Influences of Alloying Elements on the Tribological Properties of Aluminum Zinc Alloy Composite": A Literature Review

Dhananjay P.Narmala[1] Sahil Naghate[2] Sagar Hiswankar[3]
[1,2,3]Assistant Professor
[1,2,3]Department of Mechanical Engineering
[1,2,3]CSMSS's Chh.Shau College of Engineering, Aurangabad (M.S.), India

Abstract— Aluminium Zinc alloys are occupying attention of both researches and industries as a promising material for tribological applications. These are light weight having good malleability, formability, high corrosion resistance and high electrical and thermal conductivity. However pure aluminium alloys are having some problems such as relatively low strength, unstable mechanical properties. The microstructure can be modified and mechanical properties can be improved by alloying, cold working and heat treatment in these regards. These paper reviews the influences of alloying elements on the tribological properties of AZ alloy composite.

Key words: AZ Alloy, Aluminum Zinc Alloy Composite

I. INTRODUCTION

These AZ alloy are gaining huge industrial significance because of their outstanding combination of mechanical, physical and tribological properties over the base alloys. These properties include high specific strength, high wear and seizure resistance, high stiffness, better high temperature strength, controlled thermal expansion coefficient and improved damping capacity. These properties obtained through addition of alloy elements, cold working and heat treatment. Alloying elements are selected based on their effects and suitability. Tribological performance of Zn-Al alloy have been tested and applied in a variety of engineering applications. These alloys in general were found to be superior to the traditional bearing materials including bronze, cast iron, steel, plastics etc. as far as their high resistance to wear, high strength, low density, low cost, low coefficient of friction.

This alloy are having limited applications at high stress conditions due to its lower creep resistance, as compared to traditional aluminium alloys and other structural materials, especially at temperatures above 100^0C. This has resulted in a major loss of market potential for this alloy; otherwise it is an excellent material. The second important problem relating to zinc–aluminium alloys refers to dimensional instability, which is caused by the presence of metastable phases. In the real casting conditions the ZA alloys have the typical dendrite structure, wherein the dendrite size and interdendritic spacing depend on the casting parameters. The cooling speed imposes a strong influence on the grain size during the cooling. The consequences of the dendrite structure primarily result in lower ductility, as well as in relatively high heterogeneity of mechanical properties of the cast alloy. Recently, it has been shown that these problems can be overcome to a great extent by replacing zinc with aluminium.

The alloying elements may be classified as major and minor elements, microstructure modifiers or impurities, however the impurity elements in some alloys could be major elements in others. Also it has been shown that this problem could be reduced through alloying with different elements such as Cu, Si, SiC, Ni, Mn, and Mg etc. SiC was found to be an effective alloy addition towards improving mechanical and tribological properties of AZ alloys However, the effects of SiC content on friction and wear properties of these alloys have not been fully established. On this background the aim of this experimentation work was to investigate the effect of SiC on the friction and wear properties of AZ alloys and to decide the optimum SiC content for above properties.

II. LITERATURE REVIEW

From literature survey we found that they are engineering materials well suited to applications requiring high as-cast strength, hardness and wear resistance.

Temel Savas¸kan, Osman Bican, Yasin Alemdag[3], Zinc-based ternary and quaternary alloys have been proven to be good bearing materials. Their wear resistance was found to be considerably higher than that obtained from the traditional bearing materials including bronze and cast iron .However, the copper containing zinc-based ternary and quaternary Alloys suffer from dimensional instability and low ductility problems. The instability problem arises mainly due to the transformation of metastable e (CuZn4) phase into the stable T0 (Al4Cu3Zn) and g phases by a four phase reaction $(\varepsilon + \alpha \rightleftharpoons T' + \eta)$ and the low ductility was related to the brittleness of zinc and copper-rich phases. To eliminate or minimize these problems zinc was replaced with aluminium in these alloys and this resulted in the formation of stable h (CuAl2) particles instead of metastable e phase.

Pruthviraj R. D. [12], this paper describes the fabrication and testing of Zinc aluminium – based metal matrix composites (MMCs) reinforced with silicon carbide particles cast in sand moulds containing metallic (copper, steel and cast iron), chills respectively. SiC particles (of size 50-100 μm) are added to the matrix. The dispersoid added was in steps of 3 wt. % (from 3 wt. % to 12 wt. %). The resulting composites cast were tested for their strength, hardness and wear resistance. Micro structural studies indicate good and uniform bonding between the matrix and the dispersoid. Strength and hardness increase by up to 9 wt. % of the SiC content and is highly dependent on the location of the casting from where the test specimens are taken. In addition, the wear resistance (dry and slurry wear) is significantly affected by the strength and hardness of the composite developed. It was inferred that a small amount of SiC particles are sufficient to cause a fairly large change in mechanical properties. Several investigators have reported that the incorporation of hard particles such as Al2O3 or SiC in cast Zinc aluminium alloys improve the sliding, abrasive wear resistance of these alloys.

