# Optimization of Wear by Addition of Silicon in Aluminium based alloy for Tribological Applications-A Review

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**ABSTRACT**

Zinc Aluminum Alloys over the past decayed are occupying attention of both researches and industries as a promising material for tribological applications. At this moment commercially available Zinc-Aluminum (ZA) alloys and bearing bronzes due to good cost ability and unique combination of properties. They can also be considered as competing material for cast iron, plastics and even for steels. It has been shown that the addition of alloying elements including copper, silicon, magnesium, manganese and nickel can improve the mechanical and tribological properties of zinc aluminum alloys. This alloy has still found limited applications involving high stress conditions due to its lower creep resistance, compared to traditional aluminum alloys and other structural materials especially at temperature above 100 degree Celsius. This has resulted in major loss of market potential for those alloy otherwise it is excellent material. Recently it has been shown that these problems can overcome to great extent by replacing Zinc with aluminum. Extensive research on the new alloys resulted in the development of ternary Al-40Zn-3Cu and Al-25Zn-3Cu and quaternary Al-40Zn-3Cu-2Si and Al-40Zn-3Cu-(1-3) Si alloys. They were found to be comparable to the zinc based commercial alloys as far as their specific strength and wear resistance are concerned but considerably higher ductility and dimensional change. In this paper there is discussion of the effect of Silicon on tribological properties of aluminium based Zinc alloy.

Keyword- Wear Properties, Taguchi Method, Pin- on -Disc machine

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## 1. INTRODUCTION

Wear which is one of the cause of material wastage, is an important problem associated with industrial components. Though wear resistance is not a materials property, an understanding of the dominant wear mechanism is very essential. The cost of wear to industry is high and the recognition of this fact lies behind the continuing development in the field of advanced materials, in order to provide a solution for mitigating tribological losses.

To know the nature and magnitude of coefficient of friction and the amount of wear undertaken by direct contact of Al-Zn alloy with metal counter surface EN31 steel disc. As wear depends totally on normal load and sliding velocity. It is necessary to evaluate experimentally and measure the corresponding friction and wear. The test to be carried out on under the various operating condition and controlled conditions. Here, Sliding Velocity, load and time, these three parameters were selected for experimentation. Experimentation is done by varying the speed from 200rpm to 600rpm, load varies from 30N to 90N and time from 30minutes to 90minutes. With view to generate new performance data we have chosen three alloy Such as Al-25Zn-2Cu-0.45Mn, Al-25Zn-2Cu-0.45Mn-2.5Si and Al-25Zn-2Cu-0.45Mn-5Si. Experiment are to be carried out on standard pin-on-disc machine at ambient temperature and under wet operating condition.

Whenever there is contact between solid bodies, surface phenomena, designated by friction and wear are developed. By friction we mean the resistance to the relative motion between bodies or sliding, open or closed loop, with dissipation of energy. The frictional force is tangential force that is common in the frontier of the bodies in contact. By wear it is understood the progressive lost material of the active surface of the body, by direct action of relative motion in that surface. These are phenomena that in general lead to loss of efficiency of the mechanical component where they occur, with relevant economical implication. This reason led to development of a large no. of studies on these types of problems. Therefore, precise knowledge of the influence of the mechanical parameters, the sliding velocity, load and the temperature of the contact, the wear and coefficient of friction is extremely important. The friction is the resistance to relative motion of contacting bodies. Similar to friction the wear behavior of a material is also very complicated phenomena in which various mechanism and factors are involved. Several types of wear are Scuffing wear, Abrasive and cutting wear, Fatigue wear, Corrosive wear, Erosive wear and Electrical arc-induced wear.

Compared to Aluminum, the Zinc alloys are harder and stronger, machined are more easily, have superior pressure tightness, and have substantially better wear and bearing characteristics.

Compared to copper, the most expensive of the common foundry alloys the lower inherent cost of zinc alloys combined with their lower densities can result in a material cost saving of up to 60 per cent. They also have higher as cast strength and hardness, and equivalent or superior machinability and wear resistance.

