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EFFECTS OF MANGANESE ADDITION ON HARDNESS OF AA6063 ALLOY FOR WEAR RESISTANT MATERIAL APPLICATIONS

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ABSTRACT

AA6063 alloy is usually used in boat and ship building. This is because of its interesting properties such as lightweight and aesthetic characteristics. In this work, the AA6063 alloy was melted together with 0.5 to 2.5 wt% of Mn and cast. The alloy was solutionised at 535 ^{o}C for 6 hours and followed by water-quenching. Artificial aging was performed on the alloy at 200 ^{o}C for 5 hours and followed by natural aging for 14 days. Vickers micro-hardness values indicated that the addition of Mn has increased hardness of the AA6063 alloy. A combination of artificial and natural aging has increased hardness of the alloy containing 2.5 wt% Mn from 120 VHN to 160.09 VHN. Therefore, the increase in its hardness could lead to the improvement of its wear resistance.

***Keywords**:* AA6063 alloy, manganese, hardness

1. INTRODUCTION

Manganese (Mn) has been known to be an important alloying element in aluminum alloys which contributes to a uniform deformation. It was reported that aluminium alloys with more than 0.5wt% of Mn content like 6000 and 7000 series alloys, both showed a significant increase in the yield and ultimate tensile strength without decreasing any ductility (Nam & Lee, 2000). It was reported that the strength of alloys increased gradually and linearly as the percentage of Mn was increased due to possible solid solution hardening in the Al-matrix (Seifeddine et al. 2008).

Generally, metal alloys of high hardness will exhibit good wear resistance. Jeong et al. (2002) found that the abrasive wear resistance of some annealed metals and steels was linearly proportional to their hardness. Annealed 5XXX aluminium alloy has shown a positive correlation between abrasive wear resistance and subsurface hardness (Mezlini et al. 2004). Dry sliding wear resistance increased with increasing hardness for 7075 aluminium alloy after subjecting to retrogression and re-aging treatment (Baydogan et al. 2004).

In marine environment, corrosion-resistant architectural Al-Alloy i.e. AA6063 alloy is the most popular (Kasten, 1997). The presence of magnesium and silicon has made the alloy heat treatable and weldable with good mechanical properties. It also has good surface finish, high corrosion resistance and can be easily anodised. American Bureau of Shipping (ABS) and the American Society for Testing and Materials had confirmed the AA6063 alloys with solution heat treatment and artificial aging (T6) are suitable for ship building (Ferraris, 2005).

The focus of this study is to investigate the effect of manganese addition in AA6063 alloy particularly on the hardness properties.

2. METHODOLOGY

2.1 Experimental Design

In this work, the dependence of microhardness of AA6063 alloy on manganese content and heat treatment temperature was investigated. Response surface methodology (RSM) was used to model the correlation amongst the above parameters.

Response surface methodology (RSM) is a collection of mathematical and statistical techniques. It is useful for modeling and analysis of problems in which a response of interest is normally influenced by several variables.

In this work, the response surface methodology (RSM) used a 3-Level Factorial where two numeric factors were applied, namely, addition of Mn(wt%) and heat treatment temperature(°C) with an assumption that the effect of solutionisation on hardness of artificially aged samples is constant. The lowest composition of Mn was taken as 0% wt and the highest value was 2.5%wt. The lowest heat treatment temperature was 27°C (natural aging temperature) and the highest temperature was 535°C(solution treatment temperature). The lowest and the highest hardness values for those heat-treatment temperatures were used to construct the model. The response of the RSM was microhardness(VHN).

2.2 Material Preparation

AA6063 aluminum alloy was used as the starting material. The chemical composition of the AA6063 alloy in weight percent is 0.53 Si, 0.44 Mg, 0.28 Zn, 0.25 Fe, 0.03 Ti, 0.02 Cu, 0.01 Cr, 0.01 Co and Al balance. Mn was added to AA6063 alloy and melted at 800°C with holding time of 10 minutes. The melt was cast in a steel mould with dimension of 14 mm in diameter and 120 mm in length. The Mn content of the alloy was varied from 0.5 to 2.5 wt%.

2.3 Heat Treatment

Cast samples were then solution heat-treated at 535°C for 6 hours and water-quenched to room temperature. This was followed by an artificial aging at 200°C for 5 hours (Chen et al. 2000). The samples were then naturally aged for 14 days (Daud & Wong, 2004).

