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Investigation of Wear Behavior of Aluminium Alloy and Comparison with Pure Aluminium

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Abstract

In modern age of technology Aluminium alloys have extensive application in industries. The range of physical properties that can be imparted to them is remarkable. Addition of Silicon and copper to Aluminium helps to increase their strength and wear resistance. Al-Si-Cu alloys can be extensively used in industrial applications due to better tribological properties. In the present work, an attempt has been made to study the tribological properties of Aluminium as-cast alloy sample i.e. Al alloy and pure Aluminium.Wear tests were conducted using a pin-on-disc wear test rig as per ASTM specification G99. The operational parameters were normal load and sliding velocity of pin with respect to rotating disk at room temperature. The medium used were dry and wet lubrication. The amount of wear has been reduced significantly in aluminium alloy comparative to pure aluminium. Dry condition testing of samples showed a lot of noise and relatively more amount of wear for both aluminium and aluminium alloy.The coefficient of friction for aluminium alloy in wet condition was approximately constant up to the load the applied load of 2kg and then decreased with further application of load while coefficient of friction for pure aluminium was increasing continuously with the load.

1. Introduction

Aluminum and its alloys occupy third place among the commercially used engineering materials. In commercial aluminum casting alloys, Al–Si base alloys are perhaps most common particularly due to very attractive characteristics such as high strength to weight ratio, good workability, excellent cast ability, good thermal conductivity and corrosion resistance.

Aluminum castings have played an integral role in growth of aluminum industry since its inception in late 19th century. These are emerging as one of the most dominant materials in number of sectors like transport, military, aviation and general engineering. Use of aluminum in transport sector has increased from just 6% in 1950 to 23% in year2000. Consumption of aluminum casting has increased from85, 000 ton in 1995 to 145,000 ton in year 2000.

In addition to demand in market, research and development efforts have played an important role for dramatic growth in consumption of aluminum alloys. Aluminium–silicon alloys are popular in three different forms, i.e. hypoeutectic, eutectic and hypereutectic type, classified so depending up on the silicon content. Aluminium–silicon alloys containing 11–13% silicon are termed as eutectic alloys and those having less than 11% silicon are called hypoeutectic and those having more than 13% silicon are commonly known as hypereutectic Al–Si alloys.

Aluminium and its alloys are extensively used as the materials in transportation, engine components and structural applications .Thus it becomes all the more vital to study the tribological characteristics of Aluminium and its alloys. Addition of Silicon to Aluminium gives high strength to weight ratio, low thermal expansion coefficient, and high wear resistance. These alloys also show improved strength and wear properties as the silicon content is increased beyond eutectic composition. Such properties warrant the use of these materials as structural components in automotive industries [1].

2. Properties of Aluminium alloys

The properties of Aluminium and its alloys that make them the most economically attractive for a wide variety of applications are:

- Light weight: Aluminium weighs roughly one-third as much as most of the common metals, but is one and a half times as heavy as Magnesium. It finds application to reduce weight of components and structures, particularly connected with transport, especially with aerospace.
- High strength to weight ratio: high strength to weight ratio saves a lot commercially when dead weight is decreased and payload of transport is increased. this ratio is having particular significance in engineering design problem where stiffness is involved.
- Ease of fabrication and machinability: It can be easily cast, rolled to any desired thickness stamped, drawn, spun, forged and extruded to all shapes.
- High resistance to atmospheric corrosion: When aluminium is exposed to air, a thin oxidized film forms on the surface, protecting the metal from corrosion. When scratched, the layer rapidly reforms retaining the protection. This features utilized in construction, buildings and household utensils.
- Resilience under static and dynamic loading Aluminium products behave elastically under static and dynamic loading conditions, that is, they have the ability to resume both shape and size which is good when flexible strength is required.

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- Strength at low temperature: Brittle fracture problems do not occur with aluminium. As the temperature is reduced, aluminium alloys increase in strength without loss in quality, making them particularly suitable for low temperature applications [2]

3. Aluminium-silicon alloys: Aluminium-Silicon Eutectic and hypoeutectic alloys

Alloys with Silicon as a major alloying element are by far the most important commercial casting alloys, primarily because of their superior casting characteristics in comparison to other alloys. A wide range of physical and mechanical properties is afforded by these alloys. Binary aluminium-silicon alloys combine the advantages of high corrosion resistance, good weldability, and low specific gravity. Although castings of these alloys are somewhat more difficult to machine than the aluminium-copper or aluminium-magnesium alloys, all types of machining operations are routinely accomplished, usually using Tungsten carbide tools and appropriate coolants and lubricants.

Alloy 443 (5.3% Si) may be used for all casting processes for parts in which good ductility, good corrosion resistance, and pressure tightness are more important than strength. For die casting, alloys 413 and A 413 (12% Si) also have good corrosion resistance but are superior to alloy 443 in terms of castability and pressure tightness. Alloy A444 (7%Si-0.2% iron, maximum) also has good corrosion resistance and has especially high ductility when cast in permanent mold and heat treated to a T4 condition. This alloy has good impact resistance.

