Tribological Behaviors of Al with Varying Percentage Cu and Wc

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Abstract: The use of different kind of composite materials is in constant growing over the years, because they have physical, mechanical and tribological properties comparing to matrix material. Aluminium is the second abundant metal on earth. Good material characteristics with unique qualities of aluminium and its alloys such as low density, high specific strength, fabric ability, Physical and mechanical properties and corrosion resistance, greatly grew the production and use of this metal and its alloys. For example, in many commercial applications, specific strength of material plays an important role in material selection, and aluminium and its alloys are proper candidates for these types of applications. Particulate reinforced composites have been reported to have a better plastic forming capability than whisker & fibers reinforced composites, and thus have an advantage to lower the manufacturing cost. Also, they exhibit excellent heat and wear resistance due to the superior hardness and heat resistance characteristics of the particles distributed in the matrix. Moreover, they are easily available and synthesized via a variety of manufacturing routes.

Index Terms - Composite, aluminium, wear resistance.

I. INTRODUCTION

Aluminium is the second abundant metal on earth. Good material characteristics with unique qualities of aluminium and its alloys such as low density, high specific strength, fabric ability, Physical and mechanical properties and corrosion resistance, greatly grew the production and use of this metal and its alloys. For example, in many commercial applications, specific strength of material plays an important role in material selection, and aluminium and its alloys are proper candidates for these types of applications. Aluminium alloys are widely used in aerospace and automobile industries due to their low density and good mechanical properties, better corrosion resistance and wear, low thermal coefficient of expansion as compared to conventional metals and alloys. The excellent ability of these metal matrix composites to unify the properties of ceramic phase with the metallic phase has been useful in gearing up extensive research activities all over the world. Particulate reinforced composites have been reported to have a better plastic forming capability than whisker & fibres reinforced composites, and thus have an advantage to lower the manufacturing cost. Also they exhibit excellent heat and wear resistance due to the superior hardness and heat resistance characteristics of the particles distributed in the matrix. Moreover, they are easily available and synthesized via a variety of manufacturing routes.

These techniques include stir casting, liquid metal infiltration, squeeze casting, and spray co deposition. Stir casting route is generally practiced commercially. Its advantage lies in its simplicity, flexibility and applicability to large quantity production. Numerous research work have been reported aluminium alloy is a non heat treatable Al-Cu based alloy with excellent corrosion resistance and weld ability combined with good strength and formability. Because of these advantages, this alloy is widely used for automobile and transportation industries, aerospace aluminium panels and marine applications. Recently, Al-Mg-Cu alloys have been used in car body panels due to good formability, mechanical and corrosion resistance and the enhancement of paint-baking response. The temperature used for paint-baking treatment is in the range of 150-180°C for 20-30 min in which the mechanical properties are diminished due to the recovery mechanism. But, addition of Cu to Al-Mg alloys improves the mechanical strength via precipitation hardening. Aluminium alloys constitute a significant proportion of lightweight metals used in industry. The properties of aluminium like its low density, recyclability, ductility, formability leads to a variety of industrial and automotive applications. However, the strength of conventional cast aluminium alloys is too low. The cast alloys also have a lot of casting defects like porosity which makes it difficult to use them in crucial applications. FSP can be used in these cases for localized alteration of microstructure to yield improved mechanical properties in those areas. Despite the volume of literature available, the effects of FSP on mechanical and micro structural properties of the work material have not been fully understood [1].

1.2 WHY 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
(II) **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 of significance in engineering designs where stiffness is involved. For example, stiffness for equal weights of similar beams is in ratio 1:2.9:8.2:18.9 for steel, Titanium, Aluminium and Magnesium respectively.

(III) **Ease of Fabrication and Machine Ability**: It can be easily cast, rolled to any desired thickness (aluminium foils are so common), stamped, drawn, spun, forged and extruded to all shapes.

(IV) **High Resistance to Atmospheric Corrosion**: When aluminium is exposed to air, a thin oxidised film forms on the surface, protecting the metal from corrosion. When scratched, the layer rapidly reforms retaining the protection. This feature is utilised in construction, buildings and household utensils.

(V) **Resilience under Static and Dynamic Loading**: Aluminium products behave elastically under static and dynamic loading conditions, that is, they could resume both shape and size which is good when flexible strength is required. Mast and spars of racing yachts are designed to withstand the stress of the wind versus the waves.

(VI) **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.

Copper has been the most common alloying element almost since the beginning of the aluminium industry, and a variety of alloys in which copper is the major addition were developed. Most of these alloys fall within one of the following groups:

- Cast alloys with 5% Cu, often with small amounts of silicon and magnesium.
- Cast alloys with 7-8% Cu, which often contain large amounts of iron and silicon and appreciable amounts of manganese, chromium, zinc, tin, etc.
- Cast alloys with 10-14% Cu. These alloys may contain small amounts of magnesium (0.10-0.30% Mg), iron up to 1.5%, up to 5% Si and smaller amounts of nickel, manganese, chromium.
- Wrought alloys with 5-6% Cu and often small amounts of manganese, silicon, cadmium, bismuth, tin, lithium, vanadium and zirconium. Alloys of this type containing lead, bismuth, and cadmium have superior machine ability.
- Dural, whose basic composition is 4-4.5% Cu, 0.5-1.5% Mg, 0.5-1.0% Mn, sometimes with silicon additions.
- Copper alloys containing nickel, which can be subdivided in two groups: the Y alloy type, whose basic composition is 4% Cu, 2% Ni, 1.5% Mg; and the Hyduminiums, which usually have lower copper contents and in which iron replaces 30% of the nickel.

In most of the alloys in this group aluminium is the primary constituent and in the cast alloys the basic structure consists of cored dendrites of aluminium solid solution, with a variety of constituents at the grain boundaries or interdendritic spaces, forming a brittle, continuous network of eutectics.

Wrought products consist of a matrix of aluminium solid solution with the other constituents dispersed within it. Constituents formed in the alloys can be divided in two groups: in the soluble ones are the constituents containing only one or more of copper, lithium,
magnesium, silicon, zinc; in the insoluble ones are the constituents containing at least one of the more or less insoluble iron, manganese, nickel, etc.

The type of soluble constituents forms depend not only on the amount of soluble elements available but also on their ratio. Available copper depends on the iron, manganese and nickel contents; the copper combined with them is not available.