## 2. LITERATURE REVIEW

Sachin Ghalme, Ankush Mankar and Y. J. Bhalerao [1] states that The results of Taguchi analysis and confirmation experiments presents the optimum proportion of 8 % hBN in Si3N4 for minimization of wear loss against alumina counter-face. Thus, Taguchi method not only useful to plan experiments but helps to analyze the results of the experiments. From experimental results, S/N ratio and ANOVA it is clear that wear performance is a function of load and % of hBN. From this experimental analysis 15 N load and 8 % hBN is optimum to minimize wear volume loss of Si3N4 against alumina counter-face. It indicates load and % hBN has combined effect on wear volume loss. From confirmation experiments also it is clear that for 8 % hBN in Si3N4, wear volume loss increase with an increase in load. It also signifies that wear loss in Si3N4 is a function of load and % hBN addition.

S. M. H. Ahmer, L. S. Jan, M. A. Siddig, S. F. Abdullah [2] states that the variety of materials, in the forms of gas, liquid, or solid, were interposed between two surfaces in order to improve the smoothness of relative movement and to prevent damages to the surfaces. It was noticed that the variation of friction and wear rate depends on various interfacial conditions such as normal load, geometry, relative surface motion, sliding speed, surface roughness of the rubbing surfaces, type of material, system rigidity, temperature, relative humidity, lubrication, and vibration.

M. S. Charoo, M. F. Wani [3] states thatTribological studies conducted on nanodiamond particles mixed with conventional lubricants have proved effective in reduction of friction and wear in ceramics, under boundary lubricated conditions.

Oday I. Abdullah, Josef schlattmann [4] states that the sliding speed has a significant effect on the wear rate and the heat generated due to friction between parts of the sliding system. The surface temperature of the clutches depends on the sliding speed and the contact pressure. When the sliding speed increases the contact surfaces will be soft and the friction will decrease.

Dhananjay P. Narmala, Sahil Naghate, Sagar Hiswankar [5] studied that an alloying elements are selected based on their effect and Suitability. Aluminium and aluminum based alloys are light weight, having good malleability and formability, high corrosion resistance and high electrical and thermal conductivity. Microstructure can be modified and mechanical properties can be improved by alloying different elements such as Cu, Si, SiC, Ni, Mn, Mg etc. Copper has a greatest impact on strength and hardness of aluminium casting alloys. It improves machinability of alloys by increasing matrix hardness. Increase in wear resistance and hardness is provided by SiC addition. From pre-experimentation it is observed that the variation in wear shows linear with load, rpm and sliding distance and while in case of temperature wear shows decreasing.

Mohammad M. Khan, Gajendra Dixit [6] studied that wear rate is increased with load. The composites exhibits less wear rates as compared to its parent material i.e. the matrix alloy and cast iron in all the test environment conditions. Density of composites was least. Hardness and density of cast iron was highest among all samples. Testing the samples in oil plus lubricated conditions lead to less wear than that of matrix alloy. Friction coefficient is increased with test duration.

Sandeep Shejul, Y. R. Kharde [7] studied that Sliding distance (6.0%) has the highest influence on wear rate followed by sliding speed (60.00%) and applied load (5.00%) and for coefficient of friction, the contribution of applied load is (87.5%), sliding distance is (9.2%) and sliding speed is (1.7%) for Al+15% SiC+3% Gr+1Mg metal matrix composites. Applied load (58.05%) has the highest influence on wear rate followed by sliding distance (1.25%) and sliding speed (38.5%) and for coefficient of friction, the contribution of applied load is 87.5%, sliding distance is 9.2% and sliding speed 1.7% for Al+20% SiC+3% Gr+1Mg metal matrix composites.

S. Cartigueyen, K. Mahadevan [8] studied that the microhardness of Cu/SiCp microcomposites and nanocomposites are higher than those of FSPed and as-received Cu because of the grain refinement of a matrix and improved distribution of 12 µm and 50 nm SiCps in the matrix. Nanocomposite layers show higher hardness up to 189 HV, which is 13%, 84%, and 95% higher than microcomposite, FSPed Cu, and as-received Cu, respectively. The reduction in the wear rate was greater for Cu/ SiCp than FSPed Cu and as-received Cu because of the dispersion of SiCps as a hard ceramic phase in the Cu matrix. The nanocomposites exhibited superior wear resistance of 33%, 59%, and 78% more than microcomposites, FSPed Cu, and as-received Cu, respectively.