Alloys 413, 443 and 444 are important binary aluminium-silicon alloys. Another group of aluminium-silicon alloys however represents the workhorse aluminium foundry alloys. In this group, silicon provides good casting characteristics and copper imparts moderately high strength and improved machinability, at the expense of somewhat reduced ductility and lower corrosion resistance. Alloy 319(6% Si -3.5% copper) is preferred general purpose alloy for sand foundries that may also be used in permanent mold casting. The phase diagram of Al–Si alloy shows that during the solidification of liquid metal, aluminium solidifies first with hypoeutectic alloy and primary silicon particles with hypereutectic. The silicon content determines the primary phase. Eutectic point is noted from 11–13% silicon content, depending up on the casting process.

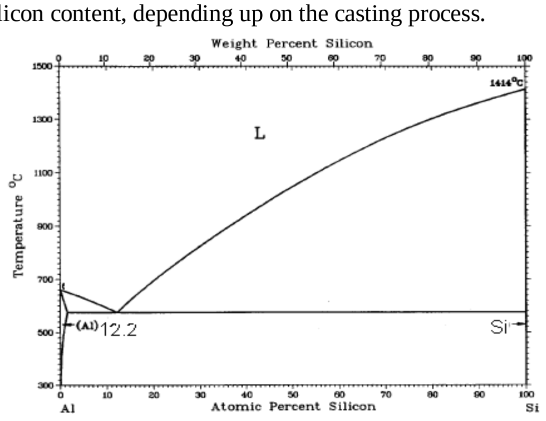

Fig: 1. Aluminium Silicon Binary Phase Diagram. The Eutectic Occurs at 12.6 wt% Si [3]

3.1 Hypereutectic Aluminium-Silicon Alloys

Aluminium silicon alloys with greater than 12% Silicon are called hypereutectic aluminium silicon alloys. These have outstanding wear resistance, a lower thermal expansion coefficient, and very good casting characteristics. Such alloys have limited use because the presence of the extremely hard primary Silicon phase reduces tool life during machining. Also the special foundry characteristics and requirements of this alloy system, needed to properly control microstructure and casting soundness, are not clearly as well understood as are the characteristics of conventional hypoeutectic alloys these alloys have have outstanding fluidity and excellent machinability in terms of surface finish and chip characteristics. A typical example is 390 alloys (17%silicon-4.5% copper-0.5%magnesium) whose outstanding wear characteristics have caused a rapid growth in its use. It is used in small engines, pistons for air conditioning compressors, master brake cylinders, and pumps and other components in automatic transmission .It is well known that microstructure and mechanical properties have strong correlation. Microstructure involves the phase and grain structure. Phase structure includes type of phase, relative amount of phases and their distribution. Grain structure includes the size, shape of grains and their distribution Aluminum–silicon alloys have become very important as basic material for engine blocks due to their favorable mass to performance ratio, high thermal conductivity, good corrosion and wear behaviour. The material's high wear resistance is a direct result of the hard silicon precipitations within the aluminum matrix that brings a reinforcing effect. In this paper pieces of an aluminum silicon–copper hypereutectic alloy, which is used in state of the art car engines, are studied. Aluminum and its alloys occupy third place among the commercially used engineering material. In commercial aluminium casting alloys, Al–Si base alloys are perhaps most common particularly due to very attractive characteristics such as high strength to weight ratio, good workability, excellent castability ,good thermal conductivity and corrosion resistance . Use of Al–Si alloys has received a boost for production of aluminium castings in recent decades. Aluminum castings have played an integral role in growth of aluminium industry since its inception in late 19th century. These are emerging as one of the most dominant materials in number of sectors like transport, military, aviation and general engineering. Use of aluminum in transport sector has increased from just 6% in 1950 to 23% in year2000. Consumption of aluminium casting has increased from85, 000 ton in 1995 to 145,000 ton in year 2000. In addition to demand in market, research and development efforts have played an important role for dramatic growth in consumption of aluminium alloys. Aluminium–silicon alloys are popular in three different forms, i.e. hypoeutectic, eutectic and hyper eutectic type, classified so depending up on the silicon content. Aluminium–silicon alloys containing 11–13% silicon are termed as eutectic alloys and those having less than 11% silicon are called hypoeutectic and those having more than 13% silicon are commonly known as hypereutectic Al–Si alloys .The phase diagram of Al–Si alloy shows that

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during the solidification of liquid metal, aluminium solidifies first with hypoeutectic alloy and primary silicon particles with hypereutectic [3]

3.2 Wear

Wear is the progressive loss of material from the operating surfaces as a result of relative motion Since the world's necessity is progressively reducing resources of material and energy therefore studies on wear are growing globally. It is hoped that an understanding of mechanism of wear will result in better understanding and specification from viewpoint of composition and surface treatment.

3.3 Mechanisms of Wear: Adhesivewear

This form of wear occurs when two smooth bodies slide over each other. The relative movement can be unidirectional or reciprocating. Due to this, fragments are pulled off from one of the surfaces and adhere to the other, later these fragments may come off the surface on which they are formed and be transferred back to the original surface, or else form loose wear particles .

