

Effect of Yttrium, Holmium and Zirconium on Microstructure and Mechanical Properties of Aluminium LM30 Alloy

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Abstract

The application of aluminium alloy in automotive and aerospace industries has supported the need to study the effect of rare earth elements on aluminium alloys. In this study, the effect of the rare earth element Yttrium (Y), Holmium (Ho) and Zirconium (Zr) on the microstructure and mechanical properties of the Aluminium alloy was reviewed. The case study method was conducted by referring from previous researches and journal articles. In the selected references, from the experiments that were conducted using optical microscopy (OM), scanning electron microscopy coupled with electron dispersive spectroscopy, Tensile test and Vickers Hardness test showed that the addition of Yttrium and Holmium in different amounts improved the grain size, Ultimate Tensile Strength and hardness value of the aluminium alloys. Both additives improved the microstructure and mechanical properties of aluminium alloys but different types of aluminium alloys have different compositions which makes the optimum weight percentage of yttrium holmium and zirconium addition to differ too.

1. Introduction

There has been an enormous increase in aluminum production as a result of the increased use of aluminum packaging, transportation, construction, and electrical engineering [1]. Aluminum is a versatile material that can be used in a wide range of applications. In addition to its economical and attractive metallic material, aluminum is widely used as structural metal apart from steel. The interest sparked by the industries is mainly because aluminum is a lightweight material. A lightweight vehicle is one way for increasing a vehicle's fuel efficiency and performance.

Micro-alloying is a standard approach for increasing the mechanical behaviors of aluminum alloys to achieve excellent high-temperature performance, low cost, and relatively high strength. The rare earth element which is all metal also called rare earth metal is used as an alloying agent to improve the properties of aluminum alloy. Aluminum LM30 alloy or Al-Si17Cu4Mg is additionally referred to as hypereutectic aluminum alloy whose composition is including aluminum and its major element which is Silicon. The reason for combining the entire element is to intensify the mechanical properties. Additionally, aluminum alloys are more castable than other

cast metals like steel. Despite the increased interest in aluminum alloys, their applicability is still restricted in comparison to steel.

There are numerous methods for improving a material's mechanical properties, including element modifications, heat treatment, and others. Alloying is one approach to achieving the modification of an element to increase the mechanical characteristics of aluminum alloys. An appropriate alloying element can aid in the improvement of aluminum alloys' mechanical and hardness properties. Other rare earth elements, such as Yttrium, Holmium and Zirconium have been found to improve the strength of Al-Zn-Mg-Cu alloy at high temperatures by reducing the grain size of the as-cast alloy, resulting in a better nucleation ratio, during artificial aging. [1,2]. However, a few studies have been conducted on the LM30 alloy to observe the effect on microstructure and hardness properties. Thus, it is critical to investigate the microstructure and hardness properties of LM30 aluminum alloy in addition to Yttrium, Holmium and Zirconium.

Despite that, different rare earth element combined with Al-Si alloys will produce different results regarding their microstructure and mechanical features. Therefore, identifying the actual type and composition of rare earth addition is an absolute must when attributing the effect of rare earth addition to the alloy properties.

2. Methodology

The main material used to manufacture the sample is aluminium LM30 alloy, and the chemical composition is expressed in weight percent, wt. %. LM30 alloy is melted into the crucible furnace and yttrium (Y), holmium (Ho) and Zirconium (Zr) additive is added at a temperature around $730^{\circ}\text{C}\pm$. As the yttrium (Y), holmium (Ho) and Zirconium (Zr) is added during the melting process, the mixture is stirred to ensure homogeneity of the composition. The melted alloys were poured into the preheated steel mould. The chemical compositions of the aluminium LM30 that are used in this study is displayed in Table 1 below. Microstructural analysis of as-cast samples was performed to determine the modification effect of Y, Ho and Zr addition.

The samples for microstructural were ground and polished before being inspected under an optical microscope at various magnifications to observe the change of the compounds with and without Y addition. Keller's reagent is used as an etchant to reveal the microstructure of polishing samples. The Vickers hardness tester was used, and the test load and dwell time were HV0.1 and 10s, respectively. To minimize inaccuracy, at least 5 points were measured for each specimen, and the average value was determined.

Table 1 The Chemical composition of LM30 Aluminium Alloy

Element	Cu	Si	Mg	Fe	Mn	Ni	Zn	Pb	Sn	Ti
Percentage, %	4.0-5.0	16.0-18.0	0.4-0.7	1.1	0.3	0.1	0.2	0.1	0.1	0.2

3. Results and Discussion

The results that will be presented and discussed includes the Optical Microscope observations, observations obtained from SEM/EDM coupling, data from tensile test and data from Vickers Hardness. The microstructure of LM30 alloy with different compositions of Yttrium (Y), Holmium (Ho) and Zirconium (Zr) is shown in Figure 2.

From the microstructure, it can be seen that the microstructure consists of α -Al phase as well as eutectic Si phases. From Figure 1, it can be seen that the addition of Yttrium (Y), Holmium (Ho) and Zirconium (Zr) has modified the microstructure of the base alloy. The microstructure of the eutectic silicon transforms the eutectic Si from a coarse acicular structure to a more fine fibrous structure as the composition of the Yttrium, Holmium and Zirconium added. Figure 2 (a) and (b) show that coarse acicular structures existed in the microstructure of the 0.1 wt% Y, 0.4wt% Ho, 0.1 wt% Zr and a short-rod structure appears as the addition of Y is 0.8 wt. %. In addition, when the amount of Holmium added increases to 0.4 wt. %, the more fine fibrous eutectic Si structure appears, as shown in Figure 1(c). As the content of Yttrium increase until 0.4 wt. %Ho, the structure of eutectic Si particles turns to rod-like morphology as shown in Figure 1 (d). However, when the amount of Ho added is raised to 0.4 wt. %, the eutectic Si of needle-like structure starts to appear. From the experimental results, it can be seen that 0.8 wt. % of Y has a good modification effect on the eutectic silicon alloy.

