"Effect of grain refinement and modification on the dry sliding wear behaviour of eutectic Al– Si alloys using gravity die casting"

AKUL PATEL[1], ASHWIN BHABHOR[2] ,VIPUL PATEL[3]
[1] P.G.Student, Mechanical Departments, L.D.R.P.
[2] Assistant Professor Mechanical Departments, L.D.R.P.
Gandhinagar, Gujarat, India
[3]Assistant Professor Mechanical Departments, U.V.P.C.E.

ABSTRACT
The present study deals with an investigation of dry sliding wear behavior of grain refined and modified eutectic Al–Si alloys. Al–Si alloy by using a Pin-On-Disc machine. The indigenously developed Al–3Ti–1B and Al–10Sr master alloys were used as grain refiner and modifier for the grain refinement of α-Al dendrites and modification of Si, respectively. Various parameters have been studied such as alloy composition, sliding speed, different time duration and normal load. The cast alloys and master alloys were characterized by optical microscope analysis. Results suggest that, the wear resistance of Al–Si alloys increases with the addition of grain refiner (Al–3Ti–1B) and modifier (Al–10Sr).

Keywords: Al–Si alloys, Al–Ti–B grain refiners, Al–Sr modifier, Sliding wear

I. Introduction
Wear is one of the most commonly encountered industrial problems leading to the replacement of components and assemblies in engineering [1]. Therefore, many efforts have been made to produce more durable materials and techniques to reduce the wear of tools and engineering components. These include modification of bulk properties of the materials, surface treatments and application of coating, etc. Over the last few years, many efforts have been made to understand the wear behaviour of the surfaces in sliding contact and the mechanism, which leads to wear [2]. The applications of aluminium and its alloys for the machine parts are increasing day to day in the industry. However, little has been reported on the wear behaviour of aluminium and its alloys with the addition of grain refiner and modifier [3]. Amongst the commercial aluminium casting alloys perhaps Al–Si alloys are the most common, particularly due to some very attractive characteristics such as high strength to weight ratio, excellent castability and pressure tightness, low coefficient of thermal expansion, good thermal conductivity, good mechanical properties and corrosion resistance [4]. Al–Si alloys find wide range of applications in marine castings, motor cars and lorry fittings/pistons and engine parts, cylinder blocks and heads, cylinder liners, axles and wheels, rocker arms, automotive transmission casings, water cooled manifolds and jackets, piston for internal combustion engines, pump parts, high speed rotating parts and impellers, etc. [4,5]. The in-service performance of the Al–Si alloy castings primarily depends on their microstructures. Basically, the microstructure consists of the primary phase α-Al in hypoeutectic, primary Si in hypereutectic alloy and Al–Si eutectic constituent. It is essential that these alloys solidify with fine equiaxed α-Al in hypoeutectic/fine primary Si particles in hypereutectic and fine eutectic Si. While the former can be achieved by suitable grain refinement treatment/ solidification processing and later the can be achieved by modification [5, 6]. A fine grain size ensures improved mechanical properties, improved feeding during solidification, reduced and more evenly distributed shrinkage porosity, good tribological properties, uniform distribution of second phase particles on a fine scale and good surface finish resulting in improved machinability [5, 7–9]. The wear resistance of these alloys may depend on the hardness of the matrix and the dispersed second phase Si particles/plates in the Al–Si alloys. The distribution state of the Si particles in the Al–Si alloys can be changed by modification [3, 9]. Therefore, Al–Si alloys are suitable for studying the effect of second phase particle on the tribological and mechanical properties of the alloys.

The present investigation is an attempt to investigate the possibility of improving the tribological properties of eutectic Al-Si alloy through melt treatment . Eutectic alloy was refined with Al-3%Ti-1%B and modified by Al-10%Sr. Influence of melt treatment on dry sliding wear has been studied.

II. EXPERIMENTAL PROCEDURE

Nominal composition of the experimental alloys is given in Table 1.

Table 1 The Chemical Composition of Cast Alloy

Material	Si	Mn	Cu	Al	Mg	Zn	Ni	Fe	Zn	Ti
Al-Alloy	11.8	0.097	1.150	83.95	0.66	0.95	0.62	0.65	0.085	0.034

The master alloy was melted in graphite crucible in oil fired furnace under cover flux GR 6512 and the melt was held at 800°C, then melt was degassed with 1% hexachloroethane tablet and molten metal was stirred with argon gas .After fluxing and proper degassing, 1% Al-3Ti-1B wrapped in aluminum foil, was added to the molten alloy with stirring of the melt at 800°C.This was followed (after 10 minute of addition of grain refiner) by addition of 1% of strontium in the form of Al-10%Sr master alloy to the melt. After the holding for 10 minute, dross was removed and subsequently molten alloy was poured in metal mould.

Wear tests were carried out on eutectic Al-Si alloys using a Pin-On-Disc type testing machine. Wear test specimens are rounded bars with flat surface having dimensions of 25mm length×8mm diameter. The flat portion of 8mm diameter of the test specimen is in contact with a rotating disc. The disc material is made up of En- 32 steel (diameter 160mm and 15mm thickness) with chemical composition as shown in Table2. A constant 100,120 and 140 mm track diameter was used the experimental work. The wear tests were carried out under various service conditions such as normal pressures, different sliding speeds and with different time duration. The details are shown in Table 3.

The mass loss in the specimen after each test was estimated by measuring the weight of the specimen before and after each test using an electronic weighing machine having accuracy up to 0.0001gm.

Table 2 The Chemical Composition of Disc Material

Material	C	S	Ph	Si	Mn	Cr	Ni	Mo
EN 31	1.000	0.029	0.040	0.340	0.55	1.100	0.200	0.06

Table 3. Shows the varying service conditions

Variable Parameters	**Level**		
	1	**2**	**3**
Sliding Speed (rpm)	125	375	500
Radial contacting surface area (Dia. mm)	100	120	140
Time(sec)	300	600	900

Diagram of the load, pin, disc and the direction of the rotation and the photography of tribometer are shown in Fig. 1.

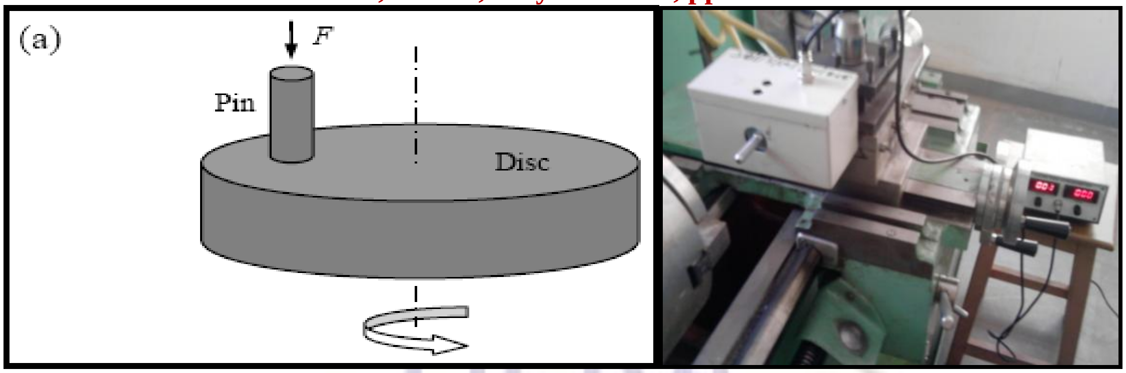

Fig. 1. Pin-on-disc tribometer: (a) schematic diagram and (b) photography

According to the design of experiments in previous chapter a constantly applied load up to 1 kg. The tests were conducted with a varied sliding speed (125, 375, 500 rpm), radial contacting surface area 100,120 and 140 mm and varied time duration 300,600 and 900 sec.

Sample required for various tests were machined from following condition:

1) Without (Grain refinement & Modifier)
2) With (Grain refinement & Modifier)

Samples for micro structural studies were cut from castings .Specimen were polished and prepared by standard metallographic procedure.

III. Results and discussions

III.I Microstructural study

Fig. (2-3) show photomicrographs of eutectic alloy. It is observed that the addition of 1% of Al-3Ti-1B master alloy grain refiner to eutectic alloy significantly refine coarse α-aluminum dendrites to fine equiaxed α-aluminum dendrites. Modification refines the primary and eutectic silicon crystals and changes the morphology of these crystals.The change in microstructure from coarse columnar grain structure to fine equiaxed grain structure and coarse dendritic structure to fine dendritic structure in case of Al–12Si alloys and with change in plate like eutectic Si to fine particles resulted in high wear resistance of Al–Si alloys.