3.4 Abrasive Wear

Abrasive wear occurs when a hard rough surface slides across a softer surface. ASTM (American Society for Testing and Materials) defines it as the loss of material due to hard particles or hard protuberances that are forced against and move along a solid surface. Wear, in turn, is defined as damage to a solid surface that generally involves progressive loss of material and is due to relative motion between that surface and a contacting substance or substances. The rate at which the surfaces abrade depends on the characteristics of each surface, the presence of abrasives between the first and second surface, the speed of contact and environmental conditions. In short, loss rates are not inherent to a material.

3.5 Mechanism Proposed

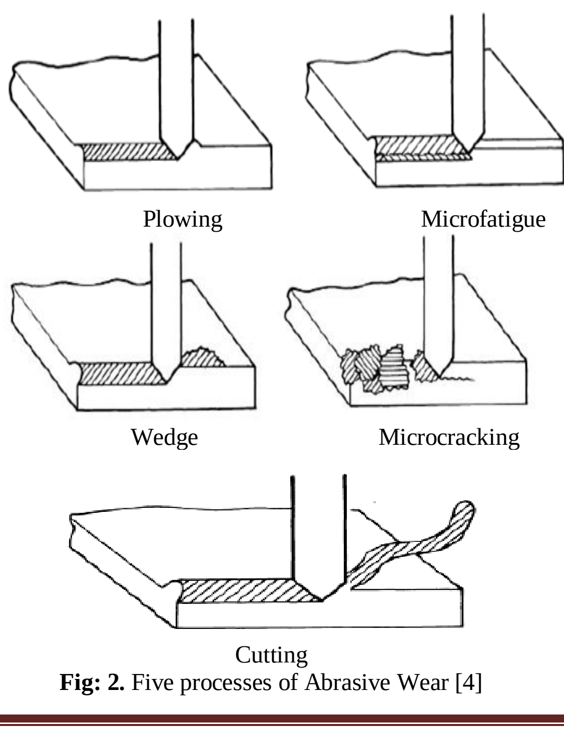

Fig: 2. Five processes of Abrasive Wear [4]

Many mechanisms have been proposed to explain how material removal during abrasion. These mechanisms include fracture, fatigue, and melting. Due to the complexity of abrasion process, no single mechanism completely accounts for all the loss. Figure depicts some of the processes which are possible when a single abrasive tip slides across a surface. They include plowing, wedge formation, cutting, micro fatigue, and microcracking.

3.6 Solid Particle Erosion

It is the loss of material that results from repeated impact of small, solid particles. In some cases SPE is a useful phenomenon, as in sandblasting and high-speed abrasive water jet cutting, but it is a serious problem in many engineering systems, including steam and jet turbines, pipelines and valves carrying particulate matter, and fluidized bed combustion (FBC) systems. Solid particle erosion is to be expected whenever hard particles are entrained in a gas or liquid medium impinging on a solid at any significant velocity (greater than 1 m/s, or 3.3ft/s). Manifestations of SPE in service usually include thinning of components, a macroscopic scooping appearance following the gas/particle flow field, surface roughening, lack of the directional grooving characteristic of abrasion, and, in some but not all cases, the formation of ripple patterns on metals. Solid particle erosion can occur in a gaseous or liquid medium containing solid particles. In both cases, particles can be accelerated or decelerated, and their directions of motion can be changed by the fluid. This is more significant in liquid media, and slurry erosion is generally treated as a different, though related, subject. In gaseous media, at least for particles larger than about 50 m, deflection of the particles by the gas stream can often be ignored in erosion tests. The distinction between erosion and abrasion should be clarified, because the term erosion has often been used in connection with situations that might be better classed as abrasion. Solid particle erosion refers to a series of particles striking and rebounding from the surface, while abrasion results from the sliding of abrasive particles across a surface under the action of an externally applied force. The clearest distinction is that, in erosion, the force exerted by the particles on the material is due to their deceleration, while in abrasion it is externally applied and approximately constant.

3.7 Corrosive Wear

This form of wear occurs when sliding takes place in corrosive environment. In the absence of sliding, the products of corrosion form a film on the surface, which tends to slow down or even arrest the corrosion. However, the formation of non-porous and adherent surface oxides such as alumina (Al_2O_3) and chromium oxide (Cr_2O_3), on the aluminium and stainless steel surface can reduce the corrosive wear.

3.8 Surface Fatigue Wear

The surface fatigue is caused by the repeated sliding or rolling over a track. The repeated loading and unloading cycles experienced by the material may induce the surface or subsurface cracks which eventually will result in breakup of surface with the formation of large fragments and leaving large pits in the surface.

3.9 Impact Wear

It is defined as wear of a solid surface due to percussion. Percussion is a repetitive exposure to dynamic contact by another solid body. Several industries employ processes that lead to impact wear. Machine components, cams, and gears mate with a certain dynamic component. Typical applications occur in electromechanical printers; a prime example is that of typefaces, which are expected to hold definition, thus assuring high print quality, often for billions of cycles.

3.10 Mechanism of Fragmentation

At the commencement of sliding, force acting on rubbing surface s transmitted to sub-surface. The ductile matrix under goes plastic deformation and develops crack in hard, brittle inter-dendrite silicon and other compounds. Even after fragmentation, the original inter-dendritic orientation is retained for some time. With an increase of force, the immediate sub-surface damage area is subjected to higher plastic deformation which in turn results in further fragmentation and dispersion of particles in the adjacent region. Sliding of metal produces very high plastic shear strain at the sliding interface and large strain gradient in materials near surface layers. Origin of cracks involved in generating debris has not been well established.