For sliding contact of materials under condition when the temperature of operation is high, oxidation of the materials plays a significant role, causing change of overall wear rate. The importance of oxidation during wear of metallic materials was first identified by Fink [14]. Archard and Hirst[15] proposed the classification of mild and severe wear based on Measurement of contact resistance, wear debris analysis and microscopic examination. The role of oxide scale was discussed extensively by Quinn [16] and Lim and Ashby [17] for ambient temperature wear. Subsequently a large volume of work was done on the elevated temperature wear of metallic materials. Most of the studies indicate the formation of glazed layers on the substrate under certain conditions of load, temperature and sliding speed.[18]

Mingwu bai, Qunji Xue [8]**,** Unreinforced AI-20Si-3Cu-1 Mg (ASCM) aluminium alloy and Sic particle reinforced AI-20Si-3Cu-1 Mg (ASCM-Sic) aluminium matrix composites were fabricated by powder metallurgy (P/M). The samples were slid against 4Cr13 stainless steel in a reciprocal friction tester under a load of 25 N to 175 N and sliding velocity of 0.3 to 1.2 m s-l at ambient conditions. The results show that SiC, particulate-reinforced aluminium matrix composites possess good wear resistance at dry sliding and less wear resistance under water lubrication. Ploughing wear is the dominant wear mechanism at dry sliding and tribochemical wear is dominant under water lubrication. SEM, XRD were used to examine the wear morphology and surface chemistry.

B.K. Prasad [1], the objective of the present investigation was to assess the influence of SiC particle dispersion in the alloy matrix, applied load, and the presence of oil and oil plus graphite lubricants on the wear behavior of a zinc-based alloy. Sliding wear performance of the zinc-based alloy and its composite containing SiC particles has been investigated in dry and lubricated conditions. Base oil or mixtures of the base oil with different percentages of graphite were used for creating the lubricated conditions. Results show a large improvement in wear resistance of the zinc-based alloy after reinforcement with SiC particles.

P.N. Bindumadhavan, Heng Keng Wah, O. Prabhakar[7], Al–Si–Mg alloy composites reinforced with up to 15 vol.% of SiC particles were prepared by the melt-stirring process. The wear behavior, under low loads, of the unreinforced Al–Si–Mg alloy and the metal matrix composites (MMCs) was investigated using a ball-on-disc test at room temperature under dry conditions. It was found that the maximum effective increase in wear resistance (ratio of percentage reduction in weight loss and volume percent of SiC added to achieve the reduction) occurred for the composite with about 7 vol.% SiC. Metallographic Investigations have revealed that the wear zone of the unreinforced alloy consisted of a hardened layer, in which fragmented Si phase was observed to be redistributed and aligned parallel to the wear direction. The delimitation of material from the hardened layer was responsible for higher wear loss observed in the unreinforced alloy. The thickness of the hardened layer formed on the MMC specimens (10–30mm as against 30–60mm in the unreinforced specimens) was reduced by the fragmentation of the incorporated SiC particles.

Nidhi Jha, Anshul Badkul, D.P. Mondal n, S. Das, M. Singh[11], The sliding wear behaviour of cenosphere-filled aluminum syntactic foam (ASF) has been studied in comparison with that of 10 wt% SiC particle reinforced aluminum matrix composite (AMC) at a load of 3 kg and varying sliding speeds under dry and lubricated conditions using a pin-on disc test apparatus. The tribological responses such as the wear rate, the coefficient of friction and the frictional heating were investigated. The wear surfaces and sub surfaces were studied for understanding the wear mechanism. It was noted that the coefficient of friction, the wear rate, and the temperature rise for ASF are less than that for AMC in both dry and lubricated conditions. The craters (vis-_a-vis exposed cenospheres) play an important role in the wear mechanism for ASF.

Temel Savaskan, Ali Pas¸a Hekimoglu [5], It was found that the tensile strength of the alloys increased, but their volume loss due to wear decreased with increasing copper content up to 2%. Above this level, the tensile strength decreased but the volume loss showed an increase. However the hardness of these alloys continuously increased with increasing copper content. This may be related to the effect of copper content on the hardness and tensile strength of the alloys. It is known that the wear loss is inversely proportional to their hardness and tensile strength. This means that as the hardness and strength of the alloys increase their wear loss should decrease. Since the hardness and tensile strength of these alloys increase with increasing copper content up to 2%, the wear loss decreased with increasing copper content up to this level. However above this level, the positive effect (i.e. reduced wear rate) of increased hardness was outweighed by the negative influence (high wear rate) of decreasing strength. This is probably why when the copper content exceeded 2%, marginal increase in wear loss was observed in the alloys. This indicates that the hardness and tensile strength of monotectoid-based zinc-aluminium-copper alloys have a strong effect on their wear resistance.

Yasin Alemdag,Tamel Savaskan [2], Hardness of the 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 alloys and bronze increased in the initial period of 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 alloys 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.

The hardness of the ternary alloys increased with increasing copper content. The highest tensile and compressive strengths and wear resistance and the lowest friction coefficient were obtained from the ternary Al–25Zn–3Cu alloy. The dimensional change measured on ageing (stabilization) of this alloy was found to be much lower than that obtained from the copper containing zinc-based alloys.

Temel Savas¸ kan, Ali Pas¸ a Hekimoglu, Genc¸ aga Purcek [13], One binary zinc-aluminium monotectoid and five ternary zinc-aluminium-copper alloys were produced by permanent mould casting. Their wear properties were examined using a block-on-ring test machine. Hardness, tensile strength and percentage elongation of the alloys were also determined and microhardness of aluminium-rich a phase was measured.It was observed that the hardness of the alloys increased continuously with increasing copper content up to 5%. Their tensile strength also increased with increasing copper content up to 2%, but above this level the strength decreased as the copper content increased further. Microhardness of the aluminium-rich a phase was also affected by the copper content in a manner similar to that of the tensile strength. It was found that the wear loss of the alloys decreased with increasing copper content and reached a minimum at 2% Cu for a sliding distance of 700 km.

III. EXPERIMENTAL PROCEDURE

A. Preparation of Alloy

The alloys were prepared from commercially pure aluminum (99.7%), high purity zinc (99.9%) and electrolytic copper (99.9%). The liquid metallurgy technique was used to prepare composite specimens.This method is most economical to fabricate composites with discontinuous fibers or particulates. In this process, matrix alloy (Al-2219) was firstly superheated over its melting temperature and then temperature was lowered gradually below the liquidus temperature to keep the matrix alloy in the semi-solid state. At this temperature, the preheated SiC particles were introduced into the slurry and mixed. The composite slurry temperature was increased to fully liquid state and automatic stirring was continued for 5 min at an average stirring speed of 300~350 r/min. Alloys were melted in an electrical furnace and poured at a temperature of 750^{0}C in to a steel mould at room temperature.The melt was then superheated above liquidus temperature and finally poured into the cast iron permanent mould of 15 mm in diameter and 150 mm in height.

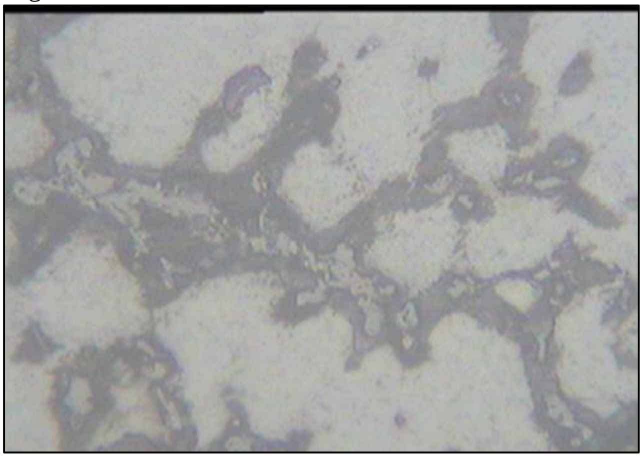

Fig. 1(a): Microstructure of Al - 25 Zn-2.5 Cu- 6 % SiC

Figure 1 (a) shows precipitated Si-Mg phase in solutionised matrix. The precipitated phase is in acicular form and no modification of precipitated phase is observed. Small pin holes are observed. Precipitated phase is in small quantity as compare to other two samples as %SiC is low.