Copper forms (CuFe)Al6 and Cu2FeAl7, with iron, (CuFeMn)Al6 and Cu2Mn3Al20 with manganese, Cu4NiAl, and several not too well known compounds with nickel and iron. The amount of silicon available to some extent controls the copper compounds formed. Silicon above 1% favours the FeSiAl5, over the iron-copper compounds and (CuFeMn)3Si2Al15, over the (CuFeMn)Al6 and Cu2Mn3Al20 compounds.

Similarly, but to a lesser extent, available silicon is affected by iron and manganese contents. With the Cu:Mg ratio below 2 and the Mg:Si ratio well above 1.7 the CuMg4Al6 compound is formed, especially if appreciable zinc is present. When Cu:Mg > 2 and Mg:Si > 1.7, CuMgAl2 is formed. If the Mg:Si ratio is approximately 1.7, Mg2Si and CuAl2 are in equilibrium. With the Mg:Si ratio 1 or less, Cu2Mg8Si6Al15, is formed, usually together with CuAl2. When the copper exceeds 5%, commercial heat treatment cannot dissolve it and the network of eutectics does not break up. Thus, in the 10-15% Cu alloys there is little difference in structure between the as-cast and heat treated alloys. Magnesium is usually combined with copper and silicon. Only if appreciable amounts of lead, bismuth or tin are present, Mg2Sn, Mg2Pb, Mg2Bi3 can be formed. The effect of alloying elements on density and thermal expansion is additive; thus, densities range from 2 700 to 2 850 kg/m3, with the lower values for the high-magnesium, high-silicon and low-copper alloys, the higher for the high-copper, high-nickel, high-manganese and high-iron contents.

Expansion coefficients are of the order of 21-24 x 10-6 1/K for the 300-4000 K range and 23-26 x 10-6 1/K for the 300-700 K range, with the higher values for the high-magnesium, low-copper and low-silicon alloys, the lower ones for the higher silicon and higher copper contents. At subzero temperatures the coefficient decreases practically in the same way as that of pure aluminium. However, release of casting stresses or precipitation and solution of copper and magnesium produce changes in length of up to 0.2%, which may affect the dimensional accuracy of parts exposed to high temperature. Subzero treatment of castings to reduce warpage has been recommended.

Specific heat of the commercial alloys is practically the same as for the binary aluminium-copper. Thermal conductivity is little affected by alloying elements other than copper: for the commercial alloys with 4-12% Cu, < 4% other elements, it is approximately 70% of that of pure aluminium at room temperature, some 75-80% at 600 K and 30-35% at 200 K.

Electric conductivity is very sensitive to copper in solution, and to a much lesser extent to magnesium and zinc, but is little affected by alloying elements out of solution. In an alloy with 5% Cu in solution the conductivity is approximately half that of pure aluminium (30-33% IACS), but in the annealed state an alloy with 12% Cu and up to 5% other elements has a conductivity of 37-42% IACS, only 25-30% lower than that of pure aluminium.

The mechanical properties of the alloys vary over an extremely wide range, from those of the sand cast 8% Cu alloys, which are among the lowest in aluminium alloys, to those of durals or wrought 5% Cu alloys, which may reach values of up to 650 MPa.

Higher purity, special compositions, fabricating techniques or heat treatments may produce higher properties. Porosity, poor feeding of castings, excessive amounts of impurities, segregation and poor quality control in fabrication may reduce the properties well below the determined limits. Surface defects reduce the properties of castings more than internal ones. Restrain or elastic strain during testing has no effect on properties. Ultrasonic vibration may reduce or increase them; and irradiation at cryogenic temperatures may slightly increase strength. Dynamic loading may produce strength and ductility values higher or lower, depending on the speed, but not at high temperature. Temperatures below room temperature increase strength and hardness, with some loss of ductility and a decrease in anisotropy.

Correspondingly, exposure to temperatures above room temperature eventually results in a decrease in strength and hardness with a decided increase in elongation. Heat treatment has a substantial effect: if the alloys are quenched from high temperature and only naturally aged, exposure to temperatures in the range up to 500-600 K may produce a temporary increase in hardness and strength due to artificial aging. Eventually this increase disappears, the faster the higher the temperature, and the normal decline sets in, as in alloys already aged to peak hardness. Prolonged heating (for up to 2 years) results in appreciable softening at all temperatures. For intermediate exposure times this softening is less if the materials are thermo-mechanically treated. In short-time tests fast heating to test temperature increases the strength. Impact resistance is low, as for all aluminium alloys: in the Charpy test values range from a minimum of 2-3 x 104J/m for cast alloys with 7% Cu to a maximum of 30-40 x 104J/m for wrought products in the naturally aged temper. Notch sensitivity is usually low, especially in the wrought alloys, or in the cast alloys heat treated to maximum ductility. The plane strain fracture toughness ranges from 85 to 100% of the yield strength, depending on a variety of factors. Both impact resistance and notch toughness increase with increasing temperature, but the decrease with sub-zero temperatures is limited. In the softer alloys at 70 K the difference is within error of testing; only for the higher-strength alloys is the decrease appreciable.

Shear strength is of the order of 70-75% of tensile strength, even at high temperature; bearing strength is approximately 1.5 of tensile; compressive yield strength is 10-15% higher or lower than ultimate tensile strength.

Most alloying elements raise the modulus of elasticity of aluminium, but the increase is not substantial: for the aluminium-copper alloys the modulus of elasticity at room temperature is of the order of 70-75 GPa and practically the same in tension and in compression. It changes regularly with temperature from a value of 76-78 GPa at 70 K to a value of the order of 60 GPa at 300 K. The change during aging is negligible for practical purposes. The Poisson ratio is slightly lower and of the order of 0.32-0.34, and so is the compressibility. The Poisson ratio increases with increasing temperature. Many of the cast alloys and of the aluminium-copper-nickel alloys are used for high-temperature applications, where creep resistance is important. Resistance is the same whether the load is tensile or compressive.

Wear resistance is favoured by high hardness and the presence of hard constituents. Alloys with 10-15% Cu or treated to maximum hardness have very high wear resistance.
Magnesium increases the strength and hardness of the alloys, but, especially in castings, with a decided decrease in ductility and impact resistance. Iron has some beneficial strengthening effect, especially at high temperature and at the lower contents (< 0.7% Fe). Nickel has a strengthening effect, like that of manganese, although more limited because it only acts to reduce the embrittling effect of iron. Manganese and nickel together decrease the room-temperature properties because they combine in aluminium-manganese-nickel compounds and reduce the beneficial effects of each other. The main effect of nickel is the increase in high-temperature strength, fatigue and creep resistance. Titanium is added as grain refiner and it is very effective in reducing the grain size. If this results in a better dispersion of insoluble constituents, porosity and non metallic inclusions, a decided improvement in mechanical properties results. Lithium has an effect very similar to that of magnesium: it increases strength, especially after heat treatment and at high temperatures, and there is a corresponding decrease in ductility. Zinc increases the strength but reduces ductility [2].

1.3 ALUMINIUM-COPPER ALLOYS

The Copper-aluminium alloys, commonly known as Aluminium Bronzes, are a range of copper-based alloys in which aluminium up to 14% is the primary alloying element. In addition, other major alloying elements are nickel, iron, manganese and silicon. Varying the proportions of these results, alloys to meet a wide variety of engineering requirements. Aluminium-Copper alloys have been associated with the aerospace industry since its inception. In the very first flight in 1903, the Wright brothers used an Aluminium 8wt% Copper alloy for the crankcase of their engine. Copper is one of the most important alloying elements for Aluminium due to its relatively high solubility in Aluminium and its strengthening effect. Copper, as a principle alloying element in Aluminium, imparts substantial precipitation hardening characteristics and excellent elevated temperature properties to the alloy. Often copper is accompanied by magnesium in order to accelerate and increase age hardening at room temperature. Often manganese is added to Al-Cu alloys to mitigate the detrimental effects of impurities such as Iron and Silicon. The eutectic temperature in the Al-Cu system is 548°C and the eutectic composition is 33.2wt% Cu. The eutectic phases that separate from the liquid in the solidification reaction are: CuAl2, Which is intermetallic phase containing 5.35wt% Cu, and the aluminium solid solution, which contains 5.65wt% Cu.

Aluminium alloy 6060 is a general commercial alloy and is the most commonly used. It is very suitable for anodizing, so provides extra protection if needed, and a decorative finish, especially useful for applications such as lighting and architectural sections. Aluminium alloy 6060 is commonly used for architectural sections for windows, doors, curtain walls, interior fittings, lighting, and furniture and office equipment, structural applications where surface finish is important.

![Figure 1.2 Aluminium rich portion of the Al-Cu phase diagram.](image)

Alloys with Copper 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-copper 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. Parent bore materials of copper-containing hypereutectic Al-Si alloys have been tried with limited success. Fundamentally the
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The majority of aluminium-copper alloy grades contain 4 to 5 percent copper (32 grades), two grades contain 6 to 8 percent copper (213.0 and 213.1), two grades contain 7 to 9 percent copper (240.0 and 240.1), and two grades contain 9.2 to 10.7 percent copper (222.0 and 222.1). There are 17 grades of aluminium alloy castings (2xx.0) and 21 grades of aluminium alloy ingots (2xx.1 and 2xx.2). Among the 38 grades, there are 30 original alloys (201.0, 204.0, 206.2, 242.1, etc.) and eight modified alloys (A201.1, B201.0, A206.2, etc.). The following aluminium-copper alloys are typical work piece materials for automotive and aerospace parts.

- The 201.0 grade [4.6 percent Cu, 0.7 percent silver (Ag), 0.35 percent Mn, 0.35 percent Mg and 0.25 percent titanium (Ti)] is used for making gasoline-engine cylinder heads and pistons, connecting rods, rocker arms, aircraft landing gears and pump housings.
- The 206.0 grade (4.5 percent Cu, 0.30 percent Mn, 0.25 percent Mg and 0.22 percent Ti) is used for making turbine and supercharger impellers, cylinder heads for gasoline and diesel motors, gear housings and other parts that require high strength at elevated temperatures.
- The 242.0 grade [4.0 percent Cu, 2.0 percent nickel (Ni) and 2.5 percent Mg] is used for making motorcycle, diesel and aircraft pistons; air-cooled cylinder heads; and other parts that require high-temperature strength.
- The 295.0 grade (4.5 percent Cu and 1.1 percent Si) is used for making flywheel housings, bus and aircraft wheels, fittings and crankcases.
- The 296.0 grade (4.5 percent Cu and 2.5 percent Si) is used for making aircraft fittings, aircraft wheels, compressor connecting rods and other parts requiring high tensile strength [4].

1.4 STIR CASTING:

Stir casting route is the most promising one for synthesizing discontinuous reinforced aluminium alloy matrix composite because of its relative simplicity and ease of adaptability with all casting techniques in metal casting industry. By resorting to proper melting and casting practice and understanding the various steps involved during the synthesis, high quality composites with good mechanical properties can be made. In this stir casting method alumina particles are mixed with molten metal matrix by means of mechanical stirring.
1.5 WEAR

It is defined as a process of removal of material from one or both of two solid surfaces in solid contact. Wear is defined as “the damage to a solid surface, generally involving the progressive loss of material, due to relative motion between two moving surfaces”. Such a process is complicated, involving time-dependent deformation, failure and removal of materials at the counter face. Research in this area is of vital importance from the economic point of view because it is a major problem and its direct cost is estimated to vary between 1% and 4% of a nation’s Gross National Product.

1.5.1 TYPES OF WEAR

Following are the various types of wear processes based on the types of wearing contacts.

- Single-phase wear: In which a solid moving relative to a sliding surface causes material to be removed from the surface. The relative motion for wear to occur may be sliding or rolling.

- Multi-phase wear: In which wear, from a solid, liquid or gas acts as a carrier for a second phase that produces the wear.

1.5.2 Wear Mechanisms

Common types of wear mechanisms are as listed below
(i) Abrasive wear
(ii) Solid particle erosion
(iii) Sliding and adhesive wear
(iv) Fretting wear
(v) Corrosive wear
(vi) Impact wear

1.5.2.1 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 surfaces, the speed of contact, and other environmental conditions. In short, loss rates are not inherent to a material. Depending on the attack angle and the interfacial shear strength three modes of abrasive wear are usually encountered in ductile metals:

- Ploughing: Ridges form along the sides of wear track.
- Wedging: A short wedge forms in front of the abrading asperity.
- Cutting: A long ribbon-like chip forms in front of the abrading asperity.

MECHANISMS PROPOSED

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 1.2 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 micro cracking [5].
1.5.2.2 SOLID PARTICLE EROSION (SPE)

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 waterjet 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 3.3 ft/s). Manifestations of SPE in service usually include thinning of components, a macroscopic scooping appearance following the gas/particle flow field, surface roughening (ranging from polishing to severe roughening, depending on particle size and velocity), 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[6].