3.11 Metal Transfer

Wear surface layers have a very fine structure and mixed composition. Debris particles are generated at least in a part from this layer. Because the structure of transfer layer and debris particles is found to be similar for both lubricated and dry wear conditions. An ultra fine grain structure generated from transfer layer is probably a result of deformation and fracture processes. Initially asperity contacts give rise to small transfer elements, which accumulate, on the surface until a critical condition isreached. Only then, loose particles are generated as wear debris from transfer layer. One possible condition for the formation of loose wear debris is that transfer layer should reach a critical thickness before detachment from the sliding surface for a given sliding condition (material, load and environment). As soon as transferlayer attains a critical thickness, it tends to give flake like wear debris by delamination process at or near the interface between transfer material and base metal. The transfer and back transfer of elements across the sliding interface takes place throughout the run-in wear period of the sliding. A critical number of layers build up on both the members of friction couple and then a wear particle produced as and when this critical number is exceed. Transfer and back transfer builds up to equilibrium at the end of run-in period of wear and commencement of the steady state wear. For aluminium alloys this number appears to about six. However, consensus does not still exist on how wear particles are formed. Once metal transfer has taken place, the generation of wear debris and subsequent ploughing is found to be different from when there is no metal transfer between two sliding surfaces. Depending up on which one of these two mechanisms is effective, the friction characteristics of sliding metals vary accordingly .Initial metal transfer from aluminium pin to steel disc does not affect the wear rate [5]

3.12 Effect of Contact Load and Speed

Contact load and sliding speed are main variables of dry sliding wear as they control the degree of adhesion (metallic intimacy), sub-surface damage, thermo-mechanical effects on the sliding surface due to frictional heat and tendency to form and break the oxide film. Surface peaks are known to deform under external load. Increase in deformation increases real area of contact which in turn increases metallic intimacy. In general, an increase in normal load is known to increase the wear rate due to increased metal to metal contact between mating surfaces. Depending up on the sliding speed, composition of alloys, counter surface, and surface finish, increase in wear rate with normal load may be linear or non-linear. Usually under low load and speed conditions, linear relationship between load and wear rate is observed. Increase in wear rate with the load has been explained by various researchers on the basis of different mechanisms such as adhesion, sub-surface damage, thermo mechanical effect and oxidation. at high load, coarsening of b phase particles occurs owing to rise in temperature during the sliding of cast Al–Si alloys. Steady wear rate of metal increases with an increase of load although the relationship hypereutectic and hypoeutectic alloy has non-linear relationship between applied load and wear rate against steel beyond certain critical load at which transition from mild to severe metallic wear takes place.

Size of debris has been reported to a function of load and can be given by: The size, shape, micro-cracking tendency and thermal stability of different micro-constituents greatly control the mechanical and tribological properties of Al–Si alloys. Influence of structure on many physical and mechanical properties is well known and therefore it can be directly related to wear .Depending upon the composition, there may be number of phases in Al–Si base alloys such as a-Al, primary and eutectic silicon crystals and inter-metallic constituents as shown in .Out of these phases, silicon has profound effect on wear resistance of these alloy. Role of microstructure is reported to be of greater importance than the gross metal properties such as tensile strength and hardness in wear resistance. Influence of silicon particles on wear depends on sliding conditions, i.e. normal load, sliding speed, counter surface and environment, etc. [5]

3.13 Methods of Testing

Numerous experimental devices and methods have been created and developed to study the wear and friction properties of material, additives and lubricants. These devices and methods are used to evaluate the suitability of materials or lubricant for a given application and in basic research for developing newer material sand to compare the properties of lubricants and materials. The techniques and devices used for the determination of anti-wear and anti-friction properties fall into two principal classes.

3.14 Laboratory Test Devices

These tests use a relatively simple test specimen configuration to study the friction and wear processes occurring in real machine sand to perform friction and wear investigation under specific conditions. Real service tests these tests are adequately equipped with measuring instruments. The testing is done under real service conditions. These tests are expensive and generally continue for long duration. Investigation cost increases substantially when passing from laboratory tests to real service tests.. Methods used for evaluation of wear the most common methods of studying the wear consists of examination of sliding material before and after the test, any difference in material is attributed to wear. The detection of wear generally uses one or the other techniques of weighing, mechanical gauging, and examination of surface and sub-surface features and wear debris.

3.14 Methods Used for Evaluation of Wear

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3.15 Weighing

This is the simplest way of detecting the wear in which specimen is weighed before and after running at room temperature using sensitive weighing balances having least count of 0.001 grams and weight loss is calculated as a difference to get wear rate in close chamber.

3.16 Gauging

In this method, the wear is measured by decrease in dimensions, using mechanical (dial gauge) or electrical system based on linear variable displacement transducer (LVDT) principle. This has resolution limit of about 10-5m.

3.17 Optical

There are number of methods for measuring wear using the optical technique. One way is to make small micro-hardness indentation on a surface and to study how its size is reduced during the sliding [5].