Parshant Kumar, V. K. Srivastava [9] studied that due to their low density, high thermal shock resistance, and good abrasive resistance, C/C–SiC composites can be used for clutch and braking systems. C/C–SiC composites show better tribological properties than grey cast iron and C/C composites. The tribological properties of C/C–SiC composites depend on many parameters. However, the nature of braking curve remains almost the same but the value varies. In brake discs, the pad material and composition greatly influence the tribological properties of C/C–SiC composite brakes. And in clutches, the material of mating disc greatly influences the tribological properties of C/C–SiC discs. Wear resistance can be highly improved by gradual increase of SiC from the centre to outer region or by using Si–SiC coatings on the outer surface.

L. Nirmala, C. Yuvaraj, K. Prahlada Rao, Seenappa [10] studied that the addition of nickel in the range of 1–3 wt. %, increases the tensile strength, yield strength and hardness of the developed alloys. The addition of nickel in Zn–Al alloys reported the formation of AlNi3, Zn, AlNi3 and Al0.403 Zn0.597 intermetallics. Which increases hardness of alloy. The decrease in ductility was due to formation of hard and brittle intermetallics. Impact energy absorbed will increase slightly with increase in nickel content.

Srinivas Athreya, Dr Y. D. Venkatesh [11] studied that the Taguchi's Method of parameter design can be performed with lesser number of experimentations as compared to that of full factorial analysis and yields similar results. Taguchi's method can be applied for analyzing any other kind of problems. It is found that the parameter design of the Taguchi method provides a simple, systematic, and efficient methodology for optimizing the process parameters. Osman Bican, Temel SavasKan [12] studied that the hardness and both tensile and compressive strength of the alloys increased with increasing silicon content but the trend reversed for the latter ones above 3% Si. It was observed that T7 heat treatment reduced the hardness and both tensile and compressive strength of the Al-40Zn-3Cu-3Si alloy but increased its elongation to fracture greatly.

Yasin Alemdag, Temelsavaskan [13] studied that the Hardness of ternary alloys increased continuously with increasing copper content, but their tensile strength decreased above 3% Cu. friction coefficient and temperature of the Al-40Zn-Cu alloy and bronze increased in the initial period of the run. This was followed by a reduction in the properties and attainment of constant levels afterwards. However Volume loss of the alloys increased rapidly at the beginning of the test run and reached almost constant levels after a sliding distance of approximately 400km. the Al-40Zn-Cu alloy were found to be much superior to the SAE 65 bronze as far as their wear resistance is concerned. Among the alloys tested, highest strength and wear resistance were obtained with the Al-40Zn-3Cu alloy.

Temel Savaskan, Osman Bican, Yasin Alemdag [14] studied that the highest hardness and tensile strength were obtained with the Al-25Znalloy among the binary ones. The microstructure of this alloy consisted of aluminum-rich and eutectoid phases. Addition of copper to this alloy resulted in the formation of $CuAl_2$Phase. The hardness of ternary alloy increased with increasing copper content. The highest tensile and compressive strength and wear resistance and lowest friction coefficient were obtained from the ternary Al-25Zn-3Cu alloy. The dimensional change measured on stabilization of this alloy was found to be much lower than obtained from the copper containing Zinc-based alloys.

Ahmet Truk, Mehmat Durman E [15] studied that The effect of manganese as an alloying element in the range 0.01%-0.53 wt.%, on the hardness, 0.2%yield, tensile and impact strength and creep properties of a gravity cast Zn-Al based ZA-8 alloy has been investigated. It was found that addition of Mn over the entire range of construction has been useful effect on the hardness of the alloy. also the 0.2% yield and ultimate tensile strength of the samples did not changes significantly with Mn addition up to 0.045 wt. % but decreased with a further increase in Mn content. Furthermore the impact strength of alloy improved with increasing Mn up to 0.045 wt. % and then decreased gradually with further increase in Mn Contents. On the other hand , the creep resistance of the alloy increased continuously with increasing Mn content up to 0.53 wt. %.

