

# Wear Behavior and Characterization of Spray Formed Al-Si and Al-Si-Sn Alloys

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**ABSTRACT:** Wear behavior of spray formed Al-17Si and Al-17Si-10Sn alloys was investigated using a pin on disk type wear testing machine and characterization of this Al-Si and Al-Si-Sn metal matrix composite alloys is done using optical microscope. The alloys were spray formed in an environmental chamber using nitrogen gas and a deposition distance of 380mm. The spray formed alloys showed considerable microstructural refinement with uniform distribution of Si particles in Al-Si alloys and that of Sn and Si particles in the matrix of primary Al phase of Al-Si-Sn alloys. Dry sliding wear behavior of these metal matrix composite alloys was studied as a function of sliding distance, applied load and sliding velocity. The wear response parameters such as wear rate and frictional force were measured. A considerable increase in the wear resistance of the alloy is observed with addition of Tin(Sn). The improved wear properties and characterization of the alloy containing Sn are discussed in light of the microstructural features of spray formed alloy.

**KEYWORDS:** Aluminium Alloys, Spray forming, Wear rate, Co-efficient of Friction, Pin-On-Disc machine

## I. INTRODUCTION

Aluminum alloys of various types are continually being developed to improve their wear resistance. Among these alloys, aluminum-silicon (Al-Si) alloys have been found to be beneficial in many industrial applications and considered to be appropriate substitutes for cast iron components. The addition of silicon in aluminum alloys improves their wear, casting, machining and corrosion characteristics.

Amongst several bearing materials currently available, Al-alloys possess the requisite combination of high specific strength, thermal conductivity and wear resistance. These are used for components Such as plain bearing, piston and cylinder liners in internal combustion engines. However, to improve the anti-friction characteristics, for better engine out-put, the incorporation of soft phases Like Sn, Pb, graphite, etc. becomes a principal necessity. In view of this, several studies have been carried out using Pb and graphite reinforcement to Al-Si alloys. Generally, the incorporation of Pb and graphite deteriorates some of the properties of Al-alloys like ductility, formability and thermal conductivity. In addition, they also increase the environmental and health concerns due to high toxicity [1]. Therefore, as an alternative, there has been an increasing trend of producing Al-Si-Sn alloys for plain bearing applications.

Conventional casting, powder metallurgy, or thermal spraying techniques are mostly used to produce these alloys. In conventional casting, coarser dendritic structure and large Si particles lead to poor mechanical properties and hence secondary processing is required to achieve desired properties [2]. Pathak and Mohan [3] examined the tribologic properties of Al bearing alloys. They studied the sliding wear characteristics of Al-Pb and Al-Sn alloys prepared by impeller mixing and bottom discharge chill casting technique. It was found in this study that Al-Pb bearing alloys exhibited a superior wear resistance than that of Al-Sn alloys. The effect of spray deposition process on the tribological performance of Al- Si alloys was reported by Raghukiran and Kumar [4]. It was concluded that the spray deposited alloys have superior wear performance in contrast to similar alloys produced through other processing routes.

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Davis and Eyre investigated the wear performance of a range of binary Al-Si alloys produced by a novel melt-spray technique [5] and it was found that wear resistance increases by increasing the silicon content. Pathak et al. [6] examined the anti-seizure and antifriction properties of Al-Si-Pb alloys produced by cast molding method under various lubrication conditions. It was observed that the addition of Pb to Al-Si alloys reduced the interfacial friction and improved the resistance against seizure.

Only few have reported the use Al-17Si-10Sn metal matrix composite hence it was very much interested to carry out the present work, In this present research work Al-17Si and Al-17Si-10Sn alloys were spray formed in the form of a disk and then their wear characteristics were investigated under dry sliding conditions and characterization of the sprayed alloy is carried to observe the distribution of contents (i.e., Sn and Si) in spray formed alloys.

## II. EXPERIMENTAL PROCEDURE

The spray forming set up consist of, an induction furnace, a graphite crucible was placed in which the alloy was allowed to melt. An exchangeable graphite melt delivery tube was fitted at the center bottom of crucible to produce melt flow stream. Other end of melt delivery tube was fitted into the atomizer which was placed above the cooling chamber. To open or close the entrance of the delivery tube, a stopper rod was used. After the starting of gas flow in atomizer immediately the stopper rod was raised up to start the atomization of melt. The atomized droplets were deposited over a copper substrate. The Al-Si base alloy was used in the present work. 17%Sn was added to the Al-Si alloy. During preparation of the alloys, desired percentage of Si and Sn added. In each run 3000gm of Al-17Si alloy and Al-17Si-10Sn alloy was heated to a temperature of 850 °C and 800 °C in the crucible kept inside the furnace. Nitrogen gas at the pressure of 4 kg/cm<sup>2</sup> was supplied for atomization prior to melt flowing through the delivery tube. Atomization of melt resulted in a spray of wide range of micron size droplets. These droplets were allowed to deposit over a copper substrate to produce a preform. This preform was taken out of the substrate after deposition.

The fig 1 and fig 2 shows spray deposited of alloy (Side view) which is take out from copper substrate and deposition collected on copper substrate (Top view) spray forming.



Figure 1 Spray formed Deposit-Side view



Figure 2 Spray formed deposit collected on copper substrate –Top view

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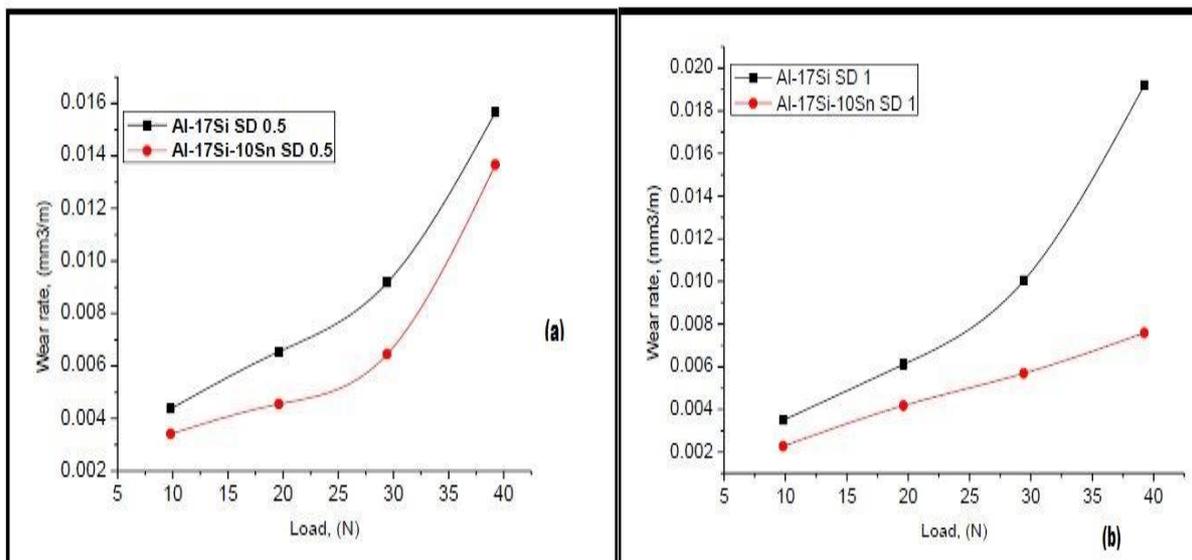
For metallography study, samples were cut down from the preform and then polished using standard metallographic technique. Afterward the samples were polishing was carried out using wet alumina paste of sub-micron grade. Specimens were etched with 2 % Nital Solution and analyzed under optical microscope (OM).

The spray formed preform of Al-17%Si and Al-17%Si-10%Sn alloy content were machined into cylindrical pins of dimensions 8 mm diameter 30 mm length.

Friction and wear testing of spray formed alloys were investigated using a pin on disk type wear testing machine. Dry sliding wear test was carried out using a hardened counter face of a polished disk of EN-32 with a hardness of HRC 62-65 at a relative humidity of 50-70 % at a room temperature of 28-32<sup>0</sup>C. Weight losses of pin were recorded using an electronic balance having an accuracy of 10-7 Kg at different interval of time. Tests were carried out at loads of 9.81N, 19.62N, 29.43N and 39.24N. Sliding speeds of 0.5 m/s, 1 m/s, 1.5 m/s and 2m/s. The mass loss of the specimen after each test was estimated by Measuring the height loss of the specimen due course of the experiment. The mass loss would be the height loss multiplied by the area of cross section of the sample and the density of the sample. Care has been taken to clean up the sample before and after each test to prevent any form of corrosion on the surface. Abrasive paper of required grit size (220  $\mu$ m optimized for the Al-Si sample) is cut into circular shape so as to fit in the ground steel disc and pasted on it with a proper adhesive ensuring no slide or detachment. The specimen was held steady and stationary with a holder of the apparatus and the required normal load was applied through lever mechanism. The sliding diameter was kept at 50 mm for all tests concerned. The worn surfaces of the wear pins after the test were examined by using OM.

