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EFFECT OF SN ADDITION ON MECHANICAL PROPERTIES OF AS21 MAGNESIUM ALLOYS

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Abstract- In this study, the effect of Sn addition on microstructure and mechanical properties of AS21 magnesium alloys. Sn additions were made by 1 and 2 wt%. Alloys were produced by conventional gravity casting. A pressure of 2 bar applied into the crucible and the melt was lifted into a steel mould preheated to 250 °C. Results showed that AS21 alloy consisted of α-Mg grains and Chinese script type Mg_2Si intermetallic phases. With increasing amount of Sn, α-Mg grains and Mg_2Si intermetallic phases were refined and the distribution of Mg_2Si phase became more discrete and dense. AS21+1Sn alloy showed the best mechanical properties alloys with a yield strength of 118.9 MPa, an ultimate tensile strength of 203.2 MPa and an elongation of 7.2. The improvements in the strength and elongation were attributed to the refinement of α-Mg grains and Mg_2Si intermetallic phases.

Index Terms- AS21 magnesium alloy, Sn modification, microstructure, mechanical properties

I. INTRODUCTION

Due to their high specific strength, magnesium alloys have gained more attention for being used as structural metal in automotive and aerospace industries. However, some properties of magnesium alloys such as, strength at room and elevated temperatures, corrosion, creep and wear resistances still remained low compared to aluminium alloys. Among the commercial as-cast magnesium alloys, AZ91 is the most commonly used Mg-Al based alloy. However, at the temperatures above 150 °C, the mechanical properties of AZ91 alloy degrade rapidly. Therefore, Mg-Al-Si alloys (AS series) were developed showing better strength and creep resistance at the temperatures above 120 °C than AZ series magnesium alloys. The improved high temperature properties are due to the formation of Mg_2Si intermetallic phase with a high melting temperature, hardness and elastic modulus and low thermal expansion coefficient and density. Blum et al. [4] compared the creep resistance of die-cast AZ91, AS21, AS41, AM60 and AE42 alloys and it was reported that at low stresses AS series alloys showed the best creep resistance although at high stresses AZ91 was found as the best creep resistant alloy. Zhang [5] et al. reported that AS21 alloy was hardened by rod-shaped Mg_2Si precipitates and work softening during tertiary creep resulted from a breakage of these precipitates. Tang et al. [6] showed that the addition of Al-10%Sr master alloy altered the morphology of eutectic Mg_2Si from Chinese script type to polyhedral or fine fibre shape. Dargusch et al. [7] reported that Mg_2Si particles had a coarse blocky shape as the Si content was above the Mg_2Si binary eutectic point. Although numerous studies investigated the creep properties of AS series magnesium alloys, there are limited studies that investigate the effect of different alloying elements on room temperature mechanical properties of AS series magnesium alloys. Therefore, this study aimed for the understanding the effect of Sn addition on microstructure and mechanical properties of AS21 magnesium alloys.

II. EXPERIMENTAL PROCEDURE

The Mg-2wt%Al-1wt%Si alloys with different Sn additions (0, 1 and 2 wt%) were produced by low pressure die casting method. The chemical compositions of the alloys were measured by wave-length dispersion X-ray fluorescence (XRF) and listed in Table 1. High purity Mg (99.9%), Al (99.9%), Sn (99.9%) and Al-30%Si master alloys were used to prepare the studied alloys. The alloys were melted in stainless steel crucible placed in an electric resistance furnace under controlled Ar gas flow. The melt was held at 750 °C for 45 minutes and stirred for 15 minutes. After that, a pressure of 2 bar applied into the crucible and the melt was lifted into a steel mould preheated to 250 °C.

Table I Chemical compositions of the alloys.

Alloy	Al	Si	Sn	Mn	Mg
AS21	2.12	1.11	-	0.21	Bal.
AS21+1Sn	2.24	1.03	1.16	0.18	Bal.
AS21+2Sn	2.05	0.98	2.01	0.25	Bal.

The microstructure images of all the samples were taken by optical microscope. Before the microstructure analysis, all the samples were mechanically ground with 240, 400, 600, 800, 1000, 1200 and 2000 grit emery papers followed by polishing with 6 μm and 1 μm diamond paste. The polished samples were etched with 3% nitral. According to EN ISO 6892-1, the dog-bone tensile specimens with a diameter of 5 mm and gauge length of 25 mm were machined from the 1/2 radius of the alloys.