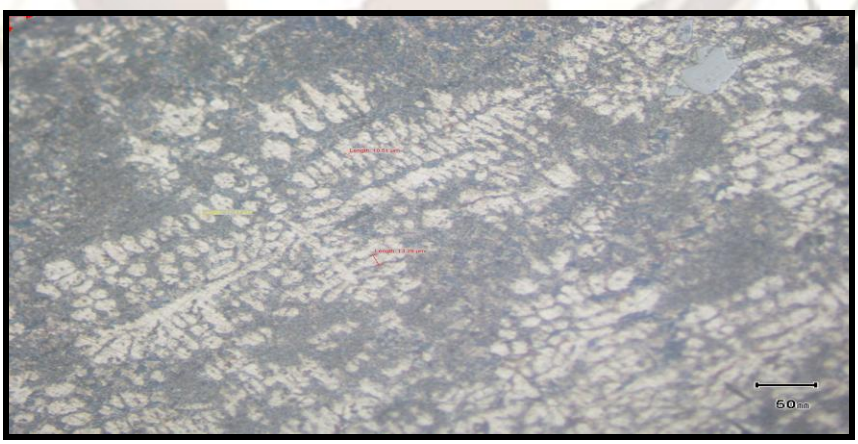

Fig 2. Without (GR+M)

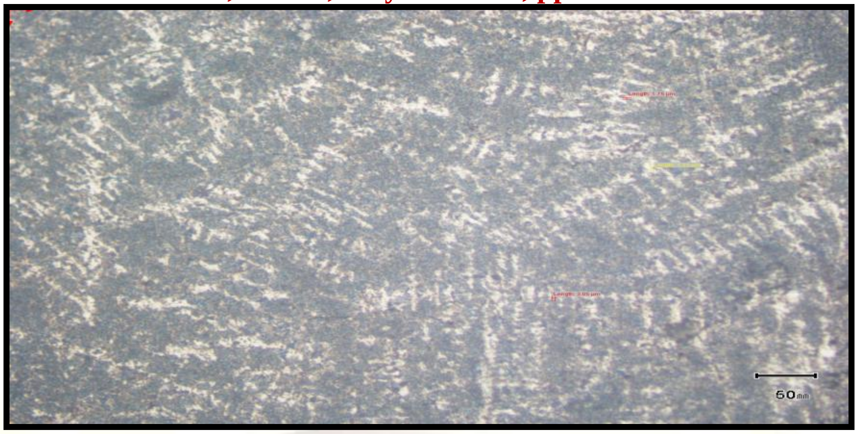

Fig 3. With (GR+M)

III.II Wear studies

Effect of sliding speed

Fig. 4, 5 and 6 shows the effect of various sliding speeds (125,375,500 rpm) on the specific wear rate with different time duration at different wear track. It is clear from Fig. 4, 5 and 6 that with increase in sliding speed from 125 to 500, there was a decrease in specific wear rate both in the case of grain refined/modified and without grain refined/modified eutectic Al-Si alloys samples. This is due to the fact that, at low sliding speeds, more time is available for formation and growth of micro welds, which increases the force required to shear off the micro welds to maintain the relative motion, due to which specific wear rate increases. However, at higher speeds, there is less residential time for the growth of micro welds leading to lesser specific wear rate [10]. In addition, less specific wear rate was observed in Al–Si alloys, when grain refiner (Al-3Ti-1B) and modifier (Al–10Sr) were added to the melt as compare to without grain refinement and modification.

