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A Study of Tribo-layer in dry Sliding of Al Si alloy

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Abstract—In this paper we are studying a tribo layer in dry Sliding of Al Si alloy. Al-Si alloys are widely used in cast form in critical components in automobile application like pistons, valve lifters, cylinder liners, engine blocks, etc due to their high strength to weight ratio, excellent casting characteristics, good mechanical property including wear resistance low coefficient of thermal expansion, high thermal conductivity and high corrosion resistance. are generally utilized in cast structure in basic segments in car application like cylinders, valve lifters, barrel liners, motor squares, and so on because of their high solidarity to weight proportion, fantastic throwing qualities, great mechanical property including wear opposition low coefficient of warm development, high warm conductivity and high erosion obstruction. The formation of tribo layer has commonly been observed in dry sliding of Al Si alloys or generally in most sliding surface, although they may not have been termed as tribo- layer. In their investigation of dreary, rash and nonstop sliding contact of different metallic sets, described the microstructure of surface and subsurface area dependent on the minuscule and spectroscopic proof. In which three unmistakable zones were distinguished and the highest layer was named as tribo-layer by a different specialist.
Keywords—Tribo-Layer, Dry, Alloy, Heat, Optical etc.

I. INTRODUCTION

Al-Si alloys are generally utilized in cast structure in basic segments in vehicle application like cylinders, valve lifters, chamber liners, motor squares, and so on because of their high solidarity to weight proportion, brilliant throwing attributes, great mechanical property including wear obstruction low coefficient of warm extension, high warm conductivity and high consumption resistance[1]. Among different Al throwing composites, Al– Si alloys containing Si as the major alloying component includes more than 90 % of the all out Al castings created and have wide spread applications, particularly in the transportation business [2].

Be that as it may, as of late, hypereutectic Al-Si composites have drawn the consideration of scientists because of their capacity to supplant cast iron parts in the transportation business [1]. The properties of the hypereutectic compound are significantly subject to the morphology, size and dispersion of essential silicon gems in the combination. Mechanical properties of the hypereutectic Al– Si combination can be improved by the concurrent refinement and alteration of the essential and eutectic silicon and by controlling the cementing parameters [1]. The as cast Al-17 wt.% Si compound shows a microstructure comprising of essential Si particles alongside α-Al grains and eutectic stage. In any case, the Si particles in eutectic stage are having long pole/acicular morphology with high perspective proportion.

Tribological conduct of cast Al-Si compounds should be examined for fruitful utilization of these alloys as motor square materials. The impact of microstructure on wear conduct is importantsince microstructure influences the mechanical properties of these cast alloys. The wear conduct of Al-Si combinations with various silicon content and other alloying components under dry sliding conditions have been contemplated for a long time [6-15]. These investigations utilized different test setups and different burden and sliding paces. In any case, point by point assessment of wear properties and their systems is constrained.

Among various Al-Si combinations, hypereutectic Al-Si alloys are found to have application in motor parts because of their great wear opposition properties. Al-Si composites, utilized as a motor square material in the linerless Chevrolet Vega 2300 motor, was a hypereutectic A390 amalgam previously presented at the AFS Casting Congress [3]. After fruitful use in the Vega, A390 amalgam was later utilized in Chevrolet Corvette ZL1, Porsche 928, Mercedes 3.8L V8, BMW, Audi, Volkswagen, Toyota, and different motors [4]. From that point, numerous business arrangements, for example, low beyond words AlSi17Cu4Mg (AlusilTM), a metal framework composite delivered by aluminum invasion of the silicon preform to acquire 15% or 25% silicon at the drag surface (LokasilTM, and splash compacted hypereutectic Al-Si 25 combination (Silitec created [5], yet their utilization has been constrained to premium vehicles because of high generation cost. Wear obstruction in Al-Si compounds is essentially because of the nearness of silicon in the aluminum framework. Expanding the silicon content in Al-Si combinations not just builds the wear obstruction of the amalgam, yet in addition the quality [6]. Be that as it may, the improvement in quality and wear obstruction comes at the expense of machinability and castability.

In this way the hypereutectic combinations are commonly treated with different modifier and grain refiners(like phosphorus) to get synchronous refinement/alteration of essential just as eutectic silicon. Despite the fact that a few refiners have been proposed as an option in contrast to phosphorus, they are still in the underlying phases of research. Utilization of semi strong warmth treatment to alter Si particles have not been accounted for by many. NaglaaFathy [7] examined microstructural development of hyper-eutectic Al-18% Si compound amid semi-Solid isothermal warmth treatment. In this exploration the impact of semi-strong isothermal warmth treatment on the size and state of essential Si and α-Al grain has been considered for a hyper-eutectic Al-18% Sialloy. Anyway point by point ponder was not taken up.