### III. RESULTS & DISCUSSIONS

Graphs indicates the Wear rate Behavior v/s Applied Load



(a)

(b)

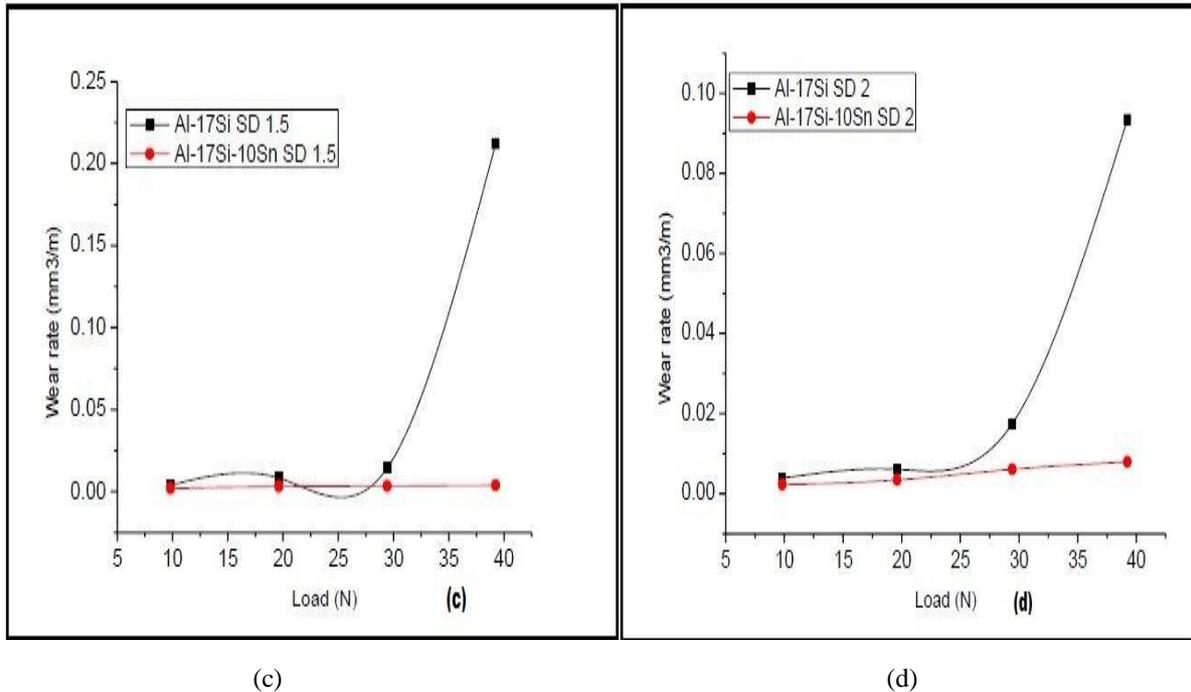


Figure 3(a b c d) Wear rate of Al-alloys as a function of (a) applied load (sliding velocity: 0.5,1,1.5,2.5m/s; sliding distance: 1000 m).

Wear rate as a function of applied load, Variation of the volumetric wear rate (mm<sup>3</sup>/m) with sliding distance under a load of 9.81N, 19.62N, 29.43N and 39.24N and sliding velocities of

- (a) 0.5 m/s
- (b) 1.0 m/s
- (c) 1.5 m/s
- (d) 2.0 m/s

is shown in figure 3(a b c d). Wear rate is increased in all the cases with increase in the applied load at all the speeds. wear rate is less in case of Al-17Si-10Sn alloy when compared with the wear rate of the Al-17Si alloy at all the considered speeds. It is observed that initially for two speeds i.e.,0.5m/s and 1m/s there is increase in wear rate in both considered alloys with increasing in loads. During sliding, a fraction of energy is spent on plastic deformation and subsequent material removal, and a considerable amount of energy is spent on overcoming the frictional force, which leads to heating of the contact surfaces. Thus, it is expected that initially the temperature of the contact surface would be less, and hence the asperities are expected to be stronger and more rigid. Thus, at the initial stage, the wear was mainly due to fragmentation of asperities and removal of materials due to cutting and ploughing actions of penetrated hard asperities into the softer surface. This is known as the running-in period where a high frictional force and high wear rate are observed[1].

