutectic Al–Si alloys increase with the addition of grain refiner and or modifier as compared to the absence of grain refiner and or modifier. Specific wear rate decreases with increase in normal pressure and sliding speed due to the addition of Si. Improved wear resistance can be achieved by the addition of grain refiner and or modifier to Al–Si alloys.

2. EXPERIMENTAL DETAILS

Al-Si alloys are prepared by foundry technique. Calculated quantities of commercial purity aluminum (99.7 Wt % purity) and Al-20 Si master alloy are melted in a resistance furnace under a cover flux (45% NaCl+45% KCl+10% NaF). The melt is held at 7200C±50C. After degassing the melt with solid hexachloroethane (C2Cl6) the melt is poured into cylindrical graphite mould (25 mm diameter and 100 mm height) surrounded by fire clay brick with its top open for pouring (for preparing the specimen for macro and micro structural studies) and also the melt is poured into the graphite split mould (12.5 mm diameter and 125 mm height- for preparing the specimen for wear pins).
Wear tests were conducted using pin on disc wear testing machine (TR-20LE- PHM-600, DUCOM, and PIN-ON-DISC MACHINE). The disc is made of low carbon alloy steel (EN-32 Steel, 160 mm diameter and 8 mm thickness) having hardness value of about 62RC. Wear pins of 30 mm length and 8 mm diameter were machined from the cast specimen obtained from graphite split mould (12.5 mm diameter and 125 mm length). Wear losses were recorded. Wear losses were measured with a linear variable differential transformer (LVDT) and it was monitored by the loss of length. The wear loss was measured in microns (µm). Weight loss method is followed to get the more accurate results. In this method using an electronic weighing machine weight of the wear pin before and after conducting the wear test is recorded. Difference between the initial and final weight gives the weight loss due to wear.

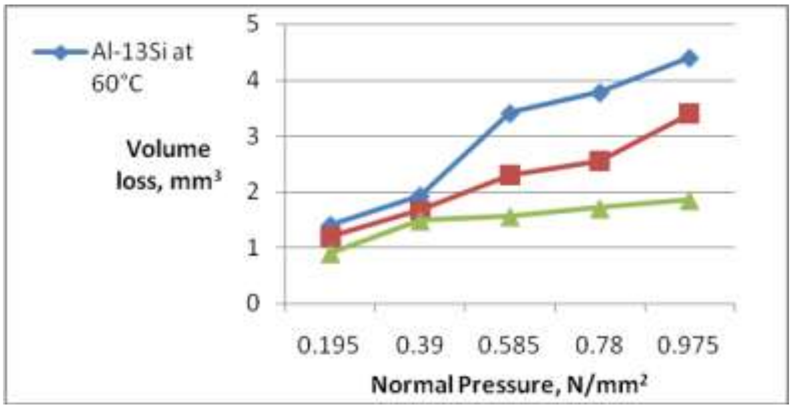
The Normal pressure dependent wear testing experiment was conducted to study the tribological wear behaviour of all these alloys.

3. RESULTS AND DISCUSSION

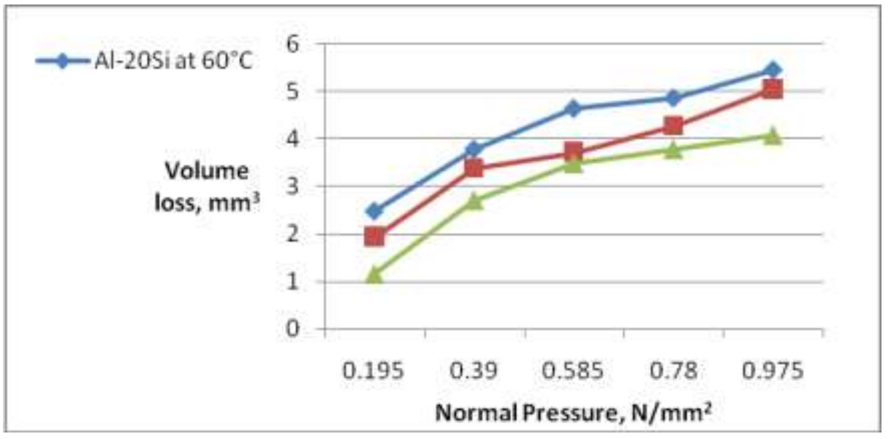
The wear tests of Al-Si alloys were carried out with varying applied load, sliding speed and sliding distance. The experiments are carried at elevated temperatures. In the present study, hyper eutectic aluminum based alloys containing 13 and 20% Silicon are tested. Series of tests were conducted by changing the Normal pressure and keeping the other parameters constant against wear and the results were obtained. The pressure is varied from 0.2 N/mm^2 to 0.98 N/mm^2; for each test the weight loss from the specimens was determined, and converted into volume loss using the measured density of the materials. The volume loss is obtained by using the density value 2700 Kg/m^3.

3.1 Effect of normal pressure

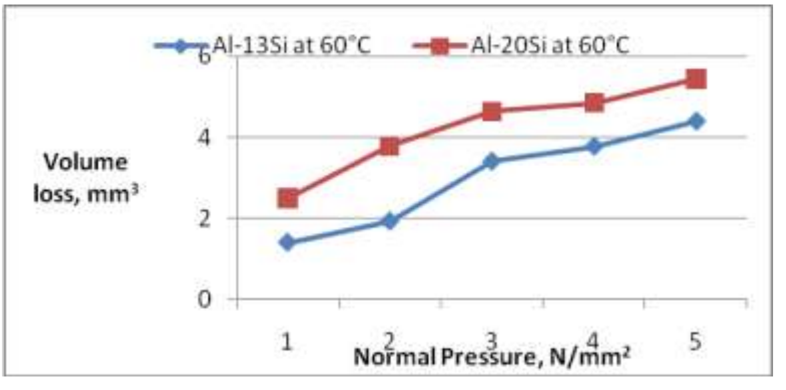
The effect of varying normal pressures (0.20, 0.39, 0.585, 0.780 and 0.98 N/mm^2) on the wear rate is shown in Fig 1. From Fig.1 it is clear that, volume loss increases with increase in normal pressures at 60°C, 120°C and 180°C. This is due to the fact that increase in load increases the real area of metal to metal contact between mating surfaces. And also as the load is increased, the oxide film becomes sensitive to bulk failure leading to increasing volume loss. Fig 1.(a), (b) shows variation of Al-13, 20Si alloys at 60°C,120°C and 180°C. In Fig 1(c), (d) and (e) comparison is made between Al-13, 20Si at 60°C, 120°C and 180°C respectively.



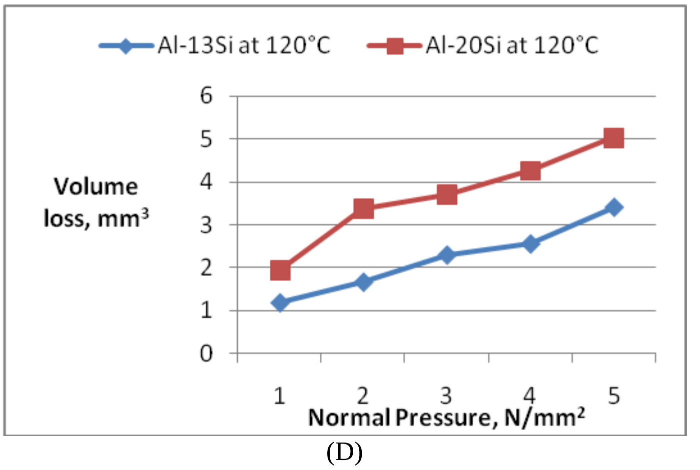
(A)


Al-20Si at 60°C
Volume loss, mm³
6
5
4
3
2
1
0
0.195
0.39
0.585
0.78
0.975
Normal Pressure, N/mm²

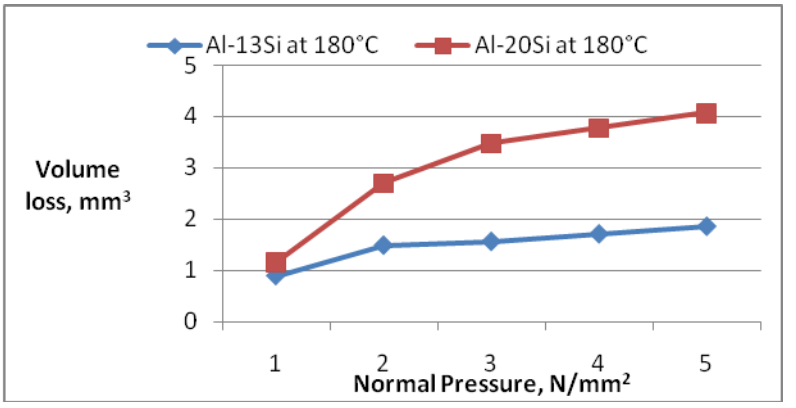
(B)


Al-13Si at 60°C
Al-20Si at 60°C
Volume loss, mm³
6
4
2
0
1
2
3
4
5
Normal Pressure, N/mm²

(C)

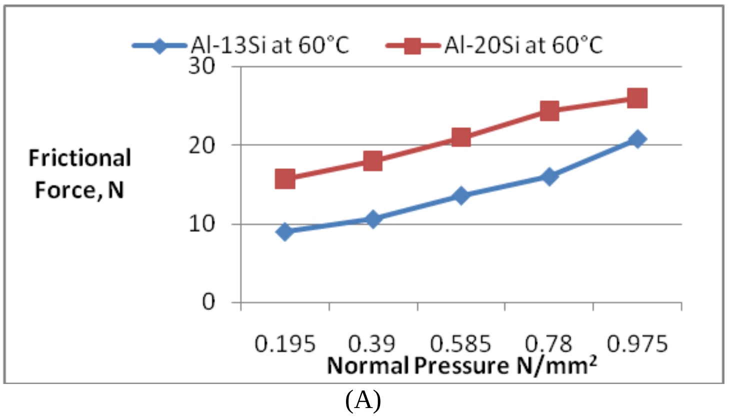

Al-13Si at 120°C
Al-20Si at 120°C
Volume loss, mm³
6
5
4
3
2
1
0
1
2
3
4
5
Normal Pressure, N/mm²

(D)

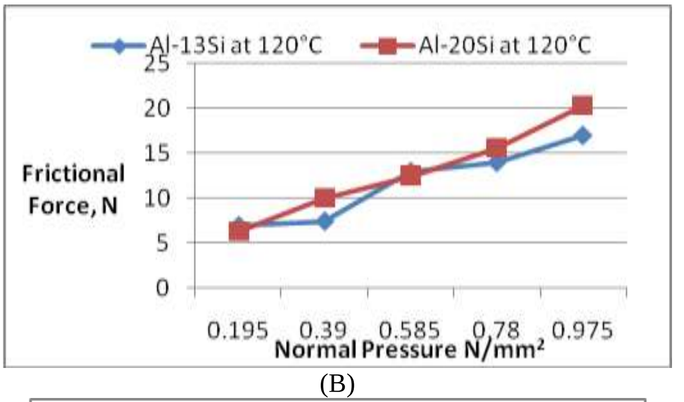


(e)

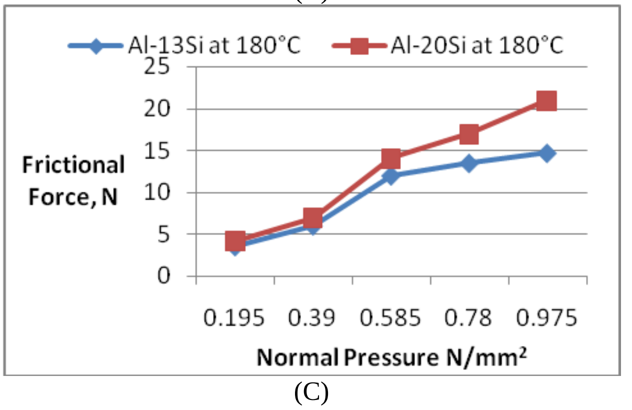
Fig.1 Normal Pressure v/s Volume loss of (A) Al-13Si alloy at 60°C, 120°C and 180°C., (B) Al-20Si alloy at 60°C, 120°C and 180°C., (C) Comparison of Al-13, 20Si at 60ºC., (D) Comparison of Al-13, 20Si at 120ºC., (E)Comparison of Al-13, 20Si at 180ºC.