In this manner the target of the present examination is to

Carry out an efficient report on the impact of different dousing times and cooling rates on the morphology, dissemination and size of essential just as eutectic Si lastly upgrade heat treatment parameters.

Carry out nitty gritty tribological concentrate to discover the impact of semi strong warmth treatment on the wear obstruction of as cast compound.

Accordingly, semi-solid heat treatment is employed in an as cast Al-17Si-4 Cu alloy (AR alloy) to modify the morphology of Si particles. Detailed microstructural investigations involving size and shape of primary as well as eutectic Si particles, porosity measurements along with hardness measurement are carried out to find the effect of different semi solid heat treatments involving varying soaking times and cooling rates. Finally the optimum heat treatment schedule is established and WQ15 alloy was further used for tribological study. Thus, dry sliding wear behaviour of WQ15 alloy along with AR alloy is studied using a pin-on-disc wear testing machine against an EN 31 steel disk (Hardness = 60 HRC, HV 695) at a sliding speed of 1m s-1, under three different normal loads viz. 20 N, 40 N, and 60 N. In order to understand the different wear mechanisms, worn surfaces are characterized using Scanning Electron Microscope.

As needs be, semi-strong warmth treatment is utilized in an as cast Al-17Si-4 Cu amalgam (AR composite) to adjust the morphology of Si particles. Point by point microstructural examinations including size and state of essential just as eutectic Si particles, porosity estimations alongside hardness estimation are completed to discover the impact of various semi strong warmth medicines including changing drenching times and cooling rates. At last the ideal warmth treatment plan is set up and WQ15 combination was additionally utilized for tribological contemplate. In this manner, dry sliding wear conduct of WQ15 amalgam alongside AR compound is examined utilizing a stick on-circle wear testing machine against an EN 31 steel plate (Hardness = 60 HRC, HV 695) at a sliding rate of 1m s-1, under three diverse ordinary burdens viz. 20 N, 40 N, and 60 N. So as to comprehend the diverse wear instruments, worn surfaces are described utilizing Scanning Electron Microscope.

II. AL-Si ALLOY

Aluminium-Silicon alloys are of greater importance to engineering industries as the exhibit high strength to weight ratio, high wear resistance, low density, low coefficient of thermal expansion etc. Si imparts high fluidity and low shrinkage, which result in good cast ability. The major feature of Al –Si alloys are as follows:

- Heat treatable
- Good flow characteristics ,medium strength
- Easily joined, especially by brazing and soldering

Effect of Si in the Al-Si alloys is as follows [12]

- Thermal expansion is reduced substantially by Silicon
- Magnetic susceptibility is only slightly reduced by Silicon
- The lattice parameter is decreased slightly by Silicon.
- Machinability is poor because of hardness of poor silicon.
- Increase the fluidity of the melt
- Reduces the melting temperature,
- Decreases the shrinkage during solidification

III. ALUMINUM ALLOY

A wide scope of physical and mechanical properties can be gotten from exceptionally unadulterated aluminum .The diverse property are-

1) Aluminum has a thickness of about 2.7g/cm3 which is 33% (around) the estimation of steel.
2) Unlike steel, aluminum counteracts dynamic oxidation by arrangement of a defensive oxide layer on its surface on introduction to air.
3) Aluminum composite show fantastic electrical and warm conductivities.

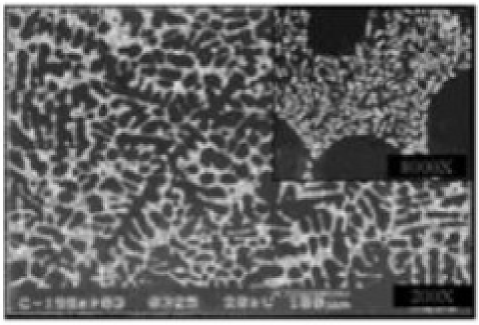
The mechanical quality of aluminum might be upgraded by virus work and alloying; anyway the two procedures will in general reduce protection from consumption. Rule alloying component incorporates copper, magnesium, silicon, manganese, and zinc. Non-heat treatable combinations comprise of a solitary stage for which an expansion in quality is accomplished by strong arrangement reinforcing. Other are rendered heat treatable (equipped for being precipitation solidified) because of alloying [10].