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Graphs indicates the Coefficient of Friction v/s Load

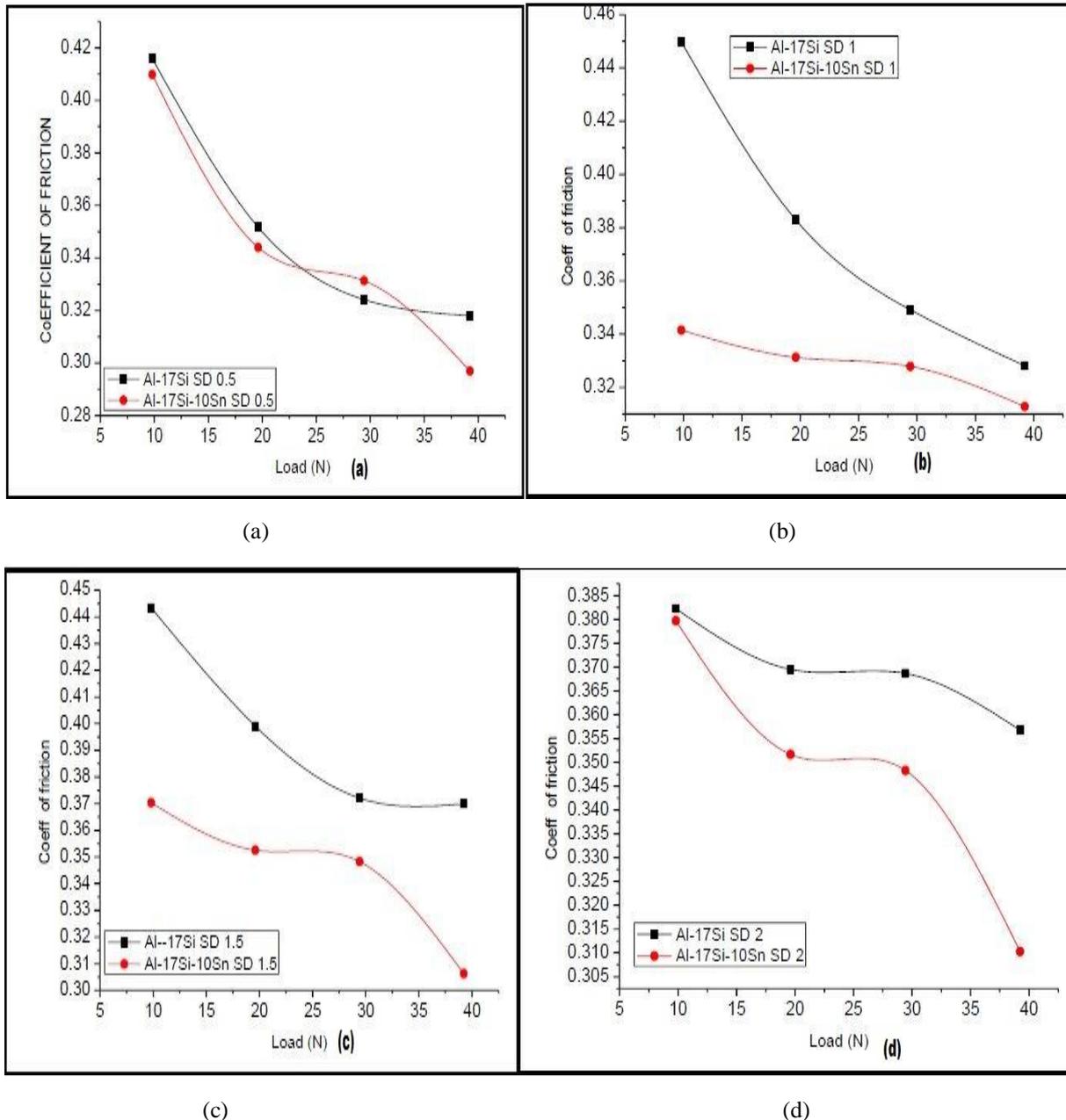


Figure 4 (a,b,c,d) Variation in coefficient of friction with applied loads at different sliding velocity: 0.5,1,1.5,2.5m/s

Figure 4 shows the variation in coefficient of friction as a function of applied load for different sliding velocity: 0.5,1,1.5,2.5m/s under a applied loads. It is observed that the coefficient of friction decreases with increasing loads for Al-17%Si alloy and similar situation for Al-17%Si-10%Sn alloy. It is observed that the coefficient of friction decreases with increasing loads for Al-17%Si alloy and similar situation for Al-17%Si-10%Sn alloy. The lower coefficient of

