RESEARCH PROGRESS IN MECHANICAL AND MANUFACTURING ENGINEERING VOL. 4 NO.2 (2023) 379-383

RPMME

Homepage: http://penerbit.uthm.edu.my/periodicals/index.php/rpmme
e-ISSN : 2773 - 4765

Effect of Erbium on Microstructure and Hardness Properties of Aluminium LM30 Alloy

Siti Noradilah Sulaiman[1], **Rosli Ahmad**[1]*

[1]Faculty of Mechanical and Manufacturing Engineering,
Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/rpmme.2023.04.02.046
Received 01 July 2023; Accepted 01 Nov 2023; Available online 15 Dec 2023

Abstract: The development of aluminium alloys aims to improve the material's strength, ductility, thermal stability, and weldability to attain a high degree of overall performance. Aluminium is desirable since it is relatively inexpensive and lightweight. In this study, the experiment will be conducted by using optical microscopy to examine the microstructure and hardness test to determine the mechanical properties. Both testings showed an improvement in the microstructure and hardness value of the aluminium LM30 alloy after the addition of Er with different amounts of composition. Observation by using an optical microscope revealed that the unaltered alloy had a coarse plate-like structure. The best modification influenced the Si phases, which were modified into fine particle and short rods. Vicker's hardness test was used to study the mechanical properties with varied Er concentrations. The hardness value also revealed that the addition significantly enhanced the hardness properties of the Al LM30 alloy, which was then treated with erbium.

Keywords: Al LM30 Alloys, Erbium, Microstructure, Hardness Properties

1. Introduction

An aluminium alloy is a mixture of aluminium and other metals that is primarily composed of aluminium. As a result of alloying with other elements, the aluminium has a higher density and/or strength compared to the pure metallic element itself. Engineers looking to lower the weight of a product (such as an aeroplane) without sacrificing its structural integrity prefer aluminium alloys. Al-17%Si is a hypereutectic alloy composed of aluminium with silicon as its primary alloy component. The goal of adding the other element is to improve the mechanical properties of the material. Increasing the mechanical qualities of an alloy can make it more useful while also lowering its cost.

Element modification is the methodology used in this investigation. Modification of one element through the addition of another element to examine the additional element's influence on the alloy, both good and bad. During the investigation, it was found that earlier studies had examined the effect by using a rare earth metal element on an alloy. In this study, aluminium LM30 alloy is treated with a little amount of a rare earth element to see how it affects the alloy's microstructure and mechanical properties.

*Corresponding author: roslee@uthm.edu.my

The Er of earth elements are utilised to improve the microstructure and hardness properties of Al LM30 alloy. Aluminium is the most common metal in the Earth's crust. It is a soft, durable, lightweight, ductile, and malleable metal that is easy to work with. Aluminium is almost always mixed with other materials to make it more useful. It is used in the transportation, construction, and packaging industries, among other places. This limitation can be overcome by adding the rare earth element which is Er to improve the mechanical properties on the microstructure of Al LM30 alloy. The rare earth element that used in this study is Erbium.

