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AL–ADDITION INFLUENCE ON TRIBOLOGICAL PROPERTIES OF ZN–BASED ALLOYS

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ABSTRACT

The alloys of different weight percentage of Al–namely, 8, 12, 27, 33, 40 and 48 wt.% are produced by conventional melting and mould casting route. The effect of different Al–weight percentage on the tensile properties, hardness and wear behavior of Zn–based alloys is investigated. Higher strength is obtained by increasing Al–weight, however, the ductility decreased. Zn–Al alloys showed a reduction in strength and increase in ductility with increasing temperature. Increasing Al–weight from 33% to 48% results in improvement of ultimate strength and percent elongation at room and elevated temperatures. Higher hardness is obtained by increasing Al–weight percentage. In addition, the wear resistance increased with the increase of Al–weight percentage and weight loss increased with increasing loads. The improved wear resistance of the Zn–Al alloys is due to change in the microstructure of the Zn–based alloys as the Al–weight percentage increases.

KEYWORDS: Zn–Based Alloy, Ultimate Strength, Ductility, Hardness, Friction Coefficient and Wear

INTRODUCTION

Zn–Al based alloys have been used for many years in various engineering and industrial applications. Barnhurst (1983) points out the extensive usage of these alloys in the production of small components and to a certain extent for plain bearings.

Hypoeutectic Zn–Al alloys have been used since 1930 [1, 2]. These alloys are based on the hypoeutectic Zn–4Al composition. The alloys are used primarily for die casting applications due to their superior properties. They display excellent castability, easy finishing, are economical and possess good mechanical strength. With such properties they are used for a wide range of decorative and light structural parts and lend themselves readily to repair mass techniques. These alloys feature clean, low-temperature, energy–saving melting, excellent castability, high strength and equivalent or often superior bearing and wear properties as compared to standard bronze bearing [3]. These factors account for their widespread use in the automotive industry. The range of zinc-aluminum alloys was expanded in the last thirty years by the introduction of a series of hypereutectic zinc-aluminum alloys referred foundry or "ZA" alloys. Zhu et al. (1994) indicates that the alloys are used for the production of gears and bushings in textile and automotive industries.

In 1962, the International Lead Zinc Research Organization (ILZRO) introduced ILZRO 12 (as ZA-12) [1]. In the late 1970s, the Noranda Research Centre developed two additional alloys, ZA-8 and ZA-27). The alloys were developed to compete with other mature alloy systems, such as brasses, bronzes, aluminum-based alloys and cast iron.

One of the major limitations of Zn-based alloys is the deterioration of their mechanical and wear resistance properties at temperature exceeding 90 ^{o}C. This problem has been suggested to be reduced through alloying with different elements like Mg, Cu and Si.

Aluminum is one of the major alloying elements in Zn alloy systems where it imparts fluidity to the alloys [4, 5]. In practice, the amount of Al added to Zn-based alloys in order to attain good engineering properties varies widely. It was found that wear resistance was obtained by increasing Al–weight percentage [6]. However, most of investigations were made on Zn-based alloys with the Al–weight percentage lower than 27% and little study has been done on the high aluminum Zn-based alloy with Al–weight percentage higher than 30% [7–13].

Nowadays the journal bearings produced from these alloys have been used particularly in high load and low speed applications such as earthmoving equipments, mining and milling machines, cable winches, ….. etc. [14, 15]. Zn-based commercial alloys have good mechanical and tribological properties and therefore they are used in many engineering applications. In addition, the mechanical properties and corrosion resistance of these alloys may be further improved by controlling their microstructures [16–21].

The effect of different Al–weight percentage on the mechanical and wear properties of Zn–based alloy containing 2.5% Cu and 0.03% Mg has been studied by Prasad et al. [4]. Wear test results showed that at a speed of 0.42 m s^{-1}, the alloy having 27.5 wt.% Al performed best prior to seizure. However, alloys with higher Al–weight percentage up to 47.5 wt.% exhibited improved seizure resistance.

MATERIALS AND METHODS

Zinc–Aluminum alloys were prepared with different weight percentage of Aluminum (8, 12, 27, 33, 40, 48 wt%). The investigated Zn–Al alloys are prepared from high purity zinc (99.9%) and commercially pure aluminum (99.7%) by permanent mould casting. The molten alloys are poured at the temperature approximately 50^{o}C above its liquidus line into a cast iron mould at room temperature. The mould is designed in the form of rectangular shape of 30*40*200 mm in height for proper feeding and directional solidification. Samples of different dimensions were cut for different tests. Wear behavior of different composition samples were studied by conducting several wear tests on computerized friction and wear monitor pin on-disc wear test machine. The hardness was measured with the Vickers hardness testing machine. The tensile properties were obtained by conducting tensile tests on universal testing machine.