3.18 Friction and Anti-friction

Friction is the resistance to motion experienced when: (a) surface of an object is moved tangentially with respect to another surface and an attempt is made to produce such motion. Importance of friction reflects from the fact that a very substantial part of the total energy consumption of mankind is expended in overcoming friction losses during sliding. When metal surfaces are loaded against each other the contacts are made through the tip of asperities. The high pressure developed at individual contact spot causes local welding and junctions formed at the interface are sheared off due to relative motion [5

3.19 The Microstructure: Primary and Eutectic Phases

Al-Si binary alloy is a eutectic system with the eutectic composition at 12.6. % Si by wt. Silicon reduces the thermal expansion coefficient, increases corrosion and wear resistance, and improves casting and machining characteristics of the alloy. When the Al-Si alloy solidifies, the primary aluminum forms and grows in dendrites or silicon phase forms and grows in angular primary particles. When the eutectic point is reached, the eutectic Al-Si phases nucleate and grow until the end of solidification. At room temperature, hypoeutectic alloys consist of a soft and ductile primary aluminum phase and a hard and brittle eutectic silicon phase. Hypereutectic alloys usually contain coarse, angular primary silicon particles as well as a eutectic silicon phase.

3.20 Intermetallic Precipitates

The Al-Si alloy usually has some other coexisting elements such as copper, magnesium, manganese, zinc, and iron. The solubility of these elements in aluminum usually increases with increasing temperature. This decrease from high concentrations at elevated temperatures to relatively low concentrations during solidification and heat treatment results in the formation of secondary inters metallic phases. For instance, the precipitation of Si, Mn, and Fe forms an Al12 (Fe, Mn) 3Si phase. The wide variety of inter metallic phases in aluminum alloys occur because aluminum is highly electronegative and trivalent, which has been the subject of considerable study.

3.21 Casting Defects

Cast Al-Si alloys usually have casting defects such as porosity and inclusion, which can greatly degrade the mechanical properties of the materials. Porosity is the most common defect in Al-Si castings. In addition to the fact that a pore cannot sustain external load, more seriously, it is a kind of stress concentrator, and thus can lead to microcrack initiation and propagation. Micro porosity usually results from exsolution of dissolved gas from the melt and/or failure of inter dendritic feeding. The solubility of hydrogen in Al-Si melt increases as temperature increases. When molten Al-Si alloy solidifies, the hydrogen atoms precipitate from the melt and form molecular hydrogen. If alloy solidifies faster than the molecular hydrogen escapes from the melt, gas porosity will be generated in the solid alloy. On the other hand, a lot of dendritic structures form in Al-Si alloy during its solidification. These dendrites take space in the melt, and reduce the fluidity of melt. Thus the shrinkage in theme lt between the dendrites cannot be fully filled, and micro porosity is formed along these dendrites after the melt solidification. Alloying elements greatly influence porosity formation via few mechanisms. First, an alloying element can change the freezing range of Al-Si alloy so that the porosity can be changed. When the freezing range is decreased, the “mushy zone” in the solidifying material is reduced and thus the porosity is reduced. Second, alloying element can form dendritic inter metallics during solidification. Porosity can form along these inter metallic dendrites. The mechanism is that Cu forms some inter dendrite Cu-rich phases, which solidify at a lower temperature and thus cannot be fully filled. Fourth, alloying elements can form high melting point phases in the melt, reducing the fluidity of the melt and thus helping to produce porosity. Finally, the alloying elements such as sodium, phosphorus, titanium, and boron in modifying silicon phase morphology or refining grains also have effects on porosity formation. In general, the addition of grain refiners increases the number of grain nucleation sites and reduces grain size. Accompanying this grain refinement is a decrease in volume fraction and size of pores and increase in the homogeneity of the pore distribution. Silicon refining also has an influence on the formation of the porosity. In hypereutectic alloys, phosphorus is added to form particles as the nucleation site for primary silicon. It was found that the addition of 19 ppm phosphorus noticeably reduces the percentage porosity in the Al-9%Si-3% Cu alloy. Modification in the Al-Si alloy refines the eutectic phase

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particles shape and improves the casting's mechanical property, but it usually increases the porosity.

3.22 Sample Preparation

Casting of the Al-Si-cu alloys and pure Al was done by pouring the molten alloy into mould .Cylindrical samples of diameter 10 mm and length 30 mm each were machined from the as-cast Al-Si alloys. Test samples are prepared from these cast ingots after polishing. The calculated density of aluminium alloy is 2.720 kg/m3 and that of pure aluminium is 2.68 kg/m3. Mild steel disk was taken as a counter surface having the diameter of 165mm.