This result obtained has shown similarity to other rare-earth. When 1.0 wt.% of Ce is added to Al-17%Si and had shown a favorable influence on the primary silicon and eutectic silicon of the alloy [3]. Similar studies also show that the addition of 1.0 wt.% of Ce alters the LM30 alloy with Ce exhibiting well distributes and finer primary silicon morphology [4]. The microstructure of the AlSi17 alloy with 2.0wt. % Y as presented in Figure1 (e) demonstrates that the higher yttrium content does not result in the grain refinement of the alloy. The Y addition had three effects roles which are reducing the length of needle-like phases (AlSi17), transforming the eutectic silicon particles from the coarse acicular structure into a fine fibrous form, and refining the α aluminium dendrites.

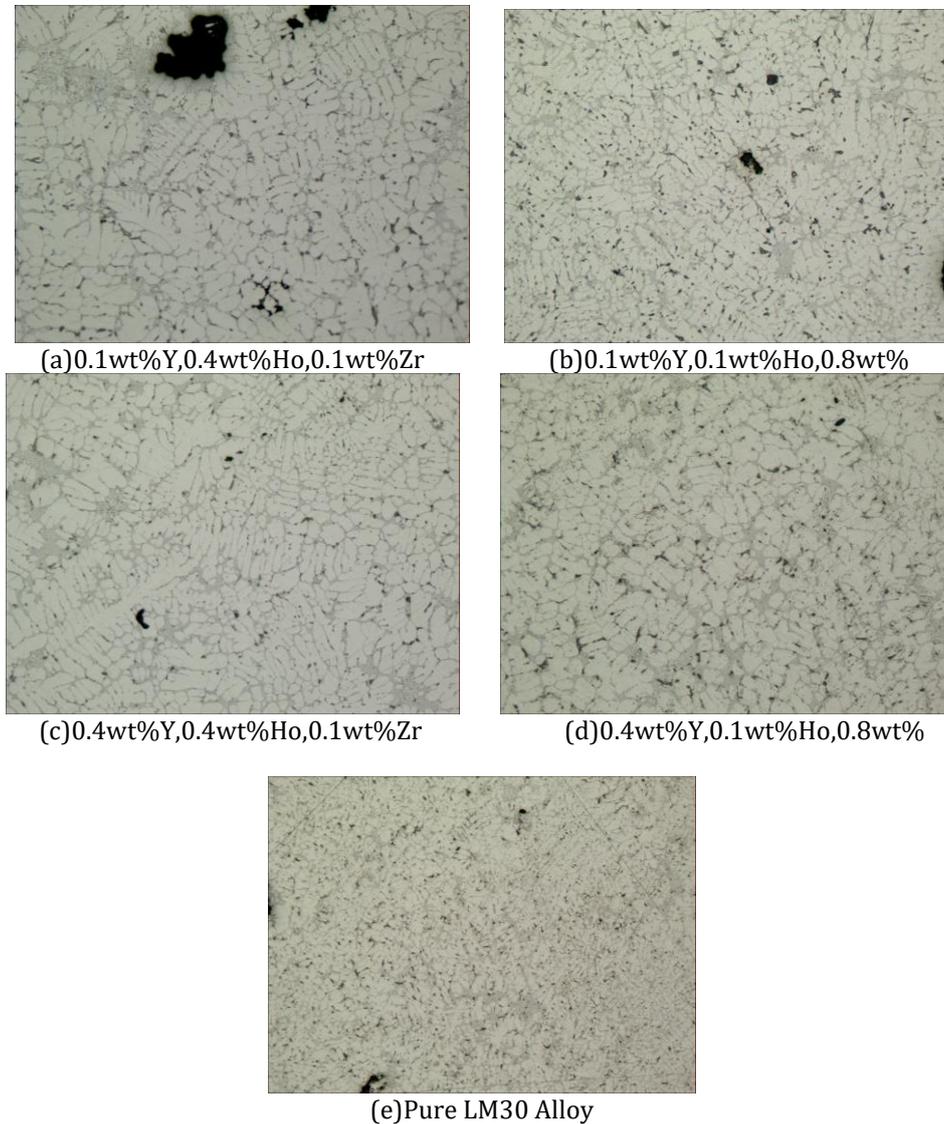


Fig. 1 Microstructures of AlSi17 alloy

4. Conclusion

The effect of the addition of Y, Ho and Zr on microstructure and mechanical properties of Aluminium base alloy was investigated. From the case study analysis, the conclusion can be summarized as the points below:

- Yttrium and holmium additives refined the microstructure of the aluminium base alloys by reducing the average grain size.
- Addition of yttrium and holmium leads to the formation of additional intermetallic phases that distributed along the grain boundaries.
- Yttrium and holmium additives improved the UTS of the aluminium base alloys.
- Yttrium additives slightly improved the hardness value of aluminium base alloys.

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