2. Methodology

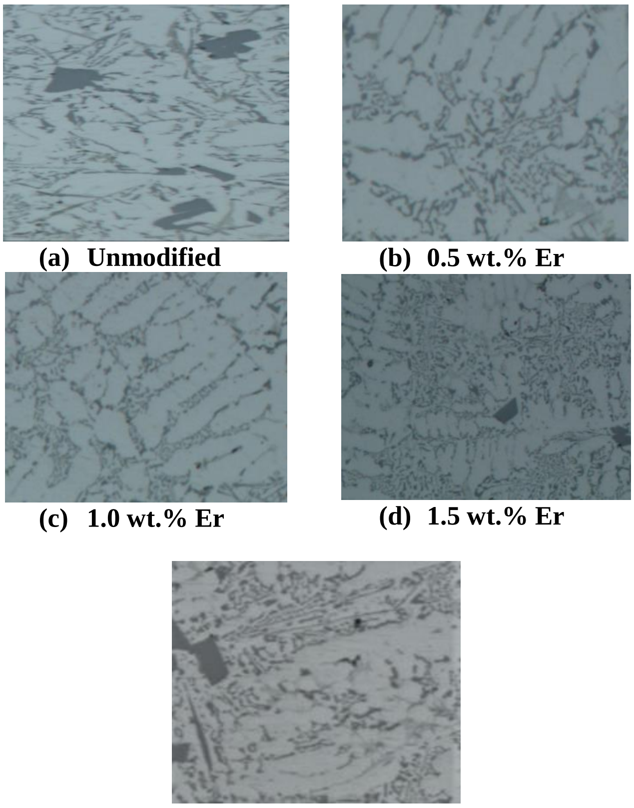
Aluminium LM30 is subsequently melted in a furnace with a crucible furnace is utilized, and the base alloy had melted at around 730℃. After melting aluminium LM30 alloy, various percentages of Er are added to the furnace. In this melting process, the molten metal is stirred to guarantee homogeneity of composition. The mold must be preheated prior to the pouring operation.

A microstructural evolution research was conducted on both as-cast and modified samples to explore the morphological alterations of the compounds and the impacts of Er modification. Before using the optical microscope, to observe the specimen grains more clearly, the specimen surface should be free of scratches. The best method for eliminating scratches is to polish the specimen but before that the abrasive paper is used. Abrasive paper that can be effectively washed with water to maintain the cutting edge's sharpness and efficiently remove particles. After polishing, immersion or swabbing of specimens in an appropriate chemical solution will be utilized for the etching procedure. Keller's Reagent is the chemical solution that will be applied. Vickers hardness test was performed to determine the hardness number. The test was conducted using a Vickers hardness tester with a 980.7 mN (HV0.1) load. The specimen was indented using a diamond-shaped indenter. The indentation is made at 5 distinct locations, and the average hardness number is then calculated.

3. Results and Discussion

The purpose of the optical microscope observations was to analyse the microstructure shown in Figures 1 (a), (b), (c), (d) and (e). Figure 1 (a) demonstrates that the unmodified LM 30 aluminium alloy had a coarse plate-like microstructure. Meanwhile, Figure 1 (b), (c), (d) and (e) show the results of the LM 30 alloy that had been modified with the addition 0.5 wt.%, 1.0 wt.%, 1.5 wt.% and 2.0 wt.% of Er. As Er has a significantly greater atomic weight and a slower diffusion rate than Al, the refining impact was significantly greater [1]. The structure of silicon underwent some alterations, transforming from a coarse plate-like structure to fine particles and short rods, as depicted in the image. The microstructure test revealed that the addition of Er decreased the particle size of silicon and enhanced the mechanical characteristics of the LM 30 aluminium alloy.

The addition of 1.0 wt. % Er to the Si phases resulted in the best alteration, which was changed into fine particles and short rods. The particle-size distribution of the silicon in the LM 30 + 1.0 wt. % Er alloy was obviously different from that of the silicon in the LM 30 alloy. Figure 1 (c) shows the matrix structure with 1.0 wt. % erbium added, which is more consistent and fine. The inclusion of a suitable amount of Er facilitated the refinement of the microstructure, and an increase in Er content could facilitate the transition from acicular to Chinese writing in the second phase [2]. It is obvious that the rare earth element Er can refine eutectic silicon and improve the mechanical properties of eutectic Al-Si alloys [3].



(a) Unmodified **(b) 0.5 wt.% Er**

(c) 1.0 wt.% Er **(d) 1.5 wt.% Er**

(e) 2.0 wt.% Er

Figure 1: Microstructure Analysis

Figure 2, Figure 3 and Figure 4 show the best concentration of Er to be added was 1.0 wt. %, as proven by the decrease in the mean area (µm²) and aspect ratio, as well as the increasing in the roundness. When 1.0 wt. % of Er was added to aluminium LM30 alloy, the mean area decreased from 66.57 µm² to 10.52 µm², while the aspect ratio decreased from 1.97 to 1.87. The value of roundness was increased for 0 wt. % until 1.0 wt. % which is the value is 0.61 to 0.65.