- **Sr-** chemical modifier
- **Mg +Cu-** strength
- **Ni +Cu** -mechanical property
- **La+Ce**- mechanical property[11]

IV. MICROSTRUCTURE OF AL-SI ALLOYS

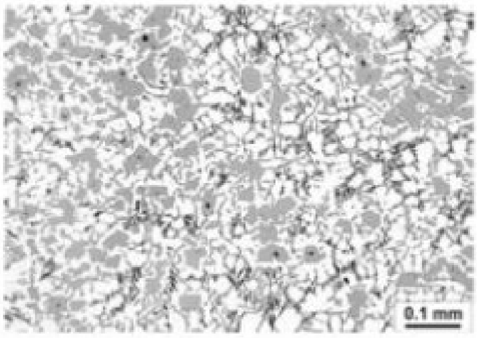
Al-Si combination with changing Si content was examined [15] to see the impact of differing Si content on the microstructure and properties of Al-Si composite. The microstructures are appeared in Figure 1.1. Double Al-Si compounds, in the unmodified state, close to the eutectic piece show acicular or lamellar eutectic silicon which is as substantial plates with sharp sides and edges. Al-Si compounds containing more than about 12% Si show a hypereutectic microstructure ordinarily containing essential silicon stage in an eutectic framework. Cast eutectic composites with coarse acicular silicon show low quality and malleability in light of the coarse plate-like nature of the Si stage that prompts untimely split commencement and crack in pressure. Correspondingly, the essential silicon in ordinary hypereutectic compounds is generally exceptionally coarse and gives poor properties to these amalgams. Subsequently, compounds with an overwhelmingly eutectic structure must be adjusted to guarantee satisfactory mechanical quality and malleability. It is generally perceived that the Group IA and IIA components (Na, Mg, Ca, Sr) are compelling modifiers of Al-Si eutectic; just sodium and strontium, nonetheless, have been utilized broadly in the business creation of these combinations. Refinement of essential silicon is generally accomplished by the expansion of phosphor to the dissolve. It is likewise detailed that uncommon earth metals are additionally fit for altering the eutectic structure of cast aluminum-silicon amalgams [15].

Hypo-eutectic aluminum-silicon composites have a gigantic segment of essential α-Al in their microstructure. An unmodified Al– Si amalgam has expansive, weak pieces of silicon, which result in poor flexibility to the throwing. Modifiers are added to eutectic and hypo-eutectic Al– Si composites to refine the eutectic Si stage from precise platelets to fine filaments. This change in microstructure results in an extra advancement in the mechanical properties. The nature of the castings can be upgraded by grain refinement which diminishes the measure of essential α-Al grains in the castings, which else cements with a coarse, columnar grain structure. A fine equiaxed structure has numerous points of interest like improved mechanical properties, better nourishing amid hardening, decreased and all the more equally appropriated shrinkage porosity, better scattering of second stage particles, better surface completion and other wanted properties. Al-Ti ace amalgams, for example, Al-3Ti-3B and Al-5Ti-1B composites can be utilized for grain refinement of aluminum-silicon compounds [16].

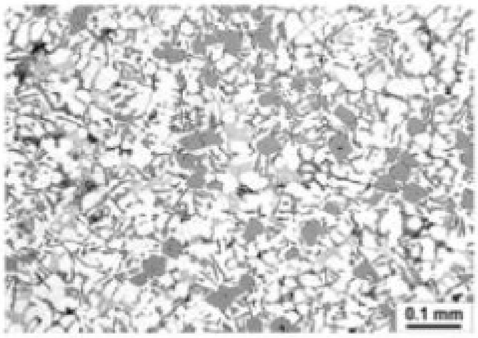


Microstructure of Al-7% Si

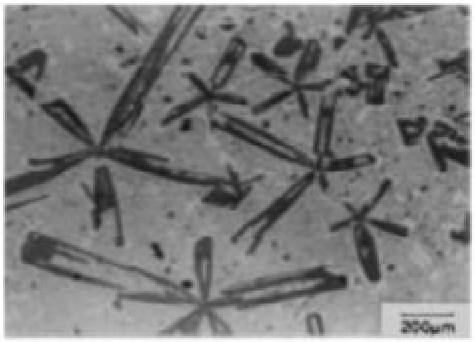
Microstructure of Al-12% Si



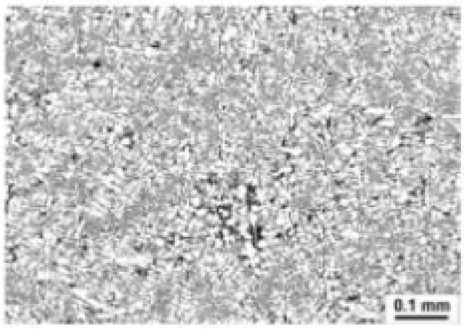
Microstructure of Al-16% Si



Microstructure of Al-18% Si



Microstructure of Al-21% Si



Microstructure of Al-22% Si

Figure 1.1: Microstructureof various Al-Si alloys [15].