2.4 Hardness Test

Prior to testing, the samples were mechanically ground using SiC papers and polished with diamond spray to 6 micron surface finish. Hardness test was carried out by using a Micro-Vickers hardness tester, with a load of 300 g for 15 sec indentation time (ASTM, 2008). The reported microhardness values were an average value of 15 measurements.

2.5 Microstructural Study

The mechanical properties of alloys including hardness are strongly influenced by their microstructure. For microstructural study, the samples were etched in Keller's reagent and observed under an optical microscope.

3. RESULTS AND DISCUSSION

Figure 1 shows that microhardness of AA6063 alloy increases as the Mn content is increased but decreases when heat-treatment temperature is decreased.

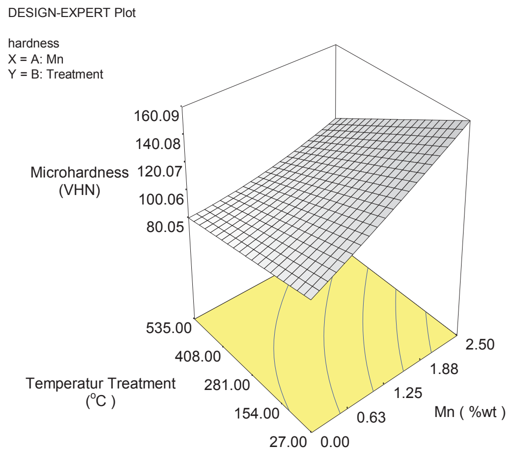

Figure 1. A plot indicating the dependence of microhardness of AA6063 on Mn content and heat-treatment temperature obtained using RSM 3-Level Factorial

The variation of hardness values of the as-cast alloy and the alloys which were subjected to solution treatment, artificial aging and natural aging is shown in Figure 2. The hardness of as-cast AA6063 alloy without Mn is 66.63 VHN and increased to 101.75 VHN with

2.5 wt % Mn (Figure 2). The increase is due to the decrease in grain size (Figure 3).

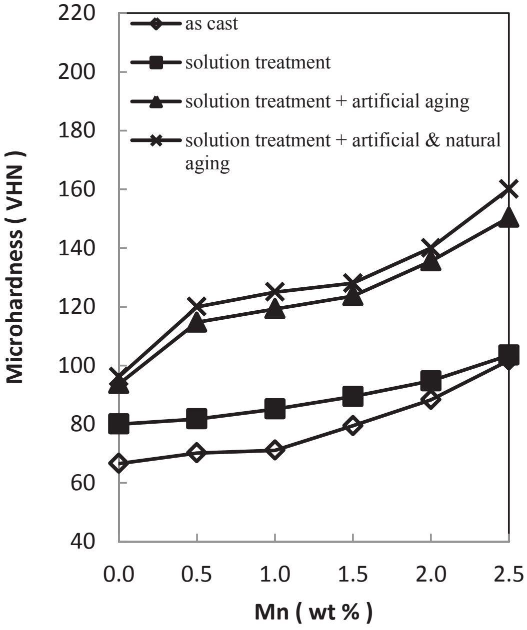

Figure 2. Effects of Mn additions on the microhardness of AA6063 alloy

Figure 3 exhibits the microstructures of the as-cast alloy with 0.5 and 2.5 wt % Mn. The as-cast alloy containing 0.5 wt % Mn has a rather bigger grain size than that of the alloy containing 2.5 wt% Mn.

Solution treatment had increased the microhardnes of the alloys containing Mn of less than 2.5 wt% which is due to a better distribution of Mn compared to the as-cast alloy (Figure 4). Solution treatment seemed to improve distribution of Mn, especially for the alloys containing Mn of less than 2.5 wt%. The hardness of the as-cast and solutionised alloys with 2.5 wt% Mn was almost the same since there is no significant different in Mn distribution in both of them (Figure 4).

After solution treatment and artificial aging, the hardness of this alloy was found to increase from 93.76 VHN without Mn, to 150.42 VHN when containing 2.5 wt % Mn. The hardness of the alloy containing 2.5 wt% Mn has increased further up to 160.09 VHN after artificially aged solutionised alloys was subjected to 14 days natural aging.