The tensile tests are performed on round specimens having diameter of 5 mm and gauge length of 25 mm at a nominal strain rate of $3.333*10^{-4}$ s^{-1}. Tensile properties of the alloys were analyzed by carrying out test on the universal testing machine. During the tests, the load elongation data is captured by induced software, whose data is used for further analysis. Three specimens are used to determine the tensile strength of each alloy. The hardness of all the samples has been done using a Vickers hardness testing machine. The applied load during the testing was 100 N, with a dwell time of 10 s. It has a square-base diamond pyramid indenter. Ten hardness readings are taken at different location to circumvent the possible effects of particle segregation.

Computerized pin on disc wear test machine was used for the wear and friction tests of alloy samples under different loads from 10 N to 1000 N and linear speed of 0.65 m s^{-1} for one hour. The rotating disc was made of carbon steel of diameter 50 mm and hardness of 64 HRC. The alloys samples were held stationary and a required normal load was applied through a lever mechanism. Wear resistances are measured by a weight loss using a four digital microbalance. Each wear sample is ultrasonically cleaned and weighed before the wear test using a balance with an accuracy of 0.01 mg. Three samples for each condition are tested and the average of the weight loss measurements is used for calculation of the wear property.

RESULTS AND DISCUSSIONS

Tensile Properties

Figures (1–2), represent the tensile and the elongation percent at room and elevated temperatures for the investigated Zn–Al alloys.

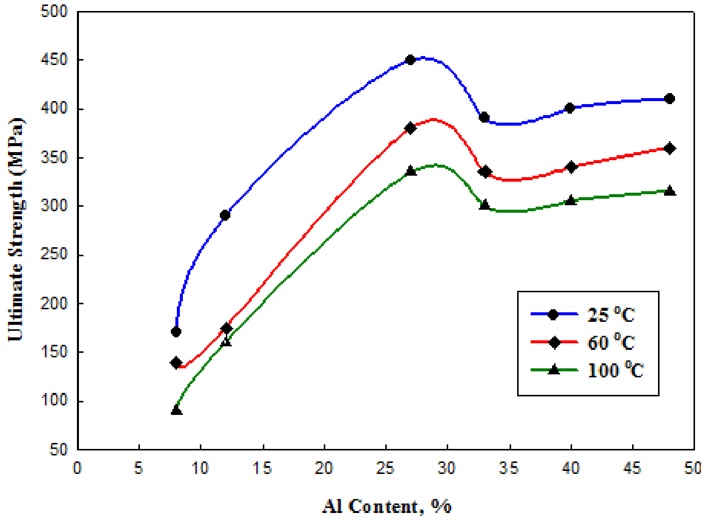

Figure 1: Effect of Al–Weight on the Ultimate Strength of Zn-Based Alloy at Different Temperatures

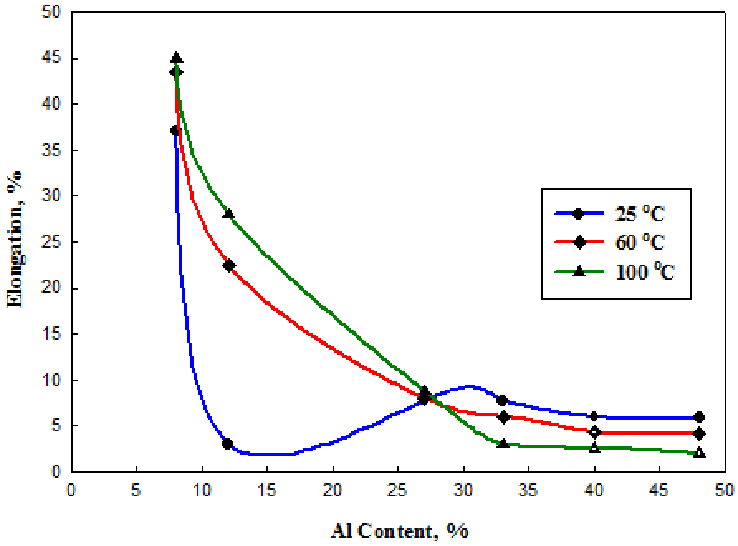

Figure 2: Effect of Al–Weight on the Percent Elongation of Zn-Based Alloy at Different Temperatures

It can be noted that increasing of Al–weight leads to a significant increase in the ultimate strength at room and elevated temperatures, but, the elongation percent decreases. This could be attributed to the replacement of η–Zn rich dendrite by α–Al rich phase and increasing the amount of α+η eutectoid as the Al–weight increases, which also leads to an increasing in thermal stability of the Zn–Al alloys. Enhancement in the elongation with temperature can be attributed to a higher level of plasticity of the alloys with increasing temperature. It can be noted that higher strength and elongation properties are obtained with the alloy having 27 wt % Al.

Hardness

The values of hardness of the investigated alloys are between 66 Hv and 127 Hv as shown in figure (3). When the Al–weight percentage increases, the hardness of the tested alloys increases due to the increase in α−Al dendrites and the decrease in (α+η) eutectoid. Increasing Al–weight percentage results in increasing the hardness due to the change in the microstructure from coarse η-Zn rich dendrite and α+η eutectoid colonies to finer η-Zn rich constituent with more eutectoid.