3.23 Image of Samples

Fig: 3. Pins of Pure Aluminium and Aluminium Alloy

4. Abrasive Wear Test Apparatus

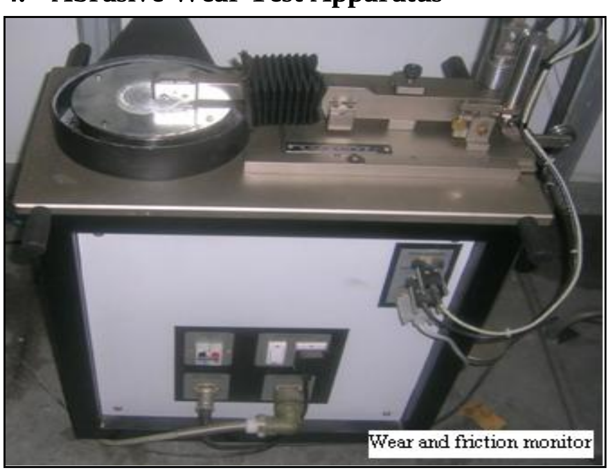

Fig: 4. Wear and Friction Monitor Used for the Wear Tests

Test up used in the study of wear test is capable of creating reproducible abrasive wear situation accessing the abrasive wear resistance of the prepared samples. It consists of a pin on disc, loading panel and controller.

The entire test was carried out using a "pin on disk" machine with both normal and lubricated condition. The normal condition has 40-50% relative humidity and a temperature of 32-35:C. 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 was measured on weigh balance (accuracy 0.001gm.) and after that specific wear has been calculated by using the given formula:

$$K = V_w / F \times S$$

Here *V*w is the wear volume, *L* the applied load and s the total sliding distance and K is specific wear ratecare has been taken to clean up the sample before and after each test to prevent any form of corrosion on the surface. The specimen was held steady and stationary within a holder of the apparatus and the required normal load was applied through lever mechanism. The sliding distance was kept at 0.5 km for all tests concerned Al-Si-Cu alloy and 1km for pure Al.

Fig: 5. Disc before Test

Fig: 6. Disc after Test

4.1 Specification of Pin on Disk Machine

The specification of pin on disk machine includes the parameters that are disk diameter, pin diameter, pin length, wear track diameter, normal load, friction force is given in the following table:

Table: 1. Specifications of the Pin on Disk Wear and Friction Monitor

Parameter	Unit	Minimum	Maximum
Disk speed	Rpm	200	2000
Pin diameter	Mm	3	12
Wear track dia	Mm	50	100
Normal load	N	1	200
Frictional force	N	0	200

4.2 Material Composition

The composition of aluminium alloy is shown in the following table.

MATERIAL	Al%	Si%	Cu%
Al alloy	84.84%	10.6%	2.4%
Pure Al	98.73%	0.496%	0.007%

The composition of materials can be verified with the help of spectroscopy report.

4.3 Design of Experiment

Design of experiment consists of variables which are load and velocity and the values of these variables is shown in the following table

Table: 3. Variables for Wear Test for Aluminium Alloy

Variables	Level 1	Level 2	Level 3	Level 4
Velocity(m/sec)	3.14	2.61	2.094	1.57
Load (kg)	1kg	1.5 kg	2 kg	2.5 kg

The following the design of experiment for the pure aluminium

Table: 4. Variables for Wear Test for Pure Aluminium

Variables	Level 1	Level 2	Level 3	Level 4
Velocity(m/sec)	6.28	5.23	4.188	3.14
Load (kg)	1kg	1.5 kg	2 kg	2.5 kg

5. Results and Discussions: Result of Pin on Disk for Aluminium Alloy in Wet Condition

In the experiment r.p.m was kept constant at the value of 500 r.p.m sliding distance was kept .5km. the initial mass of the pin was 4.7465 gm. the track diameter was varied and set at the values of 120, 100, 80 and 60mm linear velocity was calculated using this data . Coefficient of friction was calculated by using the value of friction force given by the pin on disk machine. Mass loss was carried out by subtracting the mass after the test from the mass of sample before the test. Specific wear rate was calculated by calculating the volume loss and dividing it by friction force and sliding distance for each reading.

Table: 5. Readings Obtained on Pin on Disk Machine for Al Alloy in Wet Condition

Load	r.p.m	Sliding distance	D (mm)	V(m/s)	time	Mass loss (gm)	Friction force (N)	Coefficient of friction	Specific wear rate(m3/Nm)
1	500	.5	120	3.14	160	.0002	.2	.0203	**7.24**
1.5	500	.5	100	2.61	192	.0003	.3	.02368	**7.2**
2	500	.5	80	2.094	238	.0005	.5	.0254	**7.24**
2.5	500	.5	60	1.57	319	.0007	1.1	.044	**4.6**

6. Effect of variables on Wear Rate and coefficient of Friction of Aluminium Alloy in Wet Condition

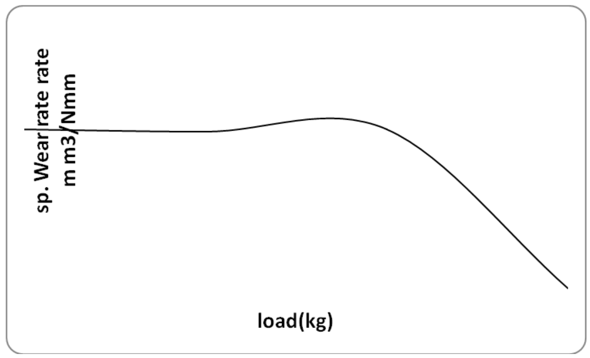

Fig: 7. Showing the Variation of Specific Wear Rate Vs. Load for Aluminium Alloy

The Fig.7 between specific wear rate and load indiacates that wear rate is nearly copnstant upyo the load oif slight increase in wear rate upto load of 1.6 kg followed by decrease in wear rate .the reason behind the decrese in wear rate may be due to debris formed between two bodies reduces the area of contact between them and hence the amount of wear has been found to decrease beyond the load of 2kg.

