Tribological Efeect On Aluminium Silicon Alloys And Aluminium Silicon Carbide Composite

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Abstract - **Among the materials of tribological importance, Aluminium-silicon composites have received extensive attention for practical as well as fundamental reasons. This investigation describes about the wear characteristics of Al-Si alloys and Al-SiC composite using particle erosion test and pin-on-disc wear test at room temperature. Here Si and SiC, having 10% and 5% (weight percentages) are taken with Aluminium by stir casting method. It is found that addition of silicon/ silicon carbide improves the wear resistance, machinability, and corrosion resistance. It has been found that the wear rate is strongly dependent on impact angle of erodent, impact pressure and velocity (in case of particle erosion); and applied load, sliding speed, alloy composition (in case of sliding wear). Erosion wear behavior is also been affected with the hardness. It is observed, Al-SiC particulate composite bears higher hardness than that of Al- 10%Si alloy. Maximum erosion has taken place at 90° angle of impingement and the erosion amount is less with Al-SiCp than that of Al-10%Si alloy. From experiment it is conclude that Al- Si alloys and Al-SiC composite can use as a potential structural material.**

keywords - **Aluminium, Silicon, Carbide, DUCOM software, WINDUCOM software**

INTRODUCTION

In recent decade, Aluminium-Silicon composites have potentially grown up in engineering structural applications ranging from automobile & aerospace industries to marine industries. Due to high strength to weight ratio, makes Al-Si composite a favorable material. Aluminum-Silicon alloys also constitute a important category among aluminum foundry alloys. Aluminum alloys with silicon, offers better corrosion resistance, excellent castability, good machinability property and easy weldability. In different industries, materials exposed in high temperatures must be high resistant to hostile environmental effects/corrosion and similarly if the component is under heavy load, it must be resistant to deformation. It is usually possible to select a material/composite with suitable combination of properties [1]. Composite materials, which can be produced using a metallic matrix and fine ceramic particles, are recently being developed in order to protect the components in the elements of combustion chambers in diesel engines as they are subjected to high loading conditions, high temperatures and corrosive and erosive media [2-7]. One possibility to increase durability and performance of the materials for these applications is to protect them by using the composite coatings having a high degree of wear resistance. Such coatings can be economically produced by co-depositing metallic matrix together with fine and inert ceramic particles [8]. Aluminum-silicon eutectic phase is an anomalous eutectic process because it constitutes a metal (aluminum) and a non-metal (silicon). Aluminum-Silicon system is a simple binary eutectic with limited solubility of aluminum in silicon and limited solubility of silicon in aluminum. The solubility of silicon in aluminum reaches a maximum 1.5 at% at the eutectic temperature, and the solubility of silicon increases with temperature to 0.016% Si at 1190°C. The characteristic property of Aluminum-silicon is comparatively high tensile strength than that of other cast alloys such as ductile cast iron, cast steel etc. The high specific tensile strength of aluminum-silicon alloys is very strongly influenced by their composed polyphase microstructure. The silicon content in standardized commercial cast aluminum-silicon alloys is in the range of 5 to 23 wt%. Some typical applications of aluminium silicon products are:

1. low-friction cylinder liners, crankcase etc. in automobile parts
2. In industry furnace (insert hole of thermometer etc.)
3. Thermal insulating material of heat and electrical equipment
4. Burner brick of industry furnace and furnace door, etc.

Aluminium-Silicon carbide composite possesses a important role among Aluminium composite due to its High Thermal Conductivity, Isotropic Controlled Thermal Expansion, High Strength, Light Weight, High Stiffness etc. in different advance application, its demand gradually increases. Typical applications are high heat dissipation and spreading materials, Integration of cooling tubes-functional components, microprocessor lids/heat sinks, microwave housings, optoelectronic housings/bases etc. In this investigation an effort has been made to understanding of the formation of the aluminum silicon composite both in unmodified and modified alloys and applying our understanding to alleviate the problems of wear in structural applications. This investigation described into different sections: 1) Background in which literatures are placed to explain Aluminum-silicon composite evolution; 2) experiments Procedures, which describes the detail plan, materials and procedures used in conducting the various experiments; 3) Results and Discussion describes the results found. Al-SiC composites have been prepared by addition of SiC powder in molten aluminium by stir-casting. Two type of Wear study have been done I.e. solid particle erosion wear test and abrasive wear test, which were done by Air Jet REG m/c and Pin on Disc machine respectively. For solid particle erosion, wear rate was calculated by measuring the cumulative mass loss. In abrasive wear testing, the wear rate was calculated in terms of wear depth by taking data from the DUUCOMP friction and wear monitor.

EXPERIMENTAL DETAIL
Materials used for testing are :
1)AlSiC metal matrix composite(5% SiC reinforcement)
2)Al-Si alloys(10% Si)

Tests Carried out for each sample:
1)Particle erosion wear test
2)Sliding wear test using Pin on disc machine with DUUCOMP monitor

Total number of samples prepared: Total four samples are prepared. two samples from AlSiC composite and two samples from Al-Si alloys. one for particle erosion test and one for sliding wear test for each of the material. AlSiC metal matrix composite is produced by stir casting route .Molten aluminium metal is poured into a crucible and SiC powder are incorporated into the mould. Stirring is done by mechanical means and they are allowed to solidify. sample of dimension is machined from the as-cast sample for erosion wear test. cylindrical samples of 12mm diameter and 15mm height are machined from the as-cast Al-SiC ingot in the lathe machine for sliding wear test .Test samples were obtained from those cylindrical pieces by polishing them. Molten Al-Si alloy is poured in to a crucible and allowed to solidify. A sample of 4cm*3cm*1cm dimension is machined from the as-cast alloy using a Hexer for erosion wear test. A cylindrical sample of 12mm diameter is machined from the as-cast alloy for sliding wear test. Surface are polished prior to testing.

SOLID PARTICLE EROSION WEAR TEST

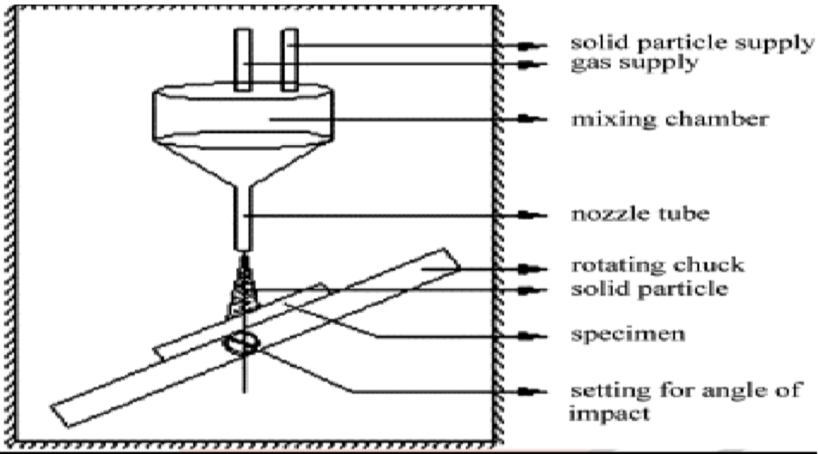


Fig. Erosion wear test apparatus

The solid particle erosion (SPE) test system involves repeated impacts erosion by pressurized air driving the potential energy of the erodent particles striking the surface of the test sample. The amount of mass loss of the tested sample divided by the mass of erodent can present the wear rate, or the volume loss can be also evaluated to rank the erosion resistance of full range of materials, ceramics, metals, coatings, thin films and composites. The impingement angles can vary from 15° to 90° assisted by a flexible holder.
particles are typically a mixture of Al_2O_3 particle and sand particles. Pressure is controlled using a compressor.
Specifications of erosion wear test apparatus-

Feed rate of erodent particles	-
Stand-off distance	10cm
Nuzzle diameter:	-
Pressure	up to 5 bar
Standard sample dimension	40x40x5-10 mm
Incident impingement angle	up to 90°
Temperature (surface)	up to 250° C

WEAR PARAMETERS
The variables involved in solid particles erosion wear tests are:
- Incident angle
- Gas Pressure
- Time of impact

The effect of each parameter on wear is studied individually in this experiment.

WEAR MEASUREMENT
Erosion wear rate can be calculated using the following formula:

$$Er=\Delta W/We$$

Where Δw =change in weight of the specimen due to bombardment with eroding particle.
W(e) =weight of the eroding particles strike at time.

DUCOM WEAR AND FRICTION MONITOR

The machine consists of a pin on disc loading panel and controller. The sample is put in that hole and screwed with a pin. For rotation of the disc to take place,time period of revolution is set up initially in the control panel. The wear is shown in the monitor in micrometer.The frictional force is shown in KN. The machine is automatically stopped when the given time period is reached. The abrasive we used for studying wear is a steel surface without any emery paper or SiC paper on it.

SLIDING WEAR TEST APPARATUS

Operating Parameters

The variables involved in wear test are:

- % Si in the Al-Si alloy
- Normal load
- Sliding velocity
- Sliding distance

Wear Measurement

Wear is directly measured from directly taking the data from the monitor. The monitor shows wear in micrometer and frictional force in KN. To study the effect of one parameter on the wear , all other parameters are fixed and the respective parameter is varied. Thus wear is studied.