B.K. Prasad [16] studied that the observations made during the sliding wear response of zinc-based alloy in different test conditions. The wear rate samples increased with applied load and sliding speed while the seizure resistance deteriorated with speed. The Zinc based alloy exhibited less wear rate and reduced frictional heating than that of the cast iron while friction coefficient followed a reverse trend.

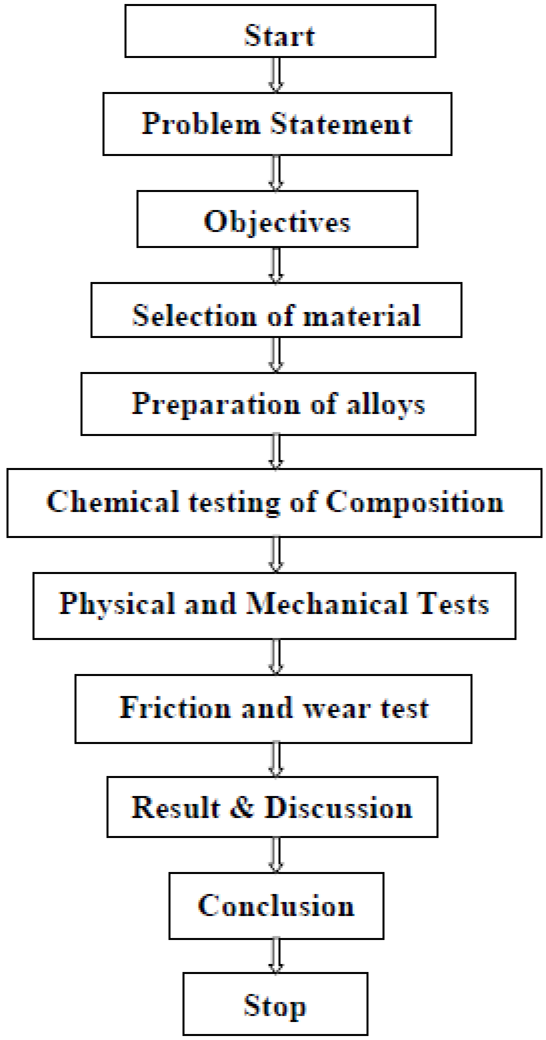
S. Basavarajappa, G. Chandramohan [17] studied that an attempt has been made to study the influence of wear parameters like applied load, sliding speed, sliding distance and percentage of reinforcement on the dry sliding wear of the metal matrix composites. A plan of experiment based on techniques of Taguchi method and was performed to acquire data in controlled way. An orthogonal array and the variance were employed to investigate the influence of process parameters on the wear composites. The objective is to establish a correlation between dry sliding wear of composites and wear parameters. These correlation were obtained by multiple regressions.

Tuti Yasmin, Asad A. Khalid, M. M. Haque [18] studied that Low expansion, low density and high resistance to corrosion at ambient temperature make the aluminum -Silicon alloys very suitable for wear resistance components in the automotive industry. The test variable were the rotational speed .input weight, and time/sliding distance. The extent of wear damage was estimated by means of weight loss technique. Silicon is added up to 5 percent to produce magnetically soft material for transformer, motor and generator, laminations. It increases the permeability of steel and reduces hysteresis losses. Silicon is present in the all steels.

Temel Savaskan, Ali Pas, Hekimoglu [19] studied that the hardness and strength of aluminum is not adequate for most of the engineering application but it forms the basis of a number of commercial alloys ZA families. It has been seen that the addition of alloying element including copper, silicon, magnesium and nickel can improve the mechanical and tribological properties of Zinc aluminum alloy. The zinc based alloy containing aluminum, copper and silicon have been shown to have low coefficient of friction and high wear resistance under lubricated sliding conditions. Copper was found more effective than silicon in increasing strength, but silicon showed that more power full effect on the wear resistance of the alloys. Zinc-Aluminum alloys containing both copper and silicon are gaining commercial importance as bearing materials.

M. Babic, R. Ninkovic [20] studied that the established level of tribological characteristics, both from aspect of wear and aspect of friction, show that Yugoslav Zn-Al alloys represent respectable tribological materials. Considering the simulated conditions of tribological interactions, results nominated these alloys as candidates for bearing's materials for conditions of limiting lubrication, that are characteristic for high loads and low sliding speeds. With respect to bronze they have better anti-frictional characteristics, higher resistance to wear and lower price costs.