V. MATERIAL

As got cast hypereutectic Al-17Si-4 Cu composite (AR) was utilized for the present investigation. Standard examples for different tests were machined from the as cast round and hollow square of roughly 25 mm distance across. Tests of size 15 mm X 15 mm were set up for optical metallography and hardness estimation. Barrel shaped wear pins of 6 mm in distance across and 20 mm long were readied. One lot of test was held for the further portrayal in the as got condition and others were exposed to various semisolid warmth medications.

VI. HEAT TREATMENT

The fluids temperature for the amalgam is 648°C and the solidus temperature for the equivalent is 577°C according to stage chart of Al-Si compound (Figure 1.2). Consequently, a temperature of

590ºC was picked for semi-strong warmth treatment (Figure 1.3). The examples were warmed at 590ºC for various splashing times of 10, 15 and 20 minutes in a suppress heater pursued by cooling to room temperature. Three distinctive cooling media were utilized to think about the impact of various cooling rates. One lot of tests were cooled in heater, while the other set was exposed to air cooling and water extinguishing (warm water tank 60°C) was done for the last arrangement of tests. As needs be the examples were assigned as FC, AC and WQ for heater cooling, air cooling and water extinguishing individually. The distinctive warmth treated composites were consequently assigned according to Table 1.1.

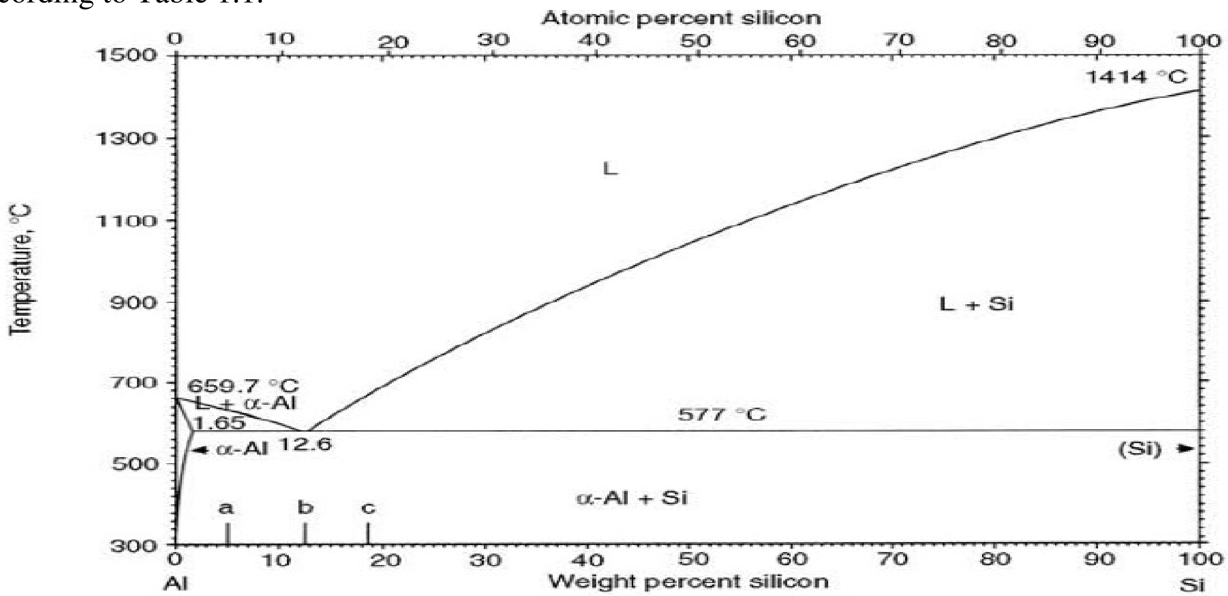


Figure 1.2: Al-Si phase diagrams [8]

