Hardness and Wear of As–Cast Mg–Al Based Alloy with Alumina Addition

تأثير إضافة الأومونيا على الصلابة ومقاومة البلي لسبيكة الماغنسيوم – ألومنيوم

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الملخص

سبائك الماغنيسيوم لها تطبيقات واسعة في الصناعات لما لها من خصائص جيدة. من أفضل وأكثر سبائك الماغنيسيوم إستخداماً هى سبائك الماغنيسيوم – ألومنيوم التى لها قدرة جيدة للسبك وخصائص ميكانيكية مميزة. ولكن هناك بعض العيوب التى يمكن تلافيها ببعض الإضافات. والهدف من البحث هو دراسة أثر إضافة الألومينا بنسب مختلفة في الصلