The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)
ISSN: 2602-3199

The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 2019

Volume 7, Pages 136-140

IConTES 2019: International Conference on Technology, Engineering and Science

Effect of Stirring on the Microstructure and Mechanical Properties of ZAMAK-12 Alloy

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Abstract: Zinc alloy ZAMAK-12 was melted in an induction melting process. The melted alloy was stirred mechanically at 400±10 ^{o}C for 5 minutes using a cast iron mixer. The speed of stirring was 1500 rpm. After stirring the melt was casted in a mold made from graphite immediately and quenched with water. The microstructures of unstirred and stirred samples were investigated with optical microscopy. The hardness' of samples were measured with Vickers indenter. The strengths of samples were determined by compression testing. The microstructural investigations showed that both stirred and unstirred ZAMAK-12 alloys have a dendritic microstructure. But, the grain size of Al-rich dendrites was finer and longer into the stirred samples. The hardness of stirred ZAMAK-12 was slightly higher than unstirred alloy. The compression yield strength and Elastic Modules of the stirred sample was lower than unstirred alloy, whereas the compression yield strain of the stirred alloy was higher.

Keywords: Zinc based alloys, Microstructure, Strength, Hardness

Introduction

Zinc based alloys are very attractive engineering materials due to their low density, very good cast ability, low energy consumption for shaping, low cost and intermediate strength and hardness etc. (Prasad et al. 1996, Pürçek et al. 2002). The commercial zinc based alloys called as ZAMAK, ALZEN and ZA are binary Zn-Al alloys and include small amounts of Cu. These alloys are based on Zn-Al eutectic, eutectoid or monotectoid composition. (Savaşkan et al. 2004).

Although their poor strength and hardness the Zn-Al alloys have been used widely in a variety of industry due to their excellent fluidity. With these alloys very thin walled and complex shaped parts can be casted using gravity or pressure die casting with/without heating the mold (Hanna et al. 1997). In recent years some works have been made intend to improve the strength and hardness of Zn-Al alloys. In these studies, some authors suggested the alloying of Zn based alloys (Prasad et al. 1996, Savaşkan et al. 2004, Pürçek et al. 2002, Hanna et al. 1997, Şevik 2014), whereas some of them suggested to reinforce the alloy with particulates or fibres (Pola et al. 2016, Li et al. 2001, Tao et al. 1995, Xu et al. 2014, Alaneme et al. 2017, Madronero et al. 1997,Almomani et al. 2016,Liu et al. 2009).

In addition to low strength and hardness low using temperature compared to other metallic materials limits the use of Zinc based alloys. Beside these properties, the Zn based alloys have been found to be an alternative material to bronzes which are used in tribological applications. It is reported that, Zn based bearings have good wear and seizure resistance, and lower coefficient of friction than bronzes under heavy load and slow to medium friction speed conditions. (Prasad et al. 1996).

Further studies have been focused on the increasing the hardness, strength and wear resistance of zinc based alloys. Abou El-Khair et al. (2004) investigated the effects of Al content on the properties of the Zn-Al binary alloys. They reported that hardness, strength, and wear resistance of alloy is increased with increasing Al

- Selection and peer-review under responsibility of the Organizing Committee of the Conference content, however ductility was degreased. Furthermore, the strength is degreased and ductility is increased with increasing temperature for Zn-Al binary alloys. Higher strength at elevated temperature was also observed with increasing Al content.

Türk et al. (2007) modified the ZA8 commercial alloy with Pb, Sn, and Cd. The samples were subjected to the wear tests and the results were compared with commercial SAE 660 bearing bronze. They found that ZA8 and modified ZA8 alloys have higher wear resistance, but also higher coefficient of friction than bearing bronze.

On the other hand, Savaşkan et al. (2014) investigated the effects of Cu and Si on the Zn-Al alloys. They increased the Si and Cu content systemically while the Al content was 15%. They found that the hardness, tensile, and compressive strength are increased whereas the elongation and impact energy were decreased with increasing Copper content for Zn-Al-Cu ternary alloys. For Zn-Al-Cu-Si quaternary alloys, the hardness and compressive strength were increased while the tensile strength, elongation, and impact energy were decreased with increasing Si content.

In this study, zinc alloy ZA12 was stirred mechanically at a temperature which was between liquidus and solidus, and subsequently quenched using water. The effect of stirring on the microstructure and mechanical properties of alloy was investigated.

Method

Zinc alloy ZAMAK-12 was produced by an induction melting furnace at the nominal composition of 88%Zn, 11.0%Al and 1.0%Cu (wt%). Firstly, Zn was melted, then Al was added, finally Cu was dissolved in the melt. The melted liquid was stirred slowly using a steel rod. After obtain a homogenous mixture the alloy was gravity casted into a graphite mold and quenched under running water. Then, the pre-casted ZAMAK-12 alloy was remelted by induction melting again and stirred mechanically at 400±10 ^{o}C for 5 minutes using a cast iron mixer. The speed of stirring was 1500 rpm. After stirring was completed the melt was casted into a graphite mold and quenched immediately using running water. The alloy has liquid and solid phases at the stirring temperature (Figure 1). The stirring was carried out to break up the primer solids and the quenching was applied to prevent grain coarsening. The casted samples were in the rod form with diameter of 8mm.

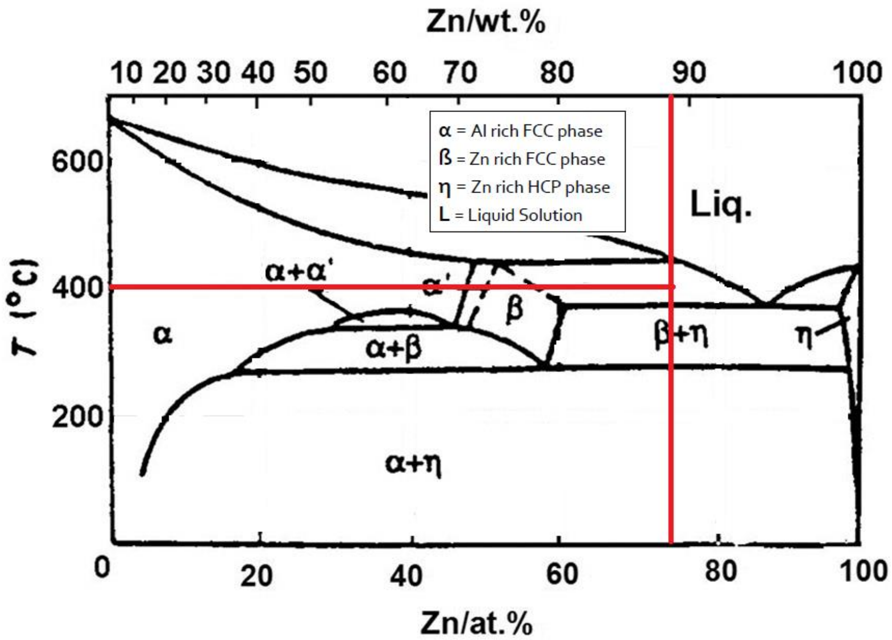

Figure 1. Al-Zn phase diagram

The alloys that are stirred and un-stirred were characterized in terms of the microstructural and mechanical properties. The microstructures of alloys were examined using optical light microscopy and the mechanical properties were determined by compression test and the hardness measurements. The compression tests were carried out at ambient temperature with crosshead rate of 10 mmmin^{-1}. Three test were done for each alloy. The hardness of the samples was measured using Vickers indenter under 300gf load at 15s duration. The hardness values were determined from mean of 5 measurements for each alloy.

Results and Discussion

The light optical micrographs of the as-cast and stirred alloys in different magnifications were given in Figure 2. From the micrographs, it is seen that both as-cast and stirred alloy have a dendritic microstructure. However, when compared with the as-cast structure the dendrites in the stirred alloy are longer and thinner. The primer Zn rich FCC □□solid phase was broken when stirring at 400 ^{o}C, and as a result, since □ transforms to Al rich FCC □ phase with cooling, the final grain size of □ was finer. On the other hand, while as-cast alloy has a smooth microstructure without pore, in the stirred alloy some pores were observed. These pores are result of stirring.