Artificial aging has refined the grains with better defined grain boundaries (Figure 5). Furthermore, when the AA 6063alloys were allowed to undergo natural aging for 14 days, the alloys retained fine grains but fine Mn precipitates and perhaps intermetallic phases seemed to be uniformly distributed in the alloys (Hwang et al, 2008), as shown in Figure 6.

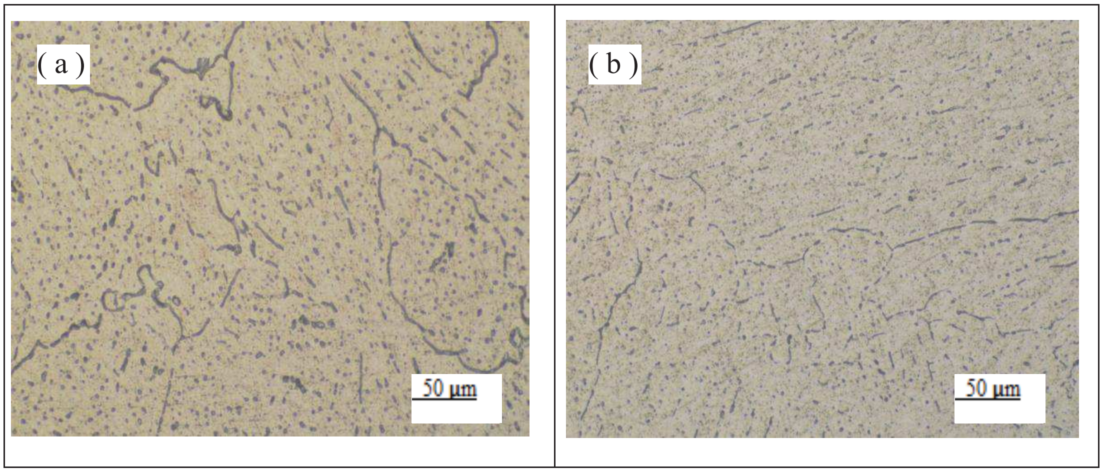

Figure 3. Microstructure of as-cast AA6063 alloys with Mn (a) 0.5 wt % and (b) 2.5 wt %.

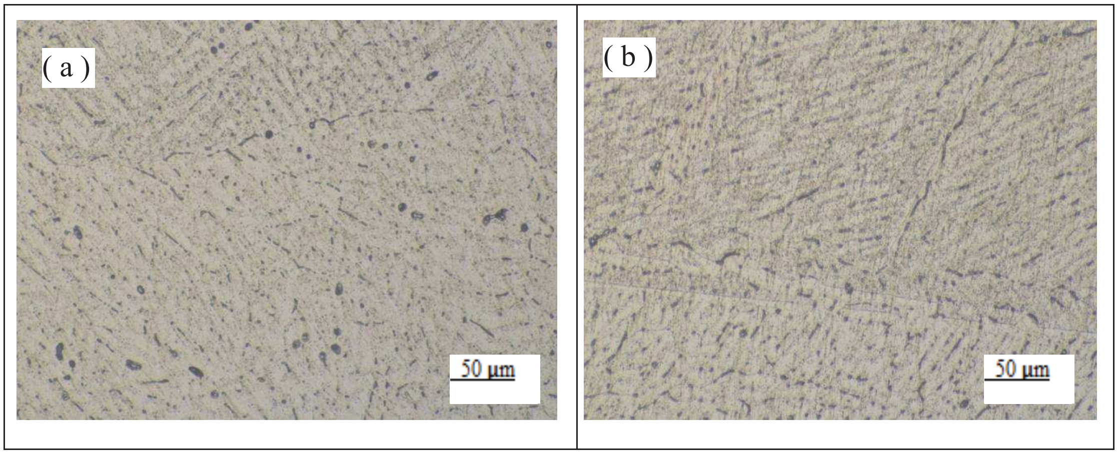

Figure 4. Microstructure of AA6063 alloys with Mn (a) 0.5 wt % and (b) 2.5 wt % after solution treatment