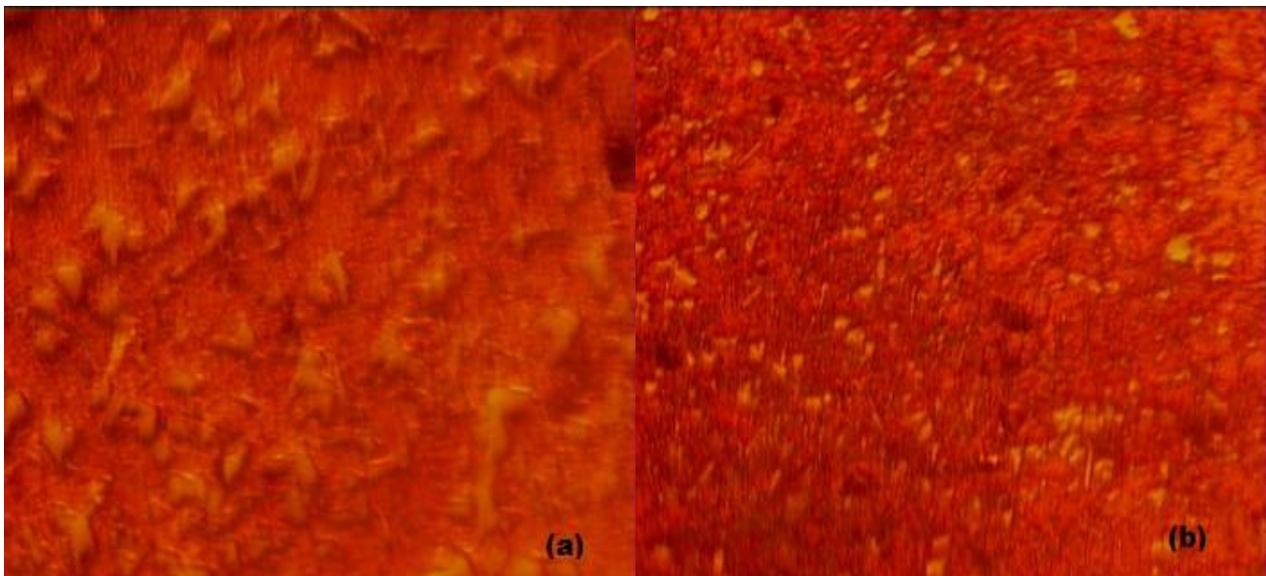
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friction is due to the smearing of the soft Sn on the sliding surfaces. This leads to easy shear deformation of a large surface area of Sn layer. But the initial wear mechanism of the materials, irrespective of the materials composition, depends upon the surface conditions which invariably includes ridges and valleys, asperities, and depressions. These undulations on the samples surface lead to high pressure on the ridges and sometimes cold welding of the two materials. These parameters provide adhesive component to the coefficient of friction. Therefore, the initial friction coefficient is higher than that in the steady state condition, irrespective of the alloy composition[1].

### Microstructural analysis



(a)

(b)

Figure 5 Optical microscope micrographs of spray deposited (a) Al-17Si alloy and (b) Al-17Si-10Sn alloy

Micrograph of Al-17Si alloy reveals a uniform distribution of fine globular shaped Si phase. A different morphology is observed in the Al-17Si-10Sn alloy. Al-17Si-10Sn alloy morphology indicates the homogeneous microstructure with equiaxed and uniform distribution of the Sn content in alloy.

Many earlier investigators [7–9] studied the effect of soft phase and their content on wear and frictional behaviour of materials. Lower wear rate of Al–Sn–Si alloy could be explained based on the reports [10–11] that during dry sliding wear experiments Sn acts as an extreme pressure lubricant and minimizes direct contact between the surfaces in relative motion by smearing and forming a thin film of low shear strength between the mating surfaces, which promotes easy shear between the sliding surfaces and thus ensures a low frictional forces [12]. In the process of sliding, the applied pressure was born by the underlying Al–Si alloy matrix, whereas, shearing takes place in a thin film of Sn having low shear strength. A spray formed alloy with uniform distribution of fine Sn particles ensures a better smearing to avoid metal–metal contact during sliding. In addition, the refined Si particles lead to increased wear resistance.

### IV. CONCLUSIONS

In the present study, the work on the microstructure, mechanical and tribological properties of spray deposited Al 17%Si and Al-17%Si-10%Sn alloys are summarized as a function of sliding distance, applied pressures and sliding

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velocities. Response parameters such as wear rate and coefficient of frictional were measured. On this basis following conclusions were drawn.

- 1) Wear behaviour is dependent on the applied load and sliding speed.
- 2) Wear is seen to increase with increase in sliding speed and applied load.
- 3) Tin content in Al-17%Si alloy decreases the wear rate in the range of speed and load studied.
- 4) From the experimental investigated results and indication from literature survey, it is concluded that spray deposited hypereutectic Al-Si alloy with Sn content has less wear rate and more enhanced service life than as-cast hypereutectic Al-Si alloy.

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