1.5.2.3 SLIDING AND ADHESIVE WEAR

It is a type of wear generated by the sliding of one solid surface against another. Erosion, cavitations, rolling contact, abrasion, oxidative wear, fretting, and corrosion are traditionally excluded from the class of "sliding" wear problems even though some sliding may take place in some of these types of wear. Apparently, sliding wear is a type of wear that is "left over" when all other types of wear have been identified under separate headings. Although sliding wear and adhesive wear are not synonymous, Adhesive wear is as ambiguously defined as sliding wear. This phenomenon denotes a wearing action in which no specific agency can be identified.
as the cause of wear. Adhesive wear is said to occur if no abrasive substances are found, amplitude of sliding is greater than that in fretting and oxidation does not take place [7].

1.5.2.4 FRETTING WEAR
Fretting can be defined as the “small-amplitude oscillatory movement that may occur between contacting surfaces, which are usually nominally at rest.” Production of oxide debris is one of the immediate consequences of this phenomenon. Hence, the terms “fretting wear” and “fretting corrosion” are applied to this process. The movement is due to external vibration. But in several cases, one of the members of the contact is subjected to a cyclic stress (fatigue). This gives rise to the initiation of fatigue cracks. This is called “fretting fatigue” or “contact fatigue” [8].

1.5.2.5 CORROSIVE WEAR
In case of corrosive wear, thin films are assumed to form through trio chemical reactions between contact surface materials and surrounding media, such as air or a liquid lubricant and wear occurs through a combination of wear and corrosion can result in total material losses that are much greater than the additive effects of each process taken alone, which shows synergism between the two processes. Corrosion accompanies the wear process to some extent in all environments, except in inert atmospheres [9].

1.5.2.6 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 [10].
2.1 INTRODUCTION

The literature survey is carried out to study and evaluate the wear properties of Al-Cu alloys. The various parameters such as Copper content, applied load, sliding distance, effect of microstructure, etc, have been studied. Pure aluminum is weak having a tensile strength between 90 to 140 N/mm², however, wrought aluminum in its alloyed form has higher strength and is like structural steels. It is mainly used for electrical conductors and for domestic products, however, for structural use it must be strengthened by alloying. Aluminium alloys are used extensively in making mechanical parts due to its high specific strength (strength/density). The main usage of aluminium alloys are in applications requiring lightweight materials as in aerospace industries and in automotive industries. The second important property of aluminium is its resistance to corrosion. Aluminium has a strong protective oxide layer which prevents continuous corrosion of the base material. Therefore, a lot of work is done to achieve better properties of aluminium by alloying, heat treatment and other processes.

On the other hand aluminium has a big disadvantage of having a low melting temperature which put limits on the temperature range of applications. Aluminium can be recycled, it retains a high scrap value. It can be recycled indefinitely without losing any of its superior characteristics, making it especially appealing according to both environmental and economic criteria aluminium recycling saves 95 percent of the energy required to produce aluminium from raw materials. Conserving natural resources is important; because it takes four pounds of bauxite ore to produce one pound of aluminium, every pound of recycled aluminium saves four pounds of ore. Increasing the use of recycled metal has an important effect on the CO₂ emission, since producing aluminium by recycling produces only about 4% as much CO₂ as by producing it from natural resources. Iron is the most common impurity found in aluminium. It has a high solubility in molten aluminium and is therefore easily dissolved in the liquid state of aluminium, however its solubility in the solid state is very low (~0.04%). The low solubility of iron in the solid state is accompanied by decreased ductility as results of formation of inter metallic phases like Fe Al and/or Fe₃Al. These inter metallic phases increases the strength of the aluminium alloy they also enhances corrosion resistance.

Can be a significant challenge. Aluminium scrap is refined by separation processes that increase metal purity such as the segregation method, the solid solution separation method, the temperature gradient method, the eutectic separation method, the inter-metallic compound method, the gravity separation method, etc. These methods, however, are difficult to apply to the manufacturing systems because of low efficiency, complicated apparatus, high cost and environmental contamination. This puts high demands for innovative separation technologies to improve the sorting, and thereby the quality, of scrap. Another approach is to reduce significantly the amounts of various elements that occur in scrap, the nearly universal alternative for controlling such elements in recycled aluminium alloys is to dilute them with purer alloy grades or virgin pig.

2.2 CONTRIBUTION OF THE RESEARCHER

The work of researchers in this respect is been considered. Their conclusions are as follows:

- Tutti Y. Alias and M.M Haque has studied the wear behaviour of as-cast and heat treated Al-Cu eutectic alloys. Wear tests on the alloys were performed on a pin on disk type wear testing apparatus and parameters were size and shape of the pin, load, speed and the material pairs. Increase in the rotational speed of the disk leads to the increase in the mass loss of the as-cast and heat treated alloys. The wear rate is higher for as-cast samples. High speed leads to reduction in wear rate. The reduction is pronounced in heat treated samples. This is because during sliding, heat is developed and the material becomes softer and weaker. This heat might not affect the hardness of heat treated alloys due to their inherent characteristics. Increase in the applied load leads to a high wear rate for both as-cast and heat treated alloys. But at higher loads, strain-hardening of the materials in contact increases, resulting in increase in the resistance to abrade or erode. At higher load, real surface area in contact is more which increases the gripping action and due to which wear rate slows down at longer sliding distances, volumetric wear rate and specific wear rate are low. This was attributed to the fact that during sliding, heat develops due to friction which makes some of the adhered materials soften and loosen. As sliding goes on, these loosened particles are thrown away showing higher loss in weight. Heat treated alloys are not much affected due to their inherent characteristics due to heat treatment cycles whereas as-cast alloys show higher weight loss[11].

- S.A. Kori and T.M. Chandrashekharaih has studied the effect of grain refiner and or modifier on the wear behaviour of hypoeutectic (Al-0.2, 2, 3, 4, 5 and 7Cu) and eutectic (Al 12Cu) alloys using a Pin-On-Disc machine under dry sliding conditions. The work of researchers in this respect is been considered. Their conclusions are as follows:

Figure 1.9 Mechanism of impact wear
It is important that Al-Cu alloys solidify with fine equated α-Al in hypoeutectic/primary Cu particles in hypereutectic and fine eutectic Cu. While the former can be achieved by a suitable grain refinement treatment/solidification processing the latter can be achieved by a suitable grain modification. A fine grain size ensures good tribological properties. Al-Ti-B was used as grain refiner and Al-10%Cr was used as modifier. Addition of grain refiner and modifier to Al-Cu alloys resulted in less specific wear rate for these samples. An increase in sliding speed led to the decrease of specific wear rate both in the case of grain refined/modified and grain unrefined/unmodified alloys. This may be due to the fact that, at low sliding speeds, more time is available for the formation and growth of micro welds, which leads to increase in the force required to shear off the micro welds to maintain the relative motion, resulting in an increase in specific wear rate. Less specific wear rate was observed in grain refined/modified alloys under these conditions. Addition of grain refiner and modifier led to decrease in wear rate at longer sliding distances. Grain refinement and modification led to increase in toughness and strength of the alloy. Increase in Silicon content leads to solid solution strengthening and precipitation hardening and a subsequent increase in the strength of the alloy. Addition of grain refiner and modifier leads to better mechanical properties [12].

G. Rajaram, S. Kumaran and T. Srinivas Rao has studied the tensile and wears Properties of Al-Cu alloys fabricated by stir-casting technique at temperatures ranging from ambient to 3500°C. It is observed that the wear rate decreases with increasing temperature. This is because an oxide film is formed at high temperature which helps to avoid direct contact between alloy and the abrasive. Continuous sliding action removes this layer which facilitates direct contact of the alloy with the abrasive which results in decrement of wear rate at high temperature (~3000°C). Another mechanism for this phenomenon has been suggested. At elevated temperatures, the agglomerated clusters of oxide formed due to tearing of oxide layers are subjected to thermal stresses and compaction by applied pressure and high temperature. At the same time sintering of the wear debris is also occurring resulting in solid smooth hard surfaces called “glazes”. These glaze layers protect the sliding surface and reduce the wear rate [13].

Dheerendra Kumar Dwivedi has studied the effect of alloying elements on binary Al 6.5wt%Cu alloy and multi-component (Al–17Si–0.8Ni–0.6Mg–1.2Cu–0.6Fe) cast alloy. A reduction in wear rate at high sliding speed was observed. This is due to the formation of an oxide layer on the sliding interface. Increase in the sliding speed leads to an increase in interface temperature. Rise in temperature increases the ability of soft Aluminium matrix to accommodate the hard and brittle Silicon. If temperature exceeds a certain critical value, thermal softening in the sub-surface region takes place which leads to large-scale plastic deformation. Multi component alloys show better wear resistance because of increased solid solution strengthening, precipitation hardening and formation of intermetallic compounds in the presence of alloying elements. Formation of thermally stable intermetallic compounds and dispersion strengthening increase the wear resistance of multicomponent alloys. High hardness of these alloys is responsible for the low coefficient of friction during sliding due to easy fracture and deformation of asperities [14].

H. Torabian, J.B Pathak and S.N Tiwari have studied the effects of alloy composition, sliding distance, sliding speed and load on the wear rate of Al-Cu alloys. The wear rate is strongly dependent on the applied load. It increases linearly with load in three distinct regions in all the alloys. Mild wear, Intermediate wear and Severe wear. Mild wear takes a longer duration and takes place under low loads. The intermediate wear and severe wear regions are distinguished from the mild region by higher rates of increase in the wear rate per unit weight. It may be observed that the transition load at which change takes place from one region to another increases with increased Copper content of the alloy. It is observed that wear rate initially decreases slightly with increasing sliding speed up to a certain value. Beyond this, there is a sharp rise in the wear rate, irrespective of the alloy composition. This value increases with increasing Copper content. The wear rate of the alloy is strongly dependent on the Copper content of the alloy. The wear rate is found to decrease with increasing Copper content. This effect is pronounced up to 15% Cu in the alloy. Thus wear rates of hypereutectic alloys are better than those of hypoeutectic alloys [15].

A.S Anasayida, A.R Daud and M.J Ghazali has studied the effect of addition of Cerium on the wear behaviour of as cast Al-4Cu-4Mg alloys. Wear test results confirm that the wear rate decreases with the addition of Cerium in the alloy. The microstructures of the alloy samples reveal that Cu in the as cast alloys is finely distributed in the interdendritic region. Copper being harder than Aluminium increases the wear resistance of the alloys. Addition of Ce resulted in the formation of intermetallic phases like Al-Ce and Al-Cu-Ce which leads to hardness and wear resistance. The volume loss of the alloys increased with increasing load and sliding distance. With increase in Ce content, volume loss decreased. This was due to the strong bonding between intermetallic phases and the matrix. Wear mechanisms involved were oxidative wear, microcutting and delamination wear as shown by presence of oxides, microchips and delamination flakes. Cerium content up to 5% increased wear resistance [16].

D. Odabas and S.Su worked on the comparison of reciprocating and continuous two body abrasive wear behaviour of solution-treated and age-hardened 2014 Al alloy. Reciprocating and continuous abrasive wear have been performed on solution treated
2014 Al alloys under similar conditions of load, speed, nominal area of contact and sliding distance. In order to compare the two bodies abrasive wear behaviour for two sliding modes. Pattern of wear is similar for both. But the average roughness in continuous wear is more than that of reciprocating. Because wear loss and abrasive wear coefficient in continuous wear is higher than that of reciprocating. Sliding distance differences can explain this phenomena.

Conclusions can be drawn as- Difference in continuous and reciprocating wear.

- Wear loss is greater in the continuous wear.
- The abrasive wear coefficient is higher in the continuous wear.
- The values of average roughness of the worn surfaces are greater in reciprocating wear.

The above phenomenon is explained by difference in sliding distance in both the cases and the greater amount of abrasion of the loose wear debris trapped between the contact surface of the pin and abrasive paper for much longer in the continuous wear mode [17].

Litian Hu, Jianmin Chun, Weimin Liu, Qunji Xue and Czeslaw Kajdas have studied the wear and friction properties of Al-Cu alloy against itself with the lubrication of pure ethylene glycol, ethanolamine, ethylenediamine and triethylenetetramine. Friction and wear tests showed that the friction coefficient for triethylenetetramine was lowest. Wear of the Al-Cu alloy lubricated with ethylene glycol was the largest whereas triethylenetetramine produced the best results. This has been explained on a molecular level. In amine like compounds, there are two electrons in the Nitrogen atom which are not bonded. Thus it is easy to interact with metals. In triethylenetetramine, though Nitrogen percentage is smaller than that in demines, it exhibits better tribological behaviour. This has been explained by the fact that triethylenetetramine has a longer molecular chain. It also oxidises easily and the oxidation products interact with the Al-Cu alloy. These products interact with the surface of the Al-Cu alloy generated during sliding. It may also form a friction polymer.

3. SCOPE OF THE PRESENT INVESTIGATION

The main objective of this research work is to blend pure aluminium, pure copper and tungsten carbide powder by stir casting technique and to investigate the behavior of this new alloy under impact, wear and corrosion tests. By these tests we have to analyze the changes in the material properties whether the properties are improving or not. By comparing with pure aluminum metal properties to Al-CuWc alloys property from this we can justify which is a better. Wear tests were conducted using a pin-on-disc type wear testing machine. Different Al-Cu Wc alloys were subjected to dry sliding wear test using pin-on-disk apparatus under 30N normal load with rotational speed of counter face disk of 400 rpm at room conditions (~20 °C and ~50% relative humidity).

The main objective of corrosion test is to check the effect of reinforcement on the corrosion rate. Corrosion test were conducted at room temperature using conventional weight loss method according to ASTM G69-80. They used for test were one normal HCL specimen washed distill water followed by acetone and allowed to dry thoroughly and weighed accurately up to fourth decimal. Weighed specimen dipped in HCL for 1 day with different concentration of HCL.

4.1 MATERIAL

Aluminium–copper tungsten carbide based alloys with different weight percentages of copper content (2.5 wt. % of Cu, 4.5 wt.% of Cu, 6.5 wt. % of Cu) and tungsten carbide content (1%,2%,3%) were used as alloying material. Alloys with Copper and tungsten carbide 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 tribological and other properties are afforded by these alloys. Binary aluminium-copper tungsten carbide alloys combine the advantages of high wear resistance and other properties like good weld ability, and low specific gravity. Castings of these alloys are somewhat easy to machine than the aluminium-copper tungsten carbide alloys, all types of machining operations are routinely accomplished, usually using Tungsten carbide tools and appropriate coolants and lubricants. To manufacture the above composition alloy die has been manufactured using “EN-38” alloying material.

Castings of the Al-Cu Wc alloys were done by pouring the molten alloy into an EN-38 die of Dimension 8mm diameter and 350mm length. Cylindrical samples of diameter 8 mm each were machined from the as-cast Al-CuWc alloys. Test samples are prepared from these cast ingots after polishing.

Then for the impact test we made the specimen of size 60*15*14mm then we have machined this specimen and bought to standard of 55*12*12mm.
4.2 SAND MOULDING PROCESS
Casting process involving the use of sand as a moulding medium is known as sand moulding. The steps in sand moulding are: Sand preparation → Pattern making → Core making → Moulding → Closing

The equipments needed in a sand moulding process are:

1. Pattern
2. Mould box
3. Moulding sand
4. Crucible

Figure 4.1 Pure copper chips

Figure 4.2 Pure aluminium ingot

Figure 4.3 Tungsten carbide powers
The pattern is placed in a bottom plate and a drag box is located around it. After taking care about the positions of the runner, ingate, etc. the thickness of sand around the casting is carefully chosen. This should be about optimum. Otherwise if the thickness of sand layer around the pattern is too much, it will provide too much of insulation and result in delay in the solidification of the casting, and it will create back pressure during the escape of the gases that evolve during the casting. If it is too less, it will make the casting cool very fast and a chilling/quenching effect will be produced which may not be desirable at times. It is now time to fill the space between the pattern and the mould box with sand. However, the sand which is adjacent to the pattern/mould cavity is of a different quality than the sand away from it and near to the walls of the mould box. The inner sand called facing sand is finer and the outer sand called backing is coarse. Backing sand is not used for facing because it cannot develop the required surface finish and fine details that are present on the faces of the pattern. A minimum of 30 mm and up to 100 mm of facing sand should be applied on the inside surfaces to obtain an acceptable mould cavity.[1] The sand is gently rammed/patted to cover all grooves and fine patterns/markings/slots. Rest of the volume of the drag box is then filled with backing sand and rammed. The top surface is made level by cutting any heap/bump that might have formed on the drag box.

The drag is inverted and the cope half of the two-piece pattern is assembled to the drag half. Cope box is made to sit on the drag box using alignment and closing pins. Parting powder is sprinkled on the exposed sand surface of the drag box. Gating, sprue, runner, riser, etc. are placed at appropriate positions around the pattern. Backing sand is again filled in the cope box and rammed to set. Vent holes are provided for passage of gases.

Then drag and cope are separated. Pattern is removed with utmost care being taken so as not to cause any damage to the mould cavity or any intricate profile. The cavity is inspected for visible scar or recess created and is repaired if needed. Cores, if necessary, are placed either solitary or with the help of core-prints. Drag and cope halves are joined and locked with the help of closing pins. Pouring basin is placed at the spruces’ open end. Enough load is placed on the cope to prevent its lifting under the action of buoyant force when liquid metal is poured.

4.3 SPECIMEN PREPARATION - CASTING PROCESS

Metal casting process begins by creating a mold, which is the ‘reverse’ shape of the part we need. The mold is made from a refractory material, for example, sand. The metal is heated in an oven until it melts, and the molten metal is poured into the mould cavity. The liquid takes the shape of cavity, which is the shape of the part. It is cooled until it solidifies. Finally, the solidified metal part is removed from the mould.

4.3.1 DIE CASTING

Die casting is a very commonly used type of permanent mold casting process. It is used for producing many components of home appliances, motors, toys and hand-tools. Surface finish and tolerance of die cast parts is so good that there is almost no post-processing required.
To the pure molten aluminium different weight percentages of copper was added.
1. 2.5% wt. Of copper
2. 4.5% wt. Of copper
3. 6.5% wt. Of copper

Then hot molten AL-CU mixture was poured in the die through the spur.

4.4 WEAR TESTS:

4.4.1 ABRASIVE WEAR TEST APPARATUS:
Test up used in the study of wear test can create reproducible abrasive wear situation accessing the abrasive wear resistance of the prepared samples. It consists of a pin on disc, loading panel and controller.

All the test was carried out using a “Ducom friction and wear monitor” machine with normal condition. The normal condition has 50-60% relative humidity and a temperature of 28-32°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 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 μm optimised for the Al-Cu 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 radius was kept at 80 mm for all tests concerned.

Table no 4.1 Specifications of the DUCOM wear and friction monitor.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wear disc</td>
<td>Mm</td>
<td>165*8</td>
<td>--------</td>
</tr>
<tr>
<td>Disc speed</td>
<td>Rpm</td>
<td>200</td>
<td>2000</td>
</tr>
<tr>
<td>Pin diameter</td>
<td>Mm</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>Pin length</td>
<td>Mm</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>Ball diameter</td>
<td>Mm</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Wear track dia</td>
<td>Mm</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>Normal load</td>
<td>N</td>
<td>5</td>
<td>200</td>
</tr>
<tr>
<td>Frictional force</td>
<td>N</td>
<td>0</td>
<td>200</td>
</tr>
</tbody>
</table>
4.4.2 WEAR PARAMETERS:

The variables involved in wear test are: % Cu and % WC in the Al-Cu Wc alloy. Wear behaviour of the fabricated samples is combined affected by the above parameters. The effect of each individual parameter is studied in these experiments.

4.4.3 WEAR MEASUREMENT:

Wear rate was estimated by measuring the mass loss in the specimen after each test and mass loss, $\Delta m$ in the specimen was obtained. We can calculate the mass loss by measuring the height loss ($\Delta h$) in each experiment, the area of cross section ($A$) of sample and the density ($\rho$) of the alloy by using the relation.

$$\Delta m = \Delta h \times A \times \rho$$

Cares have been taken after each test to avoid interaction of wear debris in the specimen. Wear rate which relates to the mass loss ($\Delta m$) and sliding distance ($L$) was calculated using the expression,

$$W = \frac{\Delta m}{L}$$

The friction force was measured for each pass and then averaged over the total number of passes for each wear test. The average value of the coefficient of friction, $\mu$ of composite was calculated from the expression,

$$\mu = \frac{F_f}{F_n}$$

Where $F_f$ is average friction force and $F_n$ is applied load.

For characterization of the abrasive wear behaviour of the composite, the specific wear rate is employed. This is defined as the volume loss of the composite per unit sliding distance and per unit applied normal load. Often the inverse of specific wear rate expresses in terms of the volumetric wear rate as

$$W_v = \frac{W}{V_s \times F_n}$$

where $V_s$ is the sliding velocity [18].

4.5 CONVENTIONAL WEIGHT LOSS TEST

Conventional weight loss test is to check the effect of reinforcement on the corrosion rate. Corrosion test were conducted at room temperature using conventional weight loss method according to ASTM G69-80. The corrdents used for test were one normal HCL specimen washed distil water followed by acetone and allowed to dry thoroughly and weighed accurately upto fourth decimal. Weighed specimen dipped in HCL for 1 day with different concentration of HCL.

Figure 4.8 Specimens for conventional weight loss test

Figure 4.9 Arrangement of beakers according to concentration of HCL
4.6 IMPACT TEST

In an impact test a specially prepared notched specimen is fractured by a single blow from a heavy hammer and energy required being a measure of resistance to impact. Impact load is produced by a swinging of an impact weight (hammer) from a height. Release of the weight from the height swings the weight through the arc of a circle, which strikes the specimen to fracture at the notch. Here it is interesting to note that height through which hammer drops determines the velocity and height and mass of a hammer combined determine the energy. Energy used can be measured from the scale given. The difference between potential energies is the fracture energy. In test machine this value indicated by the pointer on the scale. This energy value called impact toughness or impact value, which will be measured, per unit area at the notch.

Two types of impact test:
- Charpy impact test
- Izod impact test

4.6.1 CHARPY IMPACT TEST

Charpy impact testing involves striking a standard notched specimen with a controlled weight pendulum swung from a set height. The standard Charpy-V notch specimen is 55mm long, 10mm square and has a 2mm deep notch with a tip radius of 0.25mm machined on one face. In some circumstances, sub-size Charpy specimens can be tested with thickness less than 10mm. The specimen is supported at its two ends on an anvil and struck on the opposite face to the notch by the pendulum. The amount of energy absorbed in fracturing the test-piece is measured and this gives an indication of the notch toughness of the test material. The pendulum swings through during the test, the height of the swing being a measure of the amount of energy absorbed in fracturing the specimen. Conventionally, three specimens are tested at any one temperature and the results averaged. Alternatively, tests are carried out at a range of temperatures in order to generate a ductile to brittle transition curve.

Charpy tests show whether a metal can be classified as being either brittle or ductile. This is particularly useful for ferritic steels that show a ductile to brittle transition with decreasing temperature. A brittle metal will absorb a small amount of energy when impact tested; a tough ductile metal absorbs a large amount of energy. The appearance of a fracture surface also gives information about the type of fracture that has occurred; a brittle fracture is bright and crystalline, a ductile fracture is dull and fibrous.

4.2.2 IZOD IMPACT TESTING

It is an ASTM standard method of determining the impact resistance of materials. A pivoting arm is raised to a specific height (constant potential energy) and then released. The arm swings down hitting a notched sample, breaking the specimen. The energy absorbed by the sample is calculated from the height the arm swings to after hitting the sample. A notched sample is generally used to determine impact energy and not The test is similar to the izod impact test but uses a different arrangement of the specimen under test. The Izod impact test differs from the Charpy impact test in that the sample is held in a cantilevered beam configuration as opposed to a three-point bending configuration.
5.1 RESULTS OF WEAR TESTS:
The wear tests on the samples are carried out (considering the operating parameters of wear) i.e. by varying the sliding velocities, sliding distances and applied load. The effects of these parameters have been studied. Relationships between time with wear rate, Frictional force dependence of sliding distance etc. have been co-related.

Table no 5.1 tabular columns for wear test

<table>
<thead>
<tr>
<th>SL No</th>
<th>Sample Id</th>
<th>Load (N)</th>
<th>Time(mins)</th>
<th>Wear (microns)</th>
<th>FF(N)</th>
<th>COF</th>
<th>Initial Weights(gms)</th>
<th>Final weights(gms)</th>
<th>Weights loss(gms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sample 1</td>
<td>30</td>
<td>10</td>
<td>90</td>
<td>4.52</td>
<td>0.272</td>
<td>9.99821</td>
<td>9.99423</td>
<td>0.00398</td>
</tr>
<tr>
<td>2</td>
<td>Sample 2</td>
<td>30</td>
<td>10</td>
<td>64</td>
<td>8.16</td>
<td>0.314</td>
<td>9.21468</td>
<td>9.20921</td>
<td>0.00547</td>
</tr>
<tr>
<td>3</td>
<td>Sample 3</td>
<td>30</td>
<td>10</td>
<td>54</td>
<td>12.56</td>
<td>0.226</td>
<td>9.58762</td>
<td>9.58471</td>
<td>0.00291</td>
</tr>
</tbody>
</table>

Figure 5.1 Wear rate against time (seconds) for AL-2.5wt%Cu,1%wt Wc at applied load of 30 Newton.