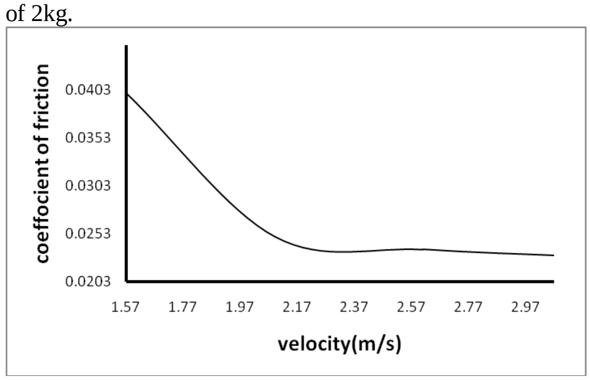

Fig: 8. Shows the Variation of Coefficient of Friction with Velocity for Aluminium Alloy

The Fig 8 is indicating that coefficient of friction is decreasing linearly upto velocity of 2.3m/s which may be due to the development of thick layer of lubricant between pin and disk but after this value of velocity the coefficient of friction is nearly constantupto 3.14m/s. Above fig. indicating that wear rate is decreasing with increase in velocity and is minumum at 2.09m/s it may be due to hydrodynamic lubrication due to which area of contact reduces so that wear rate decreases bt is followed by certain increase in wear rate upto 2.61 which may be due to debris formed between the surfaces increases thus area of contact betweeen pin and disk which is further followed by decrease in velocity due to further formation of lubricant film between pin and disk.

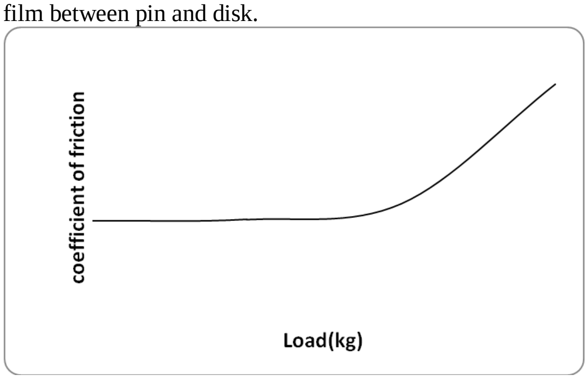

Fig: 9. Shows the Variation of Coefficient of Friction Vs. Load for Aluminum Alloy

The Fig.9 shows the variation of coefficient of friction with the variation of load.Fig. indicates that the coefficient of friction remains nearly constant upto lad 2kg but beyond this value of load it increases which may be due to incresed metal to metal contact with increase in load beyond the value of 2kg.

6.1 Result of Aluminium Alloy in Dry Condition

Table: 6. Readings Obtained on Pin on Disk Machine for Al Alloy in Wet Condition

Load (kg)	r.p.m	Sliding distance(km)	Track dia.(mm)	Velocity(m/s)	Time(sec)	Friction (N)	Mass loss(gm)
2	500	.5	140	3.66	137	1.9	.0008

There was a lot noise in dry condition and the amount of mass loss was greater in dry condition. The graph showed the value of 2.5 as force of friction then reduced below 2N.

6.2 Result of Pin on Disk Machine for Pure Aluminium

The experiment was carried out keeping the value of r.p.m constant , sliding distance of .75km. initial mass of the pin was 4.7746gm.track diameter varied as 120,100,80,60 mm.time was calculated using these values and coefficient of friction was calculated using the value of friction force givn by the machine. Specific wear was caculated by dividing volume loss by friction force and sliding distance.

Table: 7. Readings Obtained on Pin on Disk Machine for Pure Aluminum in Wet Condition

Load (kg)	**r. p. m**	**Sliding distance (Km)**	**Track dia. (mm)**	**V (m/s)**	**Time (sec)**	**Mass loss (gm)**	**Friction Force(N)**	**Coeff. Of friction**	**Specific Wear Rate** (m3/Nm)
1	1000	.75	120	6.28	120	.0003	.4	.04	7.4
1.5	1000	.75	100	5.23	144	.0005	.6	.043	11.21
2	1000	.75	80	4.188	180	.0006	.3	.015	12.4
2.5	1000	.75	60	3.14	239	.0009	.2	.008	19.7

6.3 Effect of Variables on Wear Rate and Coefficient of Friction of Pure Aluminium

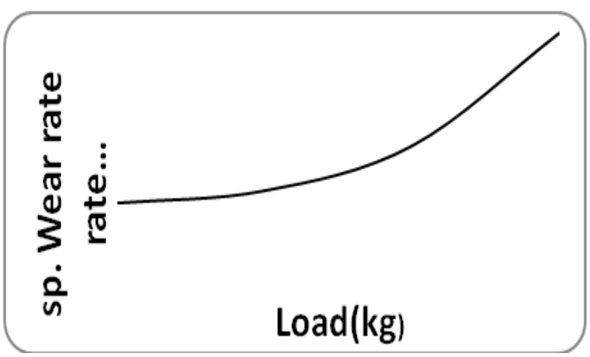

Fig: 10. Shows the Variation of Specific Wear Rate Vs. Load for Pure Aluminium

The Fig 10 shows the variation of specific wear rate with variation of load the fig shows that the increase in wear rate with increase in load this increse in wear rate is low upto load of 2kg but beyond this load as the metal to metal contact increases the wear increase at a very high rate.