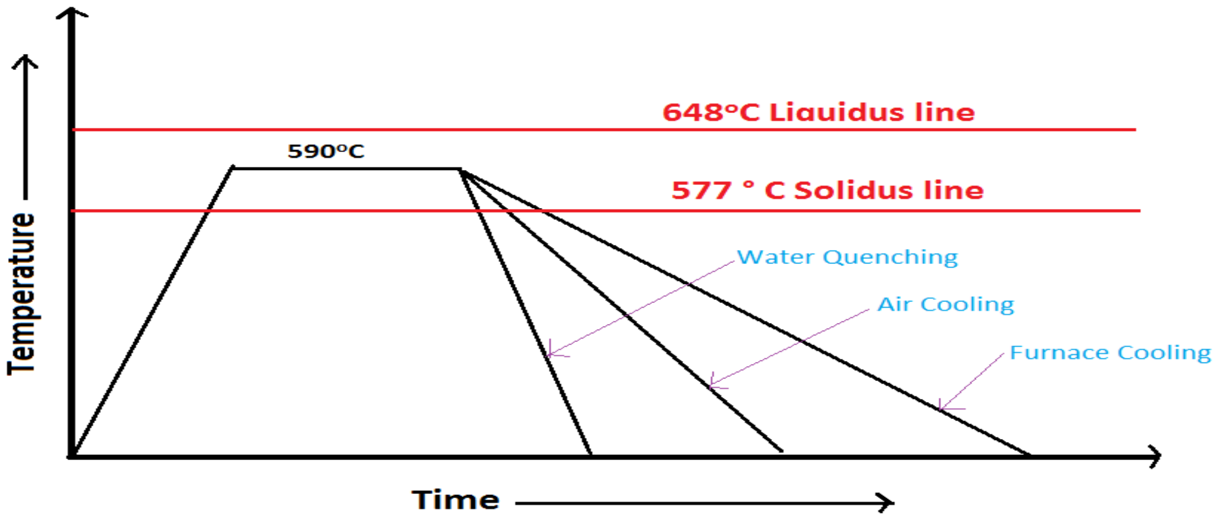


Figure 1.3: semi-solid heat treatment schedule

Table 1.1 Different heat treated alloy and their designations

Cooling Mode	Soaking Time (mins.)	Alloy Designation
Furnace cooling (FC)	10	FC 10
	15	FC 15
Air cooling(AC)	10	AC 10
	15	AC 15
	20	AC 20
Water Quenched(WQ)	10	WQ 10
	15	WQ 15
	10	WQ 20

The overall wear rate for semi solid heat treated alloy (WQ15) is found to be significantly lower compared to as cast (AR) alloy at all the applied loads, indicating remarkable improvement in wear behavior on semi solid heat treatment of as cast alloy.
Si particles (particularly eutectic) being acicular/rod like in AR alloy are removed easily during wear, the impressions of which are seen on worn surface. On the other hand, those Si particles become spherical/equiaxed on semi solid heat treatment, which bonds strongly with the matrix. Thus they remain intact during wear and provide resistance to abrasive wear. Moreover the hardness increases on semisolid heat treatment which also causes resistance to abrasive wear. Therefore, the combined effect of intact Si particles and higher hardness in semi solid heat treated alloy result into superior wear behavior at all loads compared to as cast alloy.
Dry sliding wear tests of different specimens were carried out in a pin-on-disk wear testing machine (Wear and Friction Monitor- TR-20LE-PHM 400-CHM-400, DUCOM, Bangalore, India) as per the guidelines mentioned in ASTM G99-05 (2010) standard.
During wear test, the pin (cylindrical shape: 6 mm in diameter, and 20 mm in length) was held against an EN 31 steel disk (Hardness = 60 HRC) rotating at 200 rpm under three different normal loads (P), 20N, 40N and 60N, respectively. The diameter of the circular wear track was 100 mm that accounts for a sliding speed of 1.0 m s^{-1}. The tests were conducted for duration of 32 mins. Before each test, the surface of the pin as well as the disk was ground with silicon carbide emery paper of 800 grit size.
The overall wear rate increases with load in all the specimens. However, the rate of increase decreases beyond 40 N load for both the alloys. This is attributed to the formation of adherent oxide layer and greater strain hardening effect at higher (60 N) load.
Microstructural modification by utilizing semi strong warmth treatment at 590°C for 15 minutes pursued by water extinguishing results into improved dry sliding wear opposition contrasted with as-cast condition. Consequently, future extent of work may include:
(a)Systematic ponder on the impact of other semi strong warmth treatment temperatures on microstructure, property and wear conduct of this combination.

(b) An investigation on the greasing up wear conduct of this warmth treated compound can be taken up as a future work.
(c) Similar methodical investigations on compounds containing diverse Si (hypoeutectic or eutectic) Can likewise be taken up as a future work

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