## 3. FLOW CHART OF EXPERIMENTAL STUDY AND PROCEDURE




**1. Preparation of alloys**

The alloys are prepared from commercial pure aluminum (99.7%), high purity Zinc (99.9%) and electrolytic copper. Alloys were melted in an electric furnace at a temperature of 680 degree Celsius and poured in to a permanent mould at room temperature. The mould had conical shape with length of 155mm, bottom diameter of 70mm. Sample for microstructure examination were prepared using standard metallographic techniques etched with 3% of NaOH Solution.

**2. Chemical testing of Composition**

Approximately 1gm of the alloy sample is weighed out accurately in to an acid cleaned dry 200ml conical flask and the alloy is reacted with 30ml of 30% hydrochloric acid. After the reaction has almost stopped the mixture is gently heated and 5ml of concentric nitric acid are slowly added. The clear sample is cooled and transferred to a standard volumetric flask and to exactly 100ml with distilled water. Aliquots of this sample solution may be further, if necessary, in order to bring each metal in to the appropriate concentration range for measurement by atomic absorption spectrophotometer.

**3. Physical and Mechanical Tests**

The Density was determined by measuring their volume and mass. The hardness was measured with the help of Brinell hardness tester at load of 62.5-kgf and 2.5-mm dia. Steel ball as the indenter. Tensile and compression strength was measured by the Universal testing machine.

**4. Friction and wear test**

The wear test were carried out on single pin type "Pin-on –disc friction and wear monitor TR20", Ducom make, Bangalore. Tests were carried out at room temperature under dry operating condition. To avoid the rise in temperature at interface of pin and its counter plate material the sliding time level was set at $1/3^{rd}$ time for each setting time. Then the aggregate value of wear is summed up. The cylindrical pin flat ended specimen of size 12mm diameter and 25 mm length were tested against EN-31 steel disc material. The average surface roughness value Ra of disc before test was measure as 1.1 micron. Measurement of Ra value was obtained by using "Taylor-Hobson: Surtonic-10", Denmark instrument with least count of 0.1 micron.

The loading arm is supported in bearing arrangement to allow load to be applied the specimen. Frictional force is measure by digital red out for particular setup minimum and maximum value are wear noted.

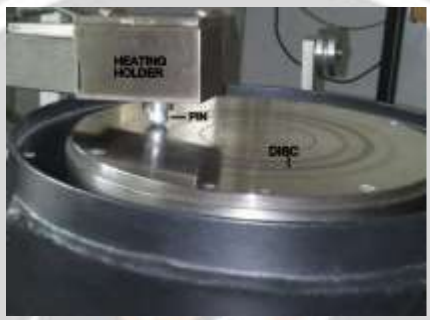



**Fig. 1**. Pin-on-disc wear tester.

## 4. CONCLUSION

From the literature survey following conclusions are drawn, Alloying elements are selected from literature survey based on their effects on wear and Suitability. Wear rate is increased with load and the composites exhibits less wear rates when compared with its parent elements. Aluminium and aluminum based alloys are light weight, having good malleability and formability, high corrosion resistance and high electrical and thermal conductivity. Microstructure can be modified and mechanical properties can be improved by alloying different elements such as Zn, Cu, Si, Ni, Mn, Mg, Tn. etc. Alloy of aluminium can be made available with above mentioned material with aluminium to form aluminium alloy. Copper has a greatest impact on strength and hardness of aluminium casting alloys. Alloy elements improves machinability of alloys by increasing matrix hardness when silicon added in to aluminium based alloy. Increase in wear resistance and hardness is provided by Si addition. From literature survey it is observed that the variation in wear shows linear with load, sliding velocity and time and Taguchi method not only useful to plan experiments but helps to analyze the results of the experiments.With respect to bronze aluminium alloy have better anti-frictional characteristics, higher resistance to wear and lower price costs. It was found that addition of Mn over the entire range of construction has been useful effect on the hardness of the alloy. We can add Mn in to the Al alloy up to 0.045% of Weight only.

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