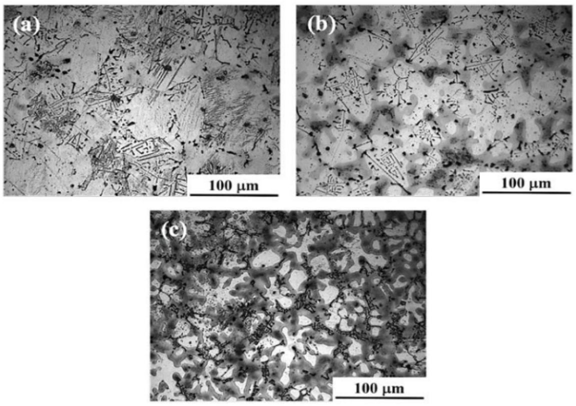

Fig. 1 Optical microstructures of as-cast (a) AS21, (b) AS21+1Sn and (c) AS21+2Sn alloys

III. RESULTS AND DISCUSSION

Fig.1 shows the optical microstructures of AS21 alloys with 0, 1 and 2 Sn additions. AS21 alloy consisted of α-Mg grains (white matrix) and Chinese script type Mg_2Si intermetallic phases (dark areas). With the addition of 1 wt% Sn, α-Mg grains and Mg_2Si intermetallic phases were refined and the distribution of Mg_2Si phase became more discrete. Sn addition also led a formation of gray areas along grain boundaries and the fraction of these areas showed an increase as the Sn content reached to 2 wt%. It is thought that the formation of these areas were promoted by the addition of Sn which can be Mg-Sn binary compounds. AS21+2Sn alloy had the finest Mg_2Si phase but the rods were thicker than the other alloys which may indicate that Sn addition led to a suppression of Mg_2Si phase growth.Fig. 2 presents the tensile properties of AS21, AS21+1Sn and AS21+2Sn alloys. It can be clearly seen that AS21+1Sn alloy showed the best mechanical properties alloys with a yield strength of 118.9 MPa, an ultimate tensile strength of 203.2 MPa and an elongation of 7.2. The improvements in the strength and elongation were attributed to the refinement of α-Mg grains and Mg_2Si intermetallic phases. However, as the Sn content reached 2 wt%, the mechanical properties decreased and became almost identical to AS21 alloy with no Sn addition. This was because the very fine and dense Mg_2Si phases and Sn-rich constituents around them may cause a premature fracture as a result of crack initiation at these areas. Therefore, the improvement by the presence of fine second phase particles and grain refinement and the degradation by the possible premature fracture balanced each other and the mechanical properties remained almost the same.

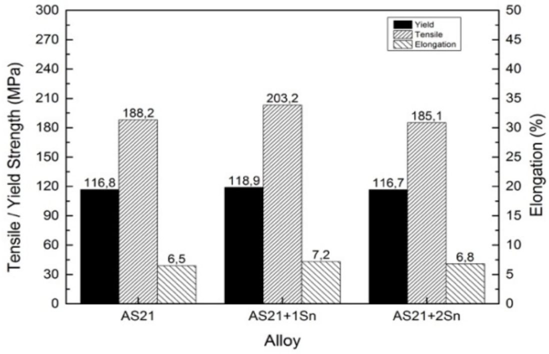

Fig. 2. Tensile test results of AS21 alloys with different Sn additions.

CONCLUSION

Following conclusions can be drawn:

- AS21 alloy consisted of α-Mg grains (white matrix) and Chinese script type Mg_2Si intermetallic phases (dark areas). With increasing amount of Sn, α-Mg grains and Mg_2Si intermetallic phases were refined and the distribution of Mg_2Si phase became more discrete and dense.
- AS21+1Sn alloy showed the best mechanical properties alloys with a yield strength of 118.9 MPa, an ultimate tensile strength of 203.2 MPa and an elongation of 7.2. The improvements in the strength and elongation were attributed to the refinement of α-Mg grains and Mg_2Si intermetallic phases.

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