Specifications of the DUCOM wear and friction monitor.

Parameter	unit	Minimum	Maximum
Disc speed	RPM	10	800
Pin diameter	mm	2	10
Pin length	mm	10	50
Wear track dia	mm	10	80
Normal load N	N	0	100
Frictional force	N	0	100

RESULTS AND DISCUSSION

Results of wear tests

In the present investigation,Al 10% Si commercial alloy available in the market and Al-5% SiC composite fabricated by stir casting route are been used.The Physico-mechanical properties are been studied in this piece of work.

Hardness measurement

Hardness is the basic requirement of a material for use in specified machine parts. The Hardness of the sample are measured using vicker's Hardness tester at 300gf,each data point is the average of five readings.

Showing Vicker's hardness value for as-cat alloys

Material	Hardness(HV)
Al-10% Si alloy	57.2
Al-SiC composite	90.7

Tribological studies

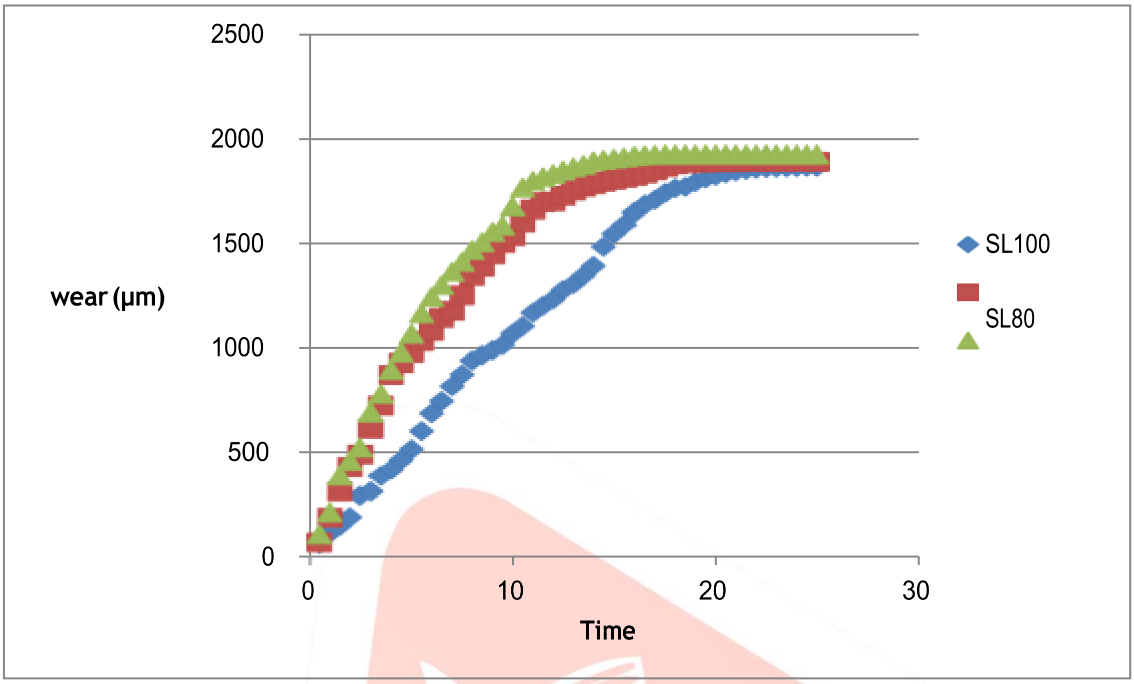
Al-Si alloys and Al-SiC composites are been used in automobile parts since years.Hence it is required to study the tribological behaviour and improvement for such materials. Aiming at these aspects sliding and erosion wear behaviour has been investigated.

Studies on sliding wear

The sliding wear tests are carried out for different time lengths and the wear charecteristics are been explained below:

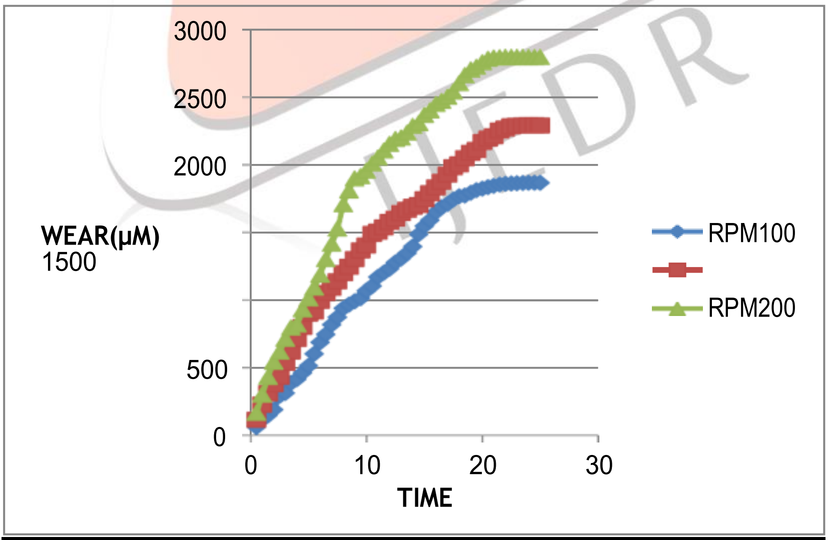
Effect of strand length on sliding wear of Al-10% Si sample

The below figure shows that with increase in strand length, time required for the wear to be static also increases. This is because as the strand length increases, the track diameter decreases. So distance covered in one revolution also decreases. A static wear is achieved after the material has covered a certain distance. With smaller strand length, the sample will take more time to attain this distance. In this test for strand length 60 mm, static wear is achieved in a minimum time where for strand length 100 it is maximum. The test was done varying the strand length and keeping load (10KN) and sliding speed (100 RPM) as constant.



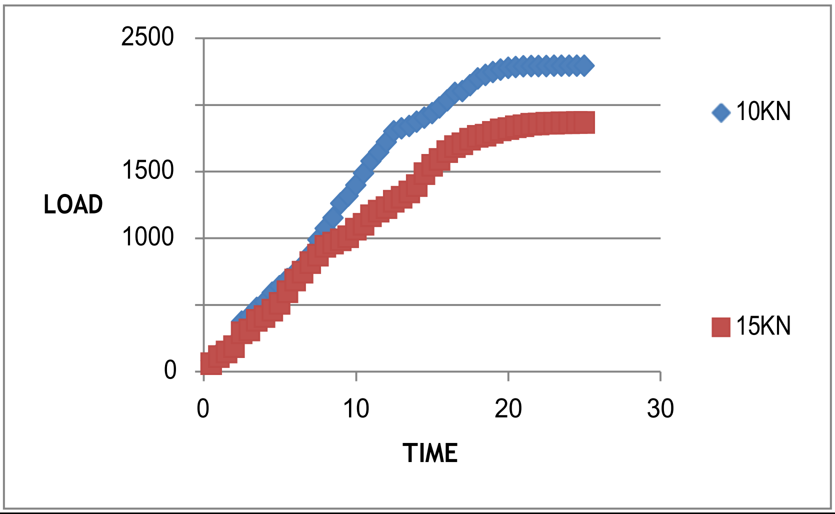
Effect of Sliding speed on wear of Al-Si sample

Wear is also dependent on sliding speed. Here the sliding speed is measured in RPM. The more is the sliding speed, the more distance will be covered by the sample. so static wear will be achieved faster .Wear will be higher for higher sliding speed. The above figure shows that with increase in sliding speed wear increases. From our figure it can be shown that at a particular time, wear is maximum for sliding speed 300 RPM where it is minimum for sliding speed 100 RPM.

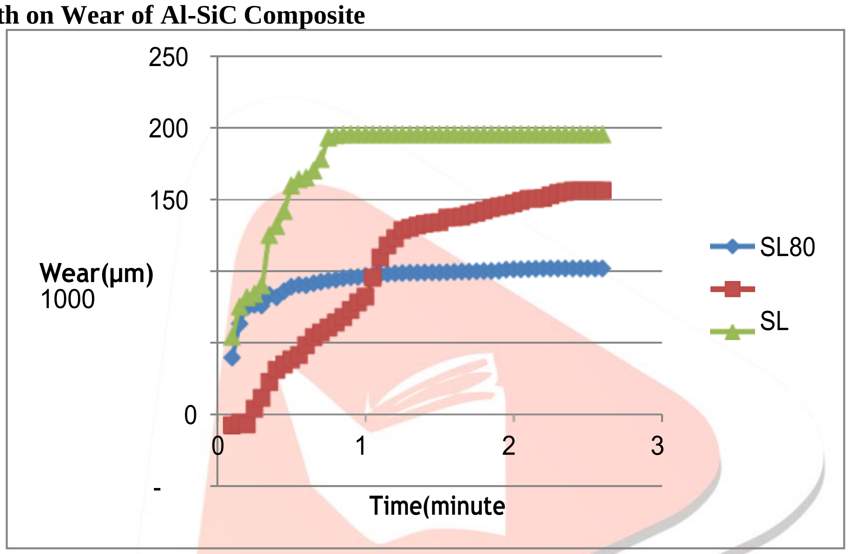


Effect of Normal Load on wear of Al-Si sample

'The more is the normal load, the more will be the wear. The tests were done varying the normal load and, keeping the strand length and sliding speed fixed. In atomic level the surface of a material can not be fully flat. When two surfaces are in contact, they touch each other at some points. when load is applied, plastic deformation occurs locally in those points which leads to removal of material. More the load more will be the plastic deformation. Hence wear will be more.