(A)



(B)



(C)

Fig.2 Frictional Force v/s Normal Pressure, of Al-13,20Si alloy at 60°C, 120°C and 180°C

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3.2. Topography and microanalysis of Al-13, 20Si alloys for normal pressure

The following SEM and EDS micro analysis was carried out for the specimen Al-13, 20Si alloy under Normal pressure 0.975N/mm^2 at 60°C, 120°C and 180°C.

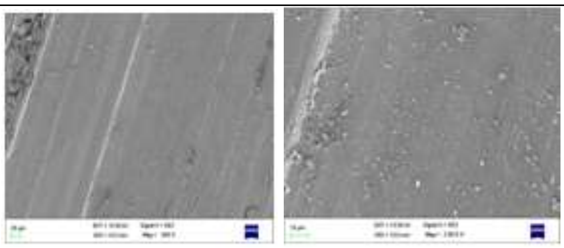
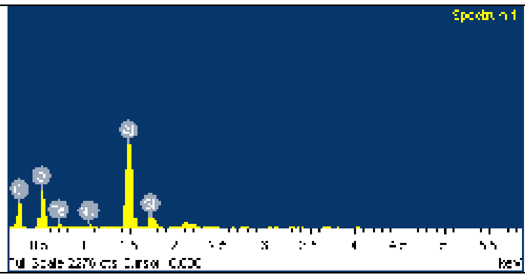
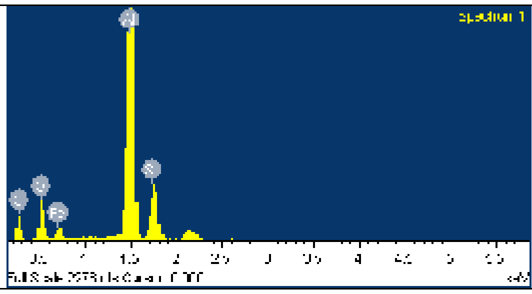
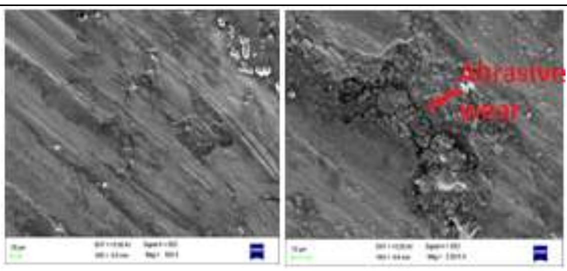
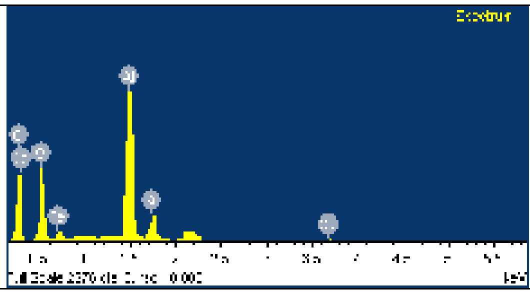
Wear Topography	EDS
At 60°C:	At 60°C:
	
	Oxygen Content: 15.38%
At 120°C:	At 120°C:
	
	Oxygen Content: 23.69%
At 180°C:	At 180°C:
	
	Oxygen Content: 29.95%

Table 1. The SEM microphotographs and EDS of Al-13Si alloys at Normal pressure 0.975N/mm^2

The EDS micro analysis clearly shows that the oxide layer formation increases as the temperature increases from 60°C to 180°C. The oxygen content increases from 15.38% to 29.95%. This leads to reduction in volume loss.