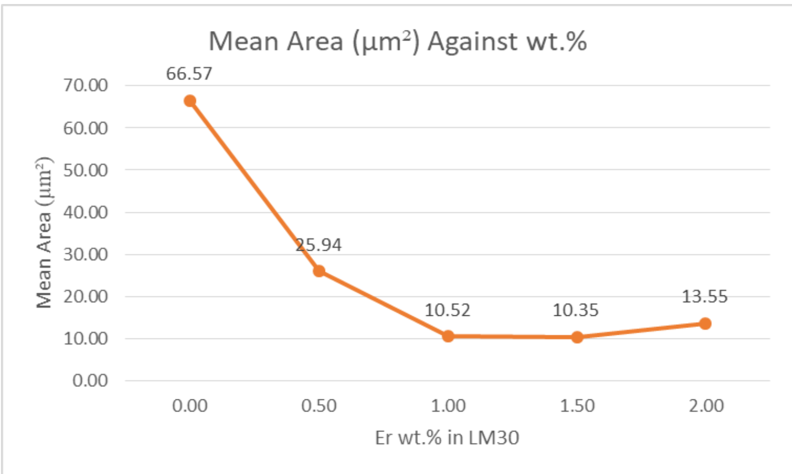


Figure 2: Graph Mean Area (µm²) against wt. %.

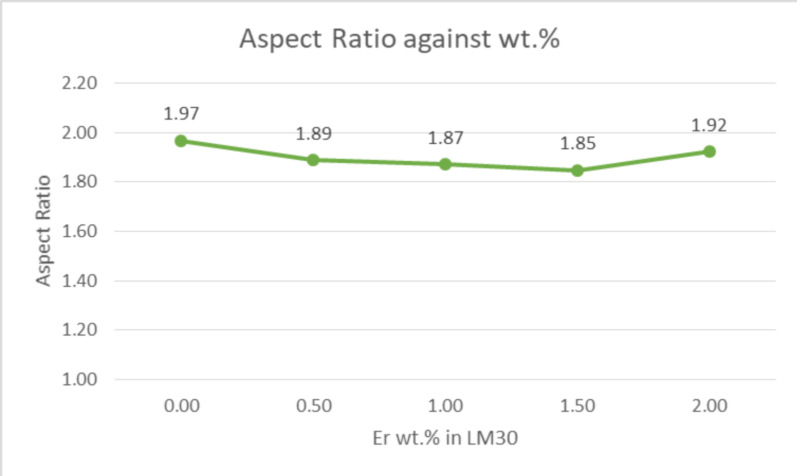


Figure 3: Graph Aspect Ratio against wt. %.

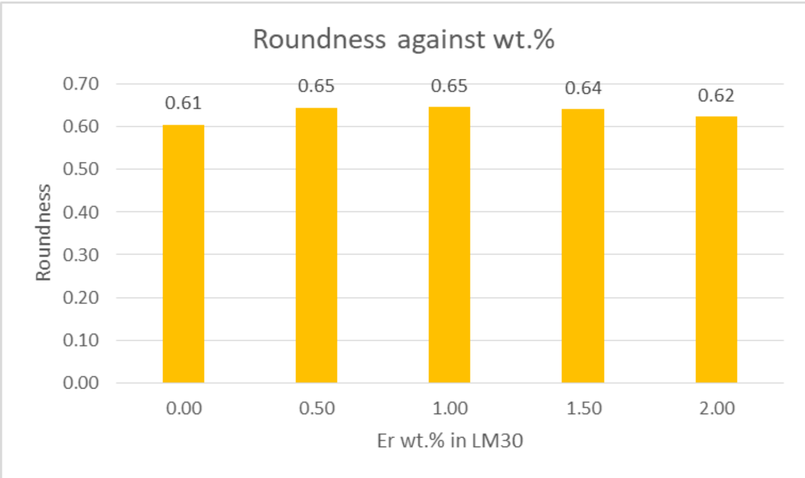


Figure 4: Graph Roundness against wt. %.