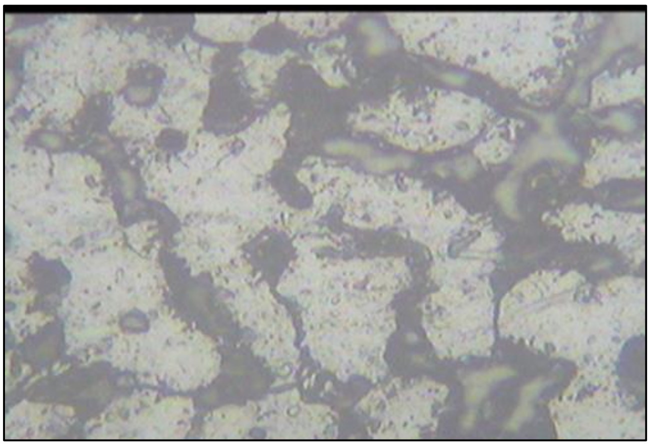

Fig. 1(b): Microstructure of Al - 25 Zn-2.5 Cu- 9 % SiC

Figure 1 (b) shows precipitated Si-Mg phase in solutionised matrix. The precipitated phase is in acicular form and no modification of precipitated phase is observed. Small pin holes are observed. Precipitated phase is in medium quantity is observed as compare to other two samples as %SiC is in medium amount.

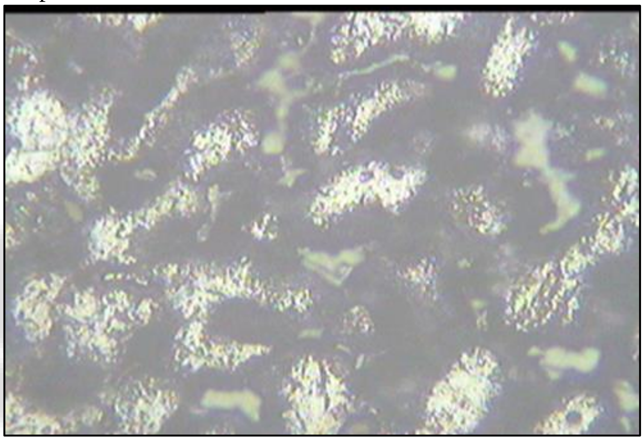

Fig. 1(c): Microstructure of Al - 25 Zn-2.5 Cu- 12 % SiC

Figure 3 (c) shows precipitated Si-Mg phase in solutionised matrix. The precipitated phase is in acicular form and no modification of precipitated phase is observed. Small pin holes are observed. Precipitated phase is in large quantity is observed as compare to other two samples as %SiC is in large amount.

B. Effect of Load, Rpm, Temperature and Sliding Distance

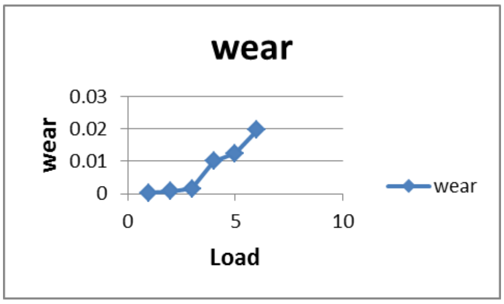

Fig. 2: Variation of wear with load

In the pre- experimentation for the study of dry wear on AZ alloy; the relationships of load, rpm,temperature and sliding distance versus wear and keeping all other remaining parameters constant is observed. The wear varies with load, rpm, temperature and sliding distance. The load varies from 1 kg to 6 kg by keeping sliding distance, temperature and rpm as constant. Rpm varies from 100 to

600 by keeping load, temperature and sliding distance constant. The temperature varies from atmosphere temperature to 400˚c by keeping load, rpm and temperature as constant. The sliding distance varies from 1 km to 6 km by keeping load, temperature and rpm as constant. The variation in wear shows linear with load, rpm and sliding distance while in case of temperature it decreases.