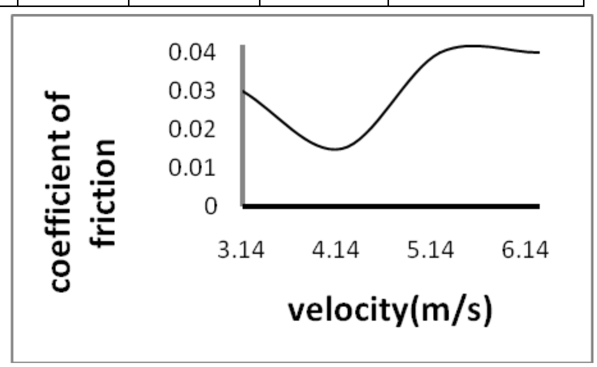

Fig: 11. Shows the Variation of Coefficient of Friction V.S. Velocity

The Fig 11 shows the variation of coefficient of friction with the variation of velocity. from the above fig. it can be seen that yhe coefficient of friction is first decreasing with increase in velocity and is minimum at 4.18m/s this decrease in value of coefficient of friction may be the hydrodynamic equilibrium but beyond that value it increase at a faster rate and then becomes content.

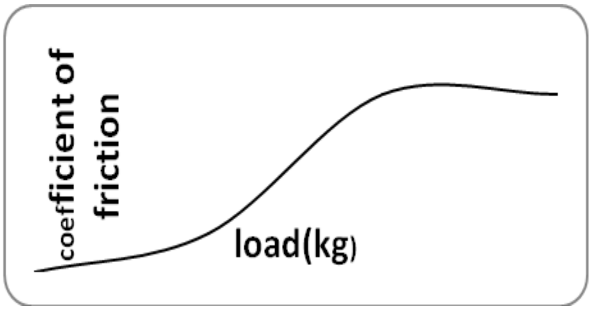

Fig: 12. Shows the Variation of Coefficient of Friction Vs. Load

The Fig. 12 shows the variation of coefficient of friction with the variation of load for pure aluminium. It can be seen from the fig. that the value of coeffficient of friction is increasing upto the load of 2kg this continuous increases because when the load is incerased the pure aluminium get weared and the debris of aluminium increases the value of coefficient of friction and in the end it becomes nearly constant.

6.4 Results of Pure Aluminium in Dry Condition

Table: 8. Readings Obtained on Pin on Disk Machine for Al Alloy in Wet Condition

Load	r.p.m	Sliding distance	Track dia.	Sliding velocity	Time(sec)	Friction force	Mass loss(gm)
2kg	1000	.25	40	2.094	120	8.5	6.7

During the test in dry condition a lot of noise was obsereved and relatively great amount of wear of pure aluminium.

7. Conclusions

The wear rate for Al-10.6%Si-2.4%Cu is not increasing at a high rate up to the load of 1.5kg instead it is constant but beyond this value of load the it is decreasing but the wear rate for pure aluminium is first increasing slowly up to the load of 2kg. and then increases sharply with increase of load. Coefficient of friction for aluminium alloy is first decreasing with velocity up to the value of 2.61 m/s and then becomes approximately constant for pure aluminium it first decreases up to the velocity of 4.18 m/s due to hydrodynamic lubrication and then increases beyond this value of velocity. coefficient of friction for auminium alloy nearly remain constant up to load of 2kg but beyond this it increases due to increased metal to metal contact and for pure aluminium Its value increases up to load of 2kg due to more formation of debris with increase of load but beyond the load of 2kg it has been found to remain approximately constant.

8. Future scope

Aluminium alloy is becoming very popular in industries of all over the world. The future of aluminum is bright. Now days the light weight components with high strength are required. Aluminium alloys can be efficiently used where the light weight and high Strength is required infect in most of the industries viz it is being used in aircraft industry to make the aircraft component lighter and with high strength ,it is also being used in marine and automobile industry. In future aluminium alloys can be used to manufacture the heavy duty transport vehicles to increase the performance and to save the fuel.

The railway sector of our country can manufacture the bogies of train using aluminum alloy like Japan has made its first bullet consist of aluminium replacing the older steel body of bullet train.The researches can be further done studying the effect of different alloying element on the properties of aluminum so as to discover more application of aluminium alloy.

Automobile industries are also making the use of aluminum alloy to manufacture the engine block, bearings, alloy wheels yet it can be further extended to manufacture the whole body with aluminium alloy, though the cost will be comparatively high but it can be compensated by the performance of the light weight vehicle . This way aluminium alloys carry huge potential to be used in maximum number of products in the industries.

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