Figure 5.2 Wear rate against time (seconds) for AL-6.5wt%Cu,3%wtWc at applied load of 30Newton.
5.2 RESULT OF CORROSION TEST

Table 5.2 Tabular columns for corrosion test for sample 1

<table>
<thead>
<tr>
<th>Concentration</th>
<th>Length (M)</th>
<th>Width (H)</th>
<th>Area (M²)</th>
<th>Initial weight (GM)</th>
<th>Final Weight (GM)</th>
<th>Weight difference</th>
<th>Corrosion rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01N</td>
<td>0.017</td>
<td>0.011</td>
<td>0.0154</td>
<td>4.7127</td>
<td>4.4775</td>
<td>0.2495</td>
<td>6.973µ</td>
</tr>
<tr>
<td>0.05N</td>
<td>0.014</td>
<td>0.0112</td>
<td>0.0156</td>
<td>5.0802</td>
<td>3.6583</td>
<td>1.4219</td>
<td>19.73µ</td>
</tr>
<tr>
<td>0.1N</td>
<td>0.014</td>
<td>0.011</td>
<td>0.0154</td>
<td>5.3109</td>
<td>2.8131</td>
<td>2.4978</td>
<td>29.772µ</td>
</tr>
</tbody>
</table>

Above graph shows that as the concentration increases corrosion rate increases and as the corrosion rate depends upon the concentration of HCL.

Table 5.3 Tabular columns for corrosion test for sample 2

<table>
<thead>
<tr>
<th>Concentration</th>
<th>Length (M)</th>
<th>Width (H)</th>
<th>Area (M²)</th>
<th>Initial weight (GM)</th>
<th>Final Weight (GM)</th>
<th>Weight difference</th>
<th>Corrosion rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01N</td>
<td>0.017</td>
<td>0.013</td>
<td>0.0122</td>
<td>8.2818</td>
<td>8.0030</td>
<td>0.2788</td>
<td>4.214µ</td>
</tr>
<tr>
<td>0.05N</td>
<td>0.0125</td>
<td>0.015</td>
<td>0.0143</td>
<td>5.7144</td>
<td>4.2266</td>
<td>1.4878</td>
<td>18.998µ</td>
</tr>
<tr>
<td>0.1N</td>
<td>0.0155</td>
<td>0.012</td>
<td>0.0186</td>
<td>6.7412</td>
<td>4.3185</td>
<td>2.4227</td>
<td>23.09µ</td>
</tr>
</tbody>
</table>

From the above graph we can see that as the concentration increases rate of corrosion also increases .we can see from the above graph that up to 0.05N corrosion rate increases .But for 0.1N corrosion rate will decrease.
<table>
<thead>
<tr>
<th>Concert ratios</th>
<th>Length(M)</th>
<th>Width(H)</th>
<th>Area (M²)</th>
<th>Initial weight(GM)</th>
<th>Final Weight(GM)</th>
<th>Weight difference</th>
<th>Corrosion rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01N</td>
<td>0.015</td>
<td>0.011</td>
<td>0.0165</td>
<td>6.2159</td>
<td>6.0122</td>
<td>0.2037</td>
<td>2.2669µ</td>
</tr>
<tr>
<td>0.05N</td>
<td>0.017</td>
<td>0.0121</td>
<td>0.0204</td>
<td>7.3986</td>
<td>5.7920</td>
<td>1.6066</td>
<td>14.45µ</td>
</tr>
<tr>
<td>0.1N</td>
<td>0.017</td>
<td>0.0121</td>
<td>0.0204</td>
<td>7.3382</td>
<td>4.9809</td>
<td>2.3593</td>
<td>21.21µ</td>
</tr>
</tbody>
</table>

Below graph shows that as the concentration increases corrosion rate increases. And also as the corrosion rate depends upon the concentration of HCL.

Figure 5.6 Corrosion rate for sample 3

5.3 IMPACT STRENGTH

SPECIFICATION

Specimen=55*12*12 in mm
Type of notch=v-notch
Angle of fall(α)=1350
Length of pendulum(r)=810*10^-3 m
Frictional loss=0J
Impact velocity(v)=(2gr(1-cosα))0.5 =5.2 m/s

Table no 5.5 Tabular columns for charpy impact test

<table>
<thead>
<tr>
<th>SL. No</th>
<th>Specimen</th>
<th>Initial reading (k₁) in J</th>
<th>Final reading (k₂) in J</th>
<th>Charpy impact value K=k₂-K₁ in J</th>
<th>Charpy impact strength I=K/(AL) in j/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sample 1</td>
<td>0</td>
<td>102</td>
<td>102</td>
<td>12.87*10⁶</td>
</tr>
<tr>
<td>2</td>
<td>Sample 2</td>
<td>0</td>
<td>120</td>
<td>120</td>
<td>15.15*10⁶</td>
</tr>
<tr>
<td>3</td>
<td>Sample 3</td>
<td>0</td>
<td>142</td>
<td>142</td>
<td>17.9*10⁶</td>
</tr>
</tbody>
</table>

6. CONCLUSION

The test is a simulation of real life application. Where the test was done under specified conditions of load and rotational speed of counter face disk, however wear in contacted surfaces is primarily due to the material removal by cutting and plowing actions, and in due course, wear grooves are generated. The depth and width of the grooves generally control the amount of material removed from the specimen surface. Corrosion test is done we found that the corrosion rate of alloy decreases and the factors effecting the corrosion rate are time and reinforcement. And in impact test we found that how the alloy behaves to the sudden load.

From this piece of experimentations following conclusions can be drawn.
Wear test: Wear is found to decrease with increase in copper and tungsten carbide content of the alloy. As the reinforcement increases, wear rate decreases.

Corrosion test: Corrosion rate increases with increases in the concentration of HCL. Corrosion rate increases with increases in time duration.

Impact test: Impact strength decreases with increases in reinforcement.

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