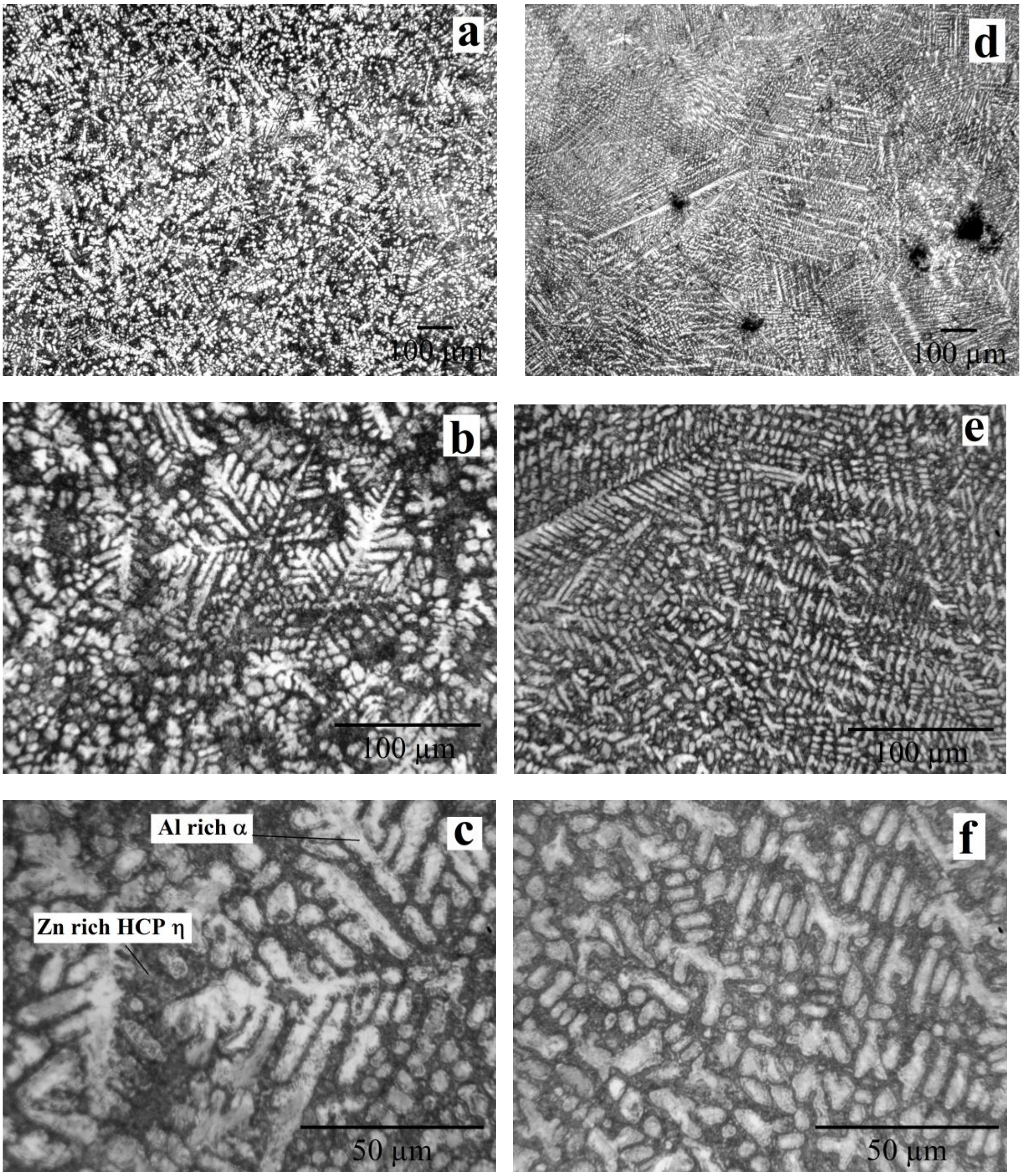

Figure 2. Light optical micrographs of the as-cast (a, b, and c) and stirred (d, e, and f) alloys at different magnifications

The mechanical properties of as-cast and stirred alloys are summarized in table 1, and figure 3 shows the compression test diagram. The hardness of stirred ZAMAK-12 was slightly higher than unstirred alloy. The compression yield strength and Modulus of Elasticity of the stirred sample are lower than unstirred alloy, whereas the compression yield strain of the stirred alloy was higher. Generally, hardness and strength are increase with reduction in grain size for metallic materials. The pores formed in the stirred alloy might be responsible for reduction in strength.

Table 1. Mechanical properties of the as-cast and stirred alloys

ZAMAK-12	Hardness (HV)	Compression Yield Strength, (MPa)	Compression Yield Strain, (%)	Elastic Modulus, (GPa)
As-cast	81	374	0,51	73
Stirred	86	332	0,56	59

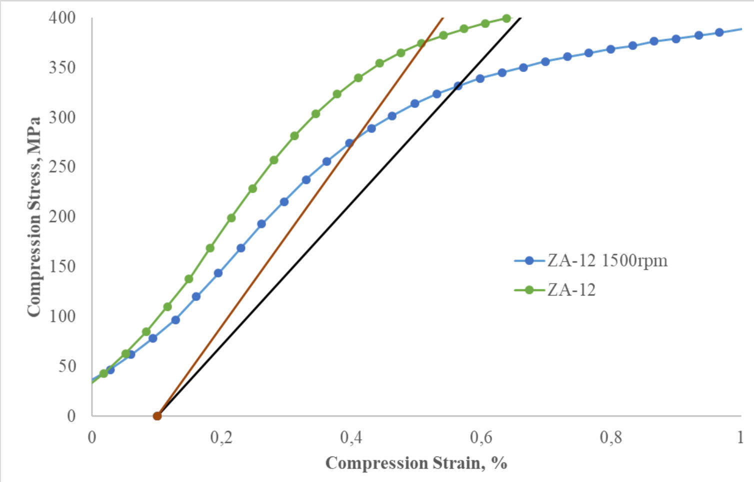

Figure 3. Compression tests of the alloys

Conclusion

The microstructure of ZAMAK-12 alloy is affected by stirring. When the alloy is stirred between solidus and liquidus temperature, the primary solid phase is broken and final grain size of dendrites is finer. The microstructural evaluation effects the mechanical properties. The finer grain size increases the hardness and yield strain, whereas it decreases the yield strength and Modulus of Elasticity.

Recommendations

The effect of the stirring on the sliding friction and wear behavior of ZAMAK-12 ally should be investigated. Because, the microstructural evolution and different mechanical properties may affect the friction and wear behavior.

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