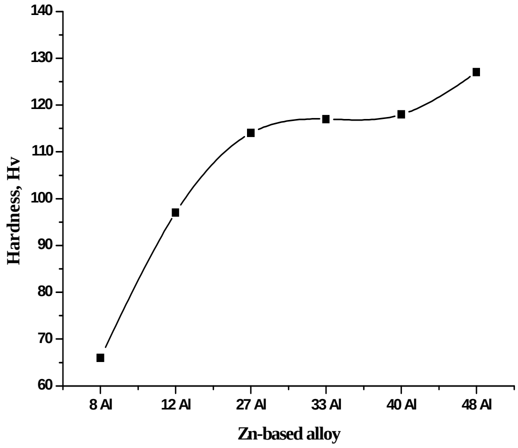

Figure 3: Effect of Al–Weight Percentage on the Hardness of Different Zn–Al Alloys

Wear Behavior

Figure (4) represents the weight loss of the different Zn–Al alloys against the applied loads at constant sliding speed of 0.65 m s^{-1}. The weight loss increases with increasing the applied load. It is interesting to note that the wear resistance enhances with increasing Al–weight percentage. The alloy with 27 wt.% Al shows the higher wear resistance at all loads.

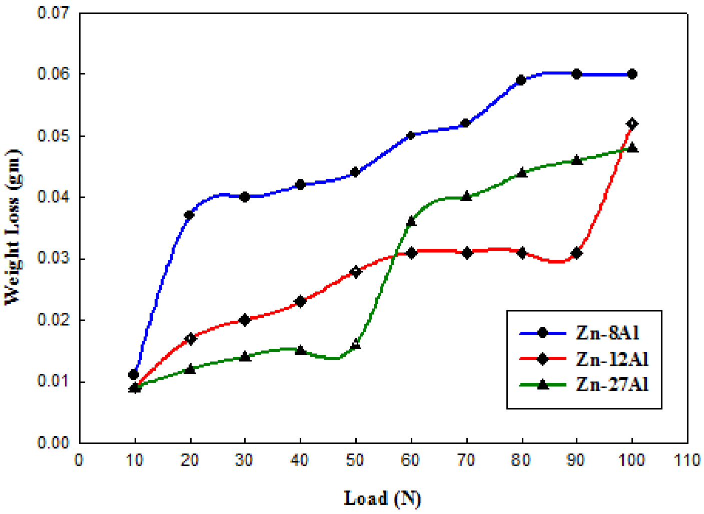

Figure 4: The Relationship between Weight Loss and Loads of Different Zn–Al Alloys

Figure (5) represents the weight loss of the different Zn–Al alloys against the applied loads at the constant sliding speed of 0.5 m·s^{-1}. It can be considered that it is quite natural for the wear rate to increase with load. The ZA27 alloy shows the higher wear resistance at all loads. As the Al–weight percentage is higher than 33% the weight loss decreases with the increase in Al–weight percentage.

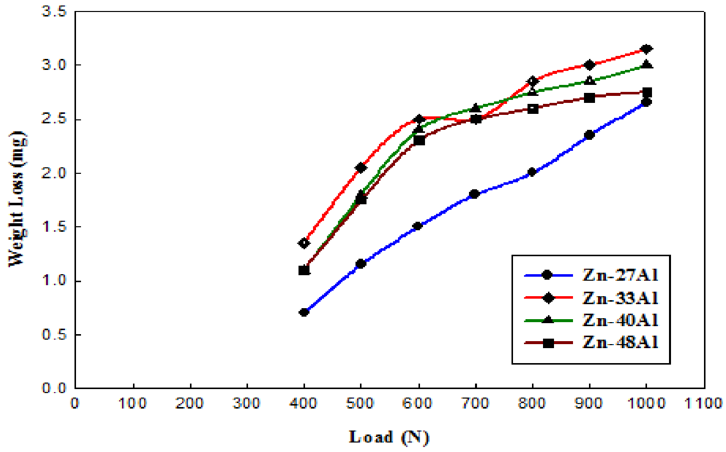

Figure 5: The Relationship between Weight Loss and Loads of Different Zn–Al Alloys

CONCLUSIONS

- Increasing Al–weight from 8% to 27% wt results in a significant improving in ultimate at room and elevated temperatures of the Zn–based alloys.
- The Zn–Al alloys exhibit a decrease in tensile strength and enhancement in elongation with increasing the test temperature from room temperature to 100 °C, irrespective of their Al–weight.
- The alloy with 27% Al shows the higher ultimate strength and elongation percent at room and elevated temperatures.
- The hardness of Zn–Al alloys increases with increasing the Al– weight percentage from 8 to 48 wt.%.
- The alloy with 27% Al exhibits the higher wear resistance at low load. These results can be attributed to the better tightness of ZA27 than the alloy with high Al–weight percentage above.

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