Wear Topography	EDS
At 60°C:	At 60°C:

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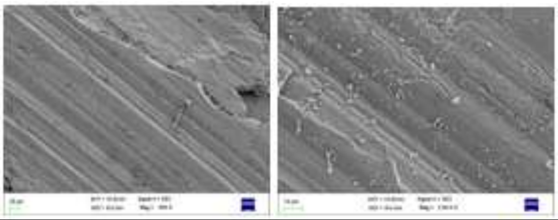
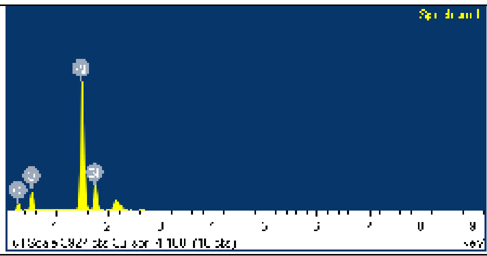
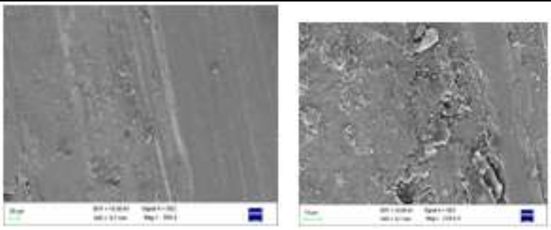
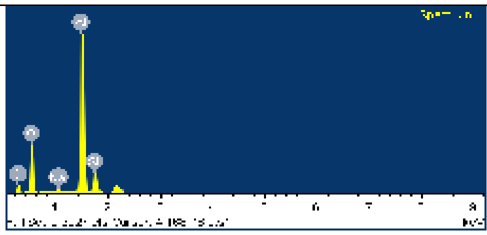
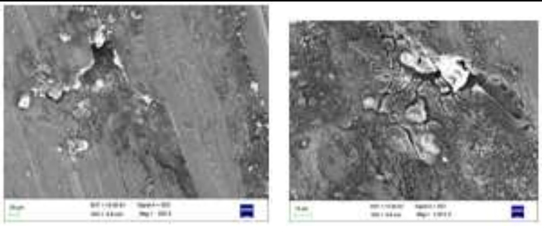
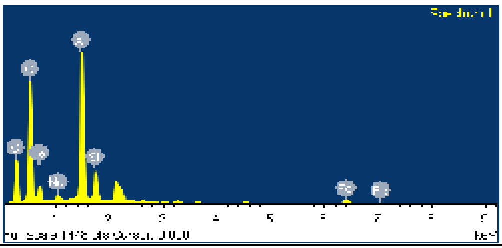
	
	Oxygen Content: 24.59%
At 120°C:	At 120°C:
	
	Oxygen Content: 30.64%
At 180°C:	At 180°C:
	
	Oxygen Content: 35.36%

Table 2: The SEM microphotographs and EDS of Al-20Si alloys at Normal pressure 0.975N/mm^2

The EDS micro analysis clearly shows that the oxide layer formation increases as the temperature increases from 60°C to 180°C. The oxygen content increases from 24.59% to 35.36%. This leads to reduction in volume loss.

4. CONCLUSION

The dry sliding wear behavior of Al–13Si and Al-20Si alloys was studied and compared at elevated temperatures and it is found that wear rate of the Al-13, 20 Si alloys increases as the normal pressure.

Experimental values of Wear test

Normal pressure (N/mm^2)	60°C		120°C		180°C	
	Volume loss, mm^3	Frictional force, N	Volume loss, mm^3	Frictional force, N	Volume loss, mm^3	Frictional force, N
0.20	1.4	9	1.185	7	0.888	3.5
0.39	1.926	10.6	1.666	7.5	1.481	6
0.59	3.407	13.6	2.296	13	1.555	12
0.78	3.777	16	2.555	14	1.703	13.5
0.98	4.4	20.8	3.407	17	1.851	14.7

Table 1.1 Experimental values of volume loss of Al-13 Si alloys for varying normal pressure

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