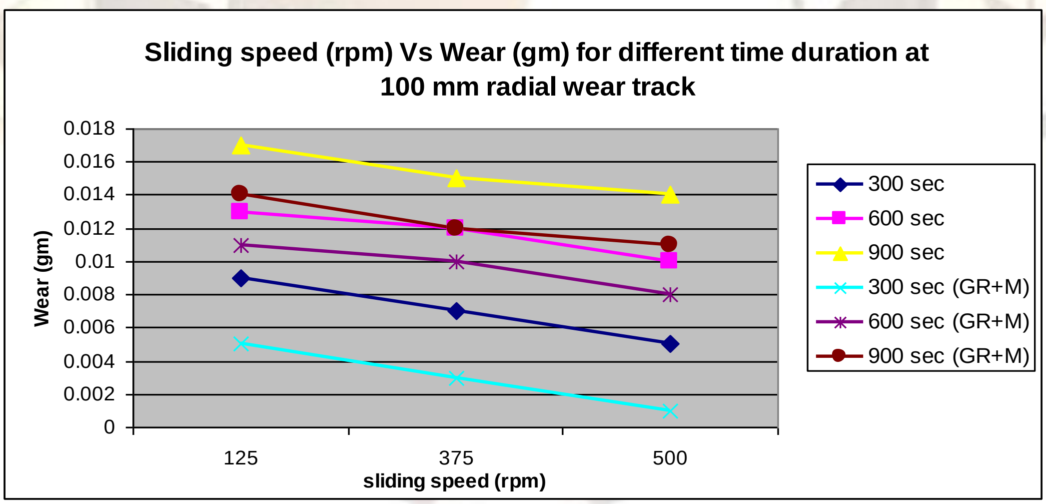

Fig 4.Sliding speed (rpm) Vs Wear (gm) for different time duration at 100 mm radial wear track

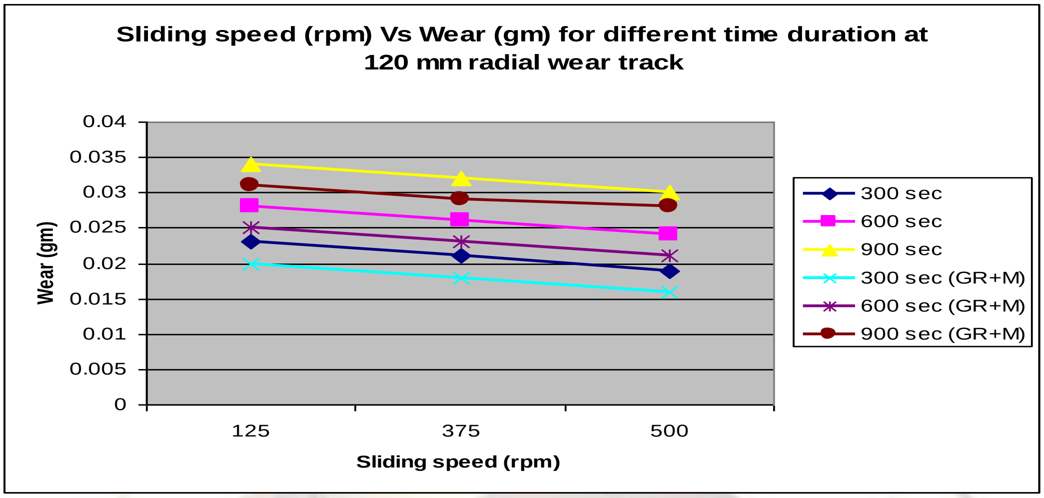

Fig 5.Sliding speed (rpm) Vs Wear (gm) for different time duration at 120 mm radial wear track