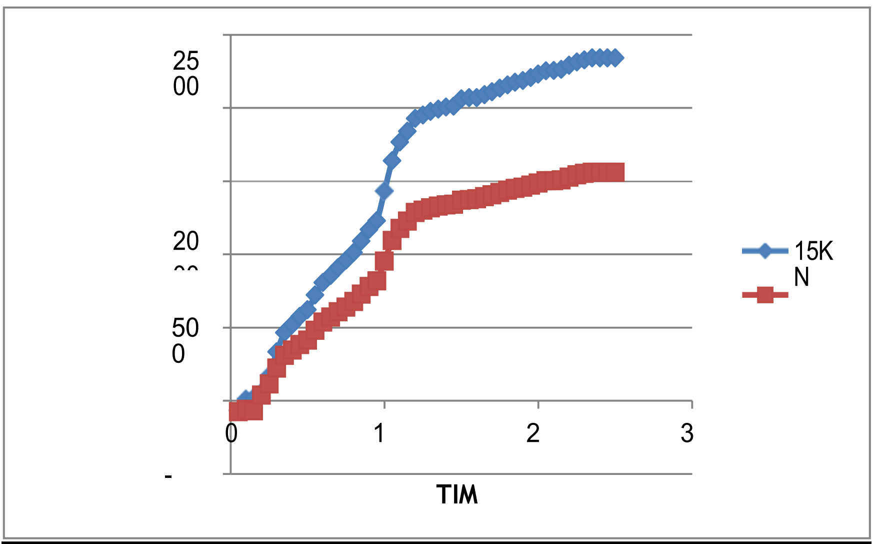


Effect of Strand Length on Wear of Al-SiC Composite



The effect of strand length on wear of Al-SiCp reinforced metal matrix composite is similar to its effect on wear of Al-Si alloy. The trend lines are similar in both case. Increase the strand length, smaller will be the track diameter.
Hence to slide the same distance, sample tested under larger strand length condition will take more time before attaining the static wear than smaller strand length.

Effect of Normal load on wear of Al-SiC composite
The above figure shows that at a particular time wear is higher for a higher load. No engineering surface is perfectly planar. some protuberance are present on the surface. There may be dirt or some other particle on the surface. When load is applied, those particles penetrate into the solid surface causing local plastic deformation. Material removes from those areas. Higher the load, higher will be the penetration and more will be the wear.



Study of Sliding wear on Pin-on-Disc machine by WINDUCOM software

This software helps to visualize the wear and frictional force with respect to time on the computer screen. The figures given below explain how it work.

Study On Al-Sic composite

Wear was studied at load 5 KN and 10 KN, fixing the strand length 100 cm and Sliding speed 100 RPM. The time period is set for 10 minutes.

Fig- Wear at load 5 KN

This figure shows that within 10 minutes time, the static load is not reached. But the large fluctuations indicate that the material develops wear resistance gradually.

Fig- Frictional force variation with time

Surface Morphology study

The surface morphology was investigated with a optical microscope at different resolutions

Fig.-initial microstructure of AlSiC composite Fig.-Erosion wear at 60° angle, 3 bar pressure for 240Sec

Fig.-magnified to showing the wavy region.

CONCLUSION

Al-SiC particulate composite bears higher hardness than that of Al-10%Si alloy.

The sliding wear behaviour of Al-SiCp material possess superior sliding wear sustanability than that of Al-10% Si alloy.

The sliding wear rate is magnified more han two and half times than the Al-10%Si alloy,When SiC is used for making aluminium metal matrix composite.

Erosion wear behaviour is also been affected with the hardness;which has been observed from the erosion wear tests.

It is found that erosion angle and impact pressure are the main parameters for erosion of the material.

It is observed that maximum erosion has taken place at 90° angle of impingement and the erosion amount is less with Al-SiCp than that of Al-10%Si alloy.

Hence it can be concluded that the hardness of the material,sliding distance and applied pressure are responsible for sliding wear behaviour; the hardness of the erodant and angle of impingement are the major factors for erosion wear.

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