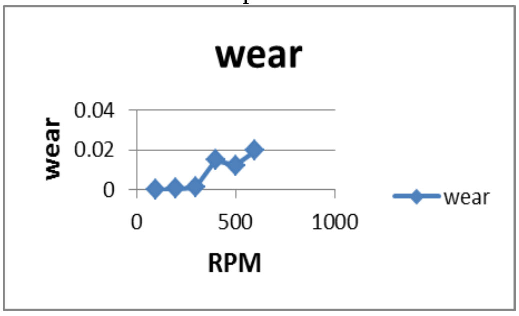

Fig. 3: Variation of wear with rpm

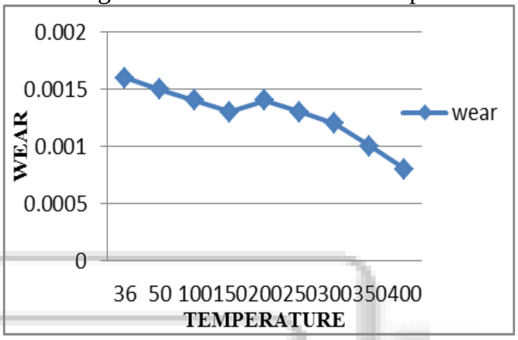

Fig. 4: Variation of wear with temperature

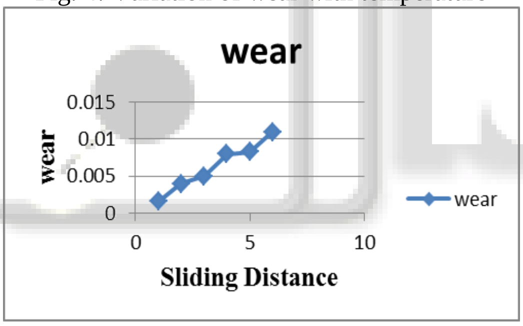

Fig. 5: Variation of wear with sliding distance

IV. Conclusion

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. However further detailed experimentation is to be carried out for precise prediction of behavior of wear for above said variable parameters.

References

[1] B. K. Prasad, "Dry sliding wear response of zinc-based alloy over a range of test speeds & loads: a comparative study with cast iron", Tribology Letters, 2007, Vol, No. 25, 103-115.
[2] YasinAlemdag˘, TemelSavas-kan, "Mechanical and tribological properties of Al–40Zn–Cu alloys", Tribology International, 2009, Vol.no.42, 176– 182.
[3] Temel Savas¸kan, Osman Bican, Yasin Alemdag, "Developing aluminium–zinc-based a new alloy for tribological applications", J Mater Sci, 2009, Vol.no.44, 1969–1976.
[4] Osman Bican , Temel Savas¸kan, "Influence of Test Conditions on the Lubricated Friction and Wear Behaviour of Al–25Zn–3Cu Alloy", Tribol Lett, 2010,Vol.no. 37,175–182.
[5] Temel Savaskan, Ali Pas¸a Hekimoglu, "Effect of copper content on the mechanical and sliding wear properties of monotectoid-based zinc-aluminium-copper alloys", Tribology International, (2004), Vol.no.37, 45–50.
[6] Temel Savas-kan, OsmanBican , "Dry sliding friction and wear properties of Al–25Zn–3Cu–3Si alloy" Vol.no.43 (2010)1346–13.
[7] P.N. Bindumadhavan, Heng Keng Wah, O. Prabhakar_, "Dual particle size (DPS) composites: effect on wear and mechanical properties of particulate metal matrix composites". Vol.no.248 (2001) 112–120.
[8] Mingwu Bai and Qunji Xue, "Investigation of wear mechanism of particulate-reinforced Al-20Si-3Cu-1Mg aluminium matrix composites under drysliding and water lubrication". Vol no 30(1997), 261-269.
[9] S. Basavarajappa, G. Chandramohan, "Wear studies on metal matrix composites a taguchi approach" Vol.no.21(2005) 845-850.
[10] P. P. Ritapure, U. N. Gujar, Dr. Y.R.Kharde, Dry Wear Behaviour Studies of Al 25Zn–2Cu-(0-5) Si Alloy: a Taguchi Approach,(2012)1-12.
[11] Nidhi Jha, Anshul Badkul, D.P. Mondal n, S. Das, M. Singh,Sliding wear behaviour of aluminum syntactic foam: A comparison with Al–10 wt% SiC composites,Vol.44 (2011) 220–231.
[12] Pruthviraj R. D. "wear characteristics of chilled zinc-aluminium alloy reinforced with silicon carbide particulate composites" Vol. 1 (2) may (2011),17-24.
[13] Temel savas¸kan, ali pas¸ a hekimoglu, gencaga purcek, "effect of copper content on the mechanical and sliding wear properties of monotectoid-based zinc-aluminium-copper alloys".Vol 37 (2004) 45–50.
[14] Fink M. Trans Am Soc Steel 1930;18:1026.
[15] Archard JF, Hirst W. Proc R Soc A 1956;236:397.
[16] Quinn TFJ, Sullivan JL, Rowson DM. Wear 1984;94:175.
[17] Lim SC, Ashby MF. Acta Mater 1987;30:1.
[18] Stott FH. Tribol Int 2002;35:489.