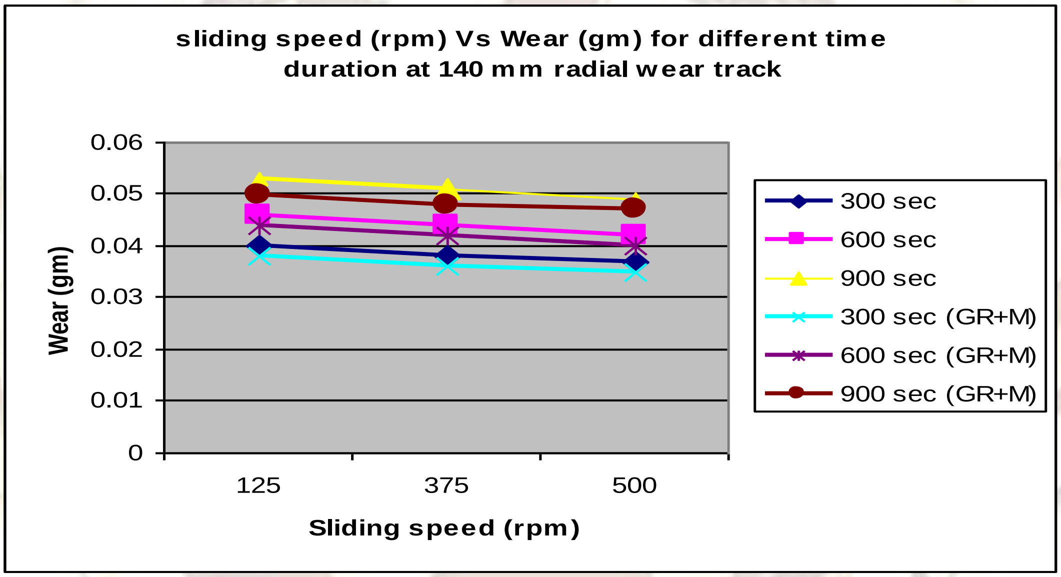

Fig 6.Sliding speed (rpm) Vs Wear (gm) for different time duration at 140 mm radial wear track

Fig.4, 5, and 6 shows the effect of wear track (100,120,140 mm) on wear loss with different sliding speed of eutectic Al–Si alloys. It is generally known that, with an increase in wear track, the wear loss increases due to more intimate contact time of the specimen with the rotating disc. However, wear rate was less in case of combined additions of grain refiner and modifier when compared to the absence of grain refiner and or modifier.

Fig.4, 5 and 6 shows the effect of different time duration (300,600,900 sec) on wear loss eutectic Al–Si alloys. It is generally known that, with an increase in time duration, the wear loss increase in both cases.

IV. Conclusions

1) Addition of 1% of Al-3Ti-1B grain refiner to eutectic alloy significantly refines coarse columnar α-aluminum dendrites to fine equiaxed α-aluminum dendrites.
2) Grain refinement reduces inter-dendrite arm spacing of α-aluminum dendrites.
3) Modification refines the primary and eutectic silicon crystals and changes the morphology of these crystals.

4) Wear rate of eutectic Al–Si alloys increases with increase in time duration and wear track and decreases with increase in sliding speed.

V.ACKNOWLEDGEMENT:

The author would like to thank Mr.Prashantbhai Panchal of Maruti Piston Pvt. Ltd., Kalol for giving permission to use their infrastructural facility of the company and co-operation.

VI.References

[1] T.S. Eyre, Wear characteristics of metals, Tribol. Int. 9 (1976) 1–10.

[2] M.M. Haque, A. Sharif, Study on wear properties of aluminiumsilicon piston alloy, J. Mater. Process. Technol. 118 (2001) 69–73.

[3] M. Katsuta, K. Oodoshi, S. Kohara, Wear resistance of Al–Si alloys, in: Proceedings of the Sixth International Conference on Aluminium alloys (ICAA-6), vol. 3, 1998, pp. 1945–1950.

[4] N. Saheb,T. Laoui, A.R. Daud, M. Harun, S. Radiman, R.Yahaya, Influence of Ti addition on wear properties of Al–Si eutectic alloys, Wear 249 (2001) 656–662.

[5] J.E. Gruzleski, B.M. Closet, The treatment of liquid aluminium silicon alloys, AFS, Illions, 1990, pp. 1–254.

[6] D.G. McCartney, Grain refining of aluminium and its alloys using inoculants, Int. Mater. Rev. 34 (1989) 247–260.

[7] B.T. Dunville, D.K. Young, G.W. Boone, A new combination grain refiner/modifier for hypoeutectic Al–Si foundry alloys, Light Metals (1994) 1065–1071.

[8] S. A. Kori, Studies on the Grain Refinement and Modification of some hypoeutectic and eutectic Al–Si alloys, Ph.D. Thesis, IIT Kharagpur, 2000.

[9] S.A. Kori, B.S. Murty, M. Chakraborty, Development of an efficient grain refiner for Al–7Si alloy and it's modified with strontium, Mater. Sci. Eng. A 280 (2000) 94–104.

[10] A.D. Sarkar, Wear of Metals, Pergaman Press, England, 1976, 50–160