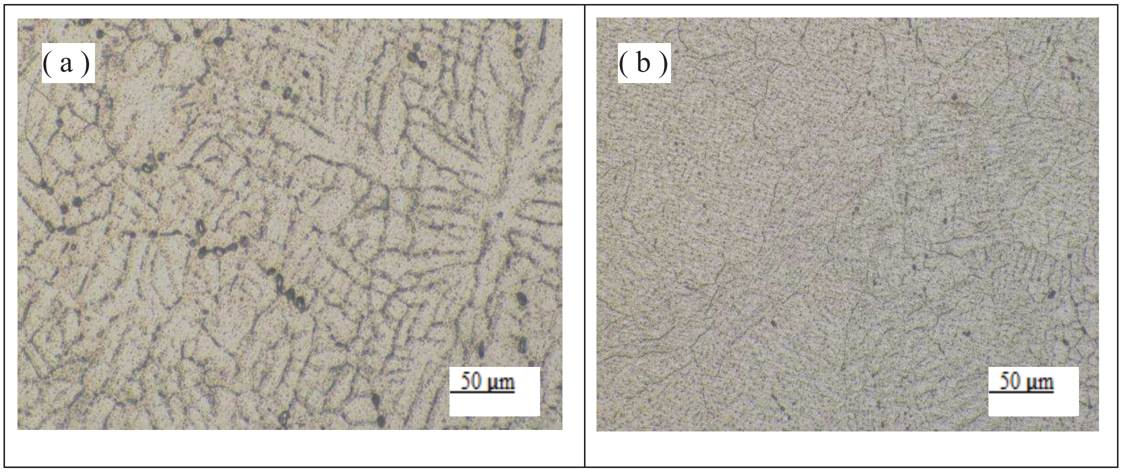

Figure 5. Microstructure of AA6063 alloys with Mn (a) 0.5 wt % and (b) 2.5 wt % after artificial aging.

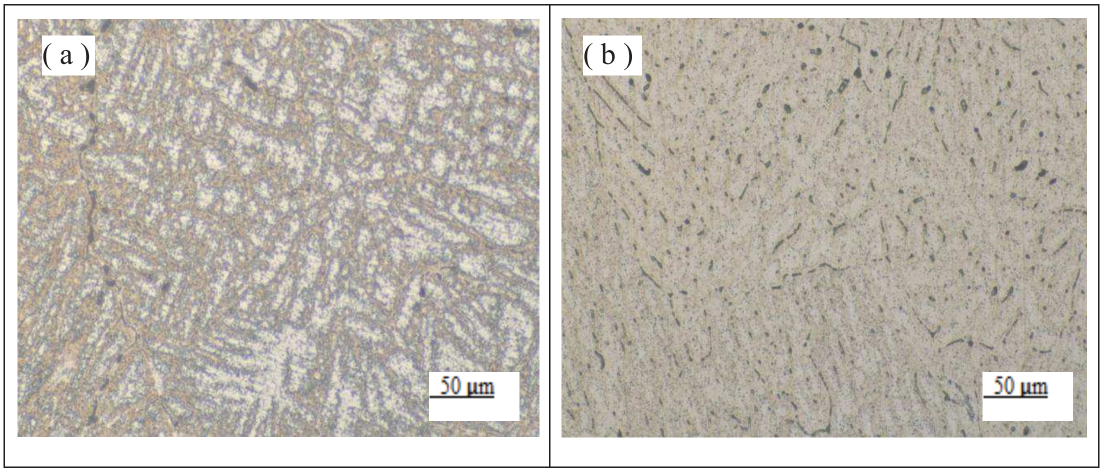

Figure 6. Microstructure of AA6063 alloys with Mn (a) 0.5 wt % and
(b) 2.5 wt % after artificial and natural aging

The well distributed precipitates and fine grains have improved further the hardness of the AA6063 alloys containing Mn where the hardness reached 160.09 VHN for the alloy containing 2.5 wt% Mn. The increase in hardness which is related to grain refinement and the formation of precipitates indicates that the alloy may have a better wear resistance (Mezlini et al. 2004, Baydogan et al. 2004).

4. CONCLUSIONS

The hardness of AA6063 alloy increases with the Mn content. Both artificial and natural aging processes have further improved the hardness property of the alloy. The increase in hardness is due to the formation of the precipitates and grain refinement. An addition of 2.5 wt% of Mn to AA6063 alloy followed by artificial and 14 days natural aging has increased the hardness of this alloy to 160.09 VHN. The increase of the alloy hardness, hence a better wear resistance can be achieved.

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