From the graph, it was determined that the value of unmodified LM30 was 102.3 HV and increased significantly with the addition of 1.0 wt.% and 1.5 wt.% Er. At 0.5 wt. %, the specimen's hardness decreases to 101.3 HV from the 102.3 HV value of the base alloy. This may be owing to a change in the morphology of eutectic Si particles and the lowering of eutectic temperature during solidification, both of which have an effect on the drop in hardness. The reduction in hardness is due to the dispersion of molecules among particles, which makes disengagement bowing considerably less difficult [4]. Therefore, found that the addition 2.0 wt. % Er on LM30 alloy increase the hardness of the aluminium. The increased micro hardness of the Er-modified samples resulted in two effects which is refinement and dissolution of the eutectic Si, and precipitation of Al_3Er particles [5].

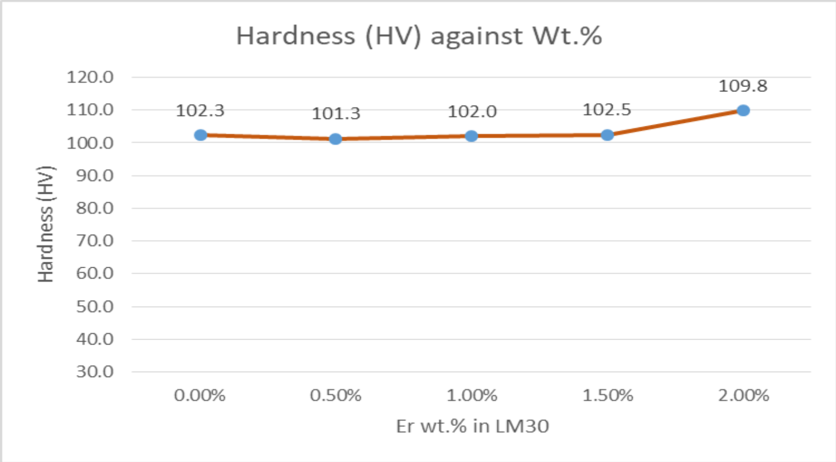


Figure 5: Graph of Hardness (HV) against Wt. %

4. Conclusion

The study was to look which additions get the better result for microstructure and hardness properties from the addition of Er. The Erbium addition increases the hardness properties of the aluminium LM30 alloy based on the hardness test. The addition of Erbium is effective for a certain quantity only. The microstructure of 1.0 wt.% Erbium added also gives the best modification which can refine the eutectic silicon structure from coarse plate-like to fine modified structure. The hardness value of the alloys improved as the mixture of Erbium content increased. The maximum hardness value is achieved at 2.0 wt.% Er compared to the other Erbium contents.

Acknowledgement

The authors would also like to thank the Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] Li Q, Xia T, Lan Y, Li P and Fan L 2013 Effects of rare earth Er addition on microstructure and mechanical properties of hypereutectic Al-20% Si alloy *Mater. Sci. Eng. A* **588** 97–102

[2] Che H, Jiang X, Qiao N and Liu X 2017 Effects of Er/Sr/Cu additions on the microstructure and mechanical properties of Al-Mg alloy during hot extrusion *J. Alloys Compd.* **708** 662–70

[3] Xing P, Gao B, Zhuang Y, Liu K and Tu G 2010 Effect of erbium on properties and microstructure of Al-Si eutectic alloy *J. Rare Earths* **28** 927–30

[4] Lastnosti M, Vzmetnost I N, Polat A, Avsar M and Ozturk F 2015 Effects of the Artificial-Aging Temperature and Time on the Mechanical Properties And Springback Behavior of AA6061 **49** 487–93

[5] Shi Z M, Wang Q, Zhao G and Zhang R Y 2015 Effects of erbium modification on the microstructure and mechanical properties of A356 aluminum alloys *Mater. Sci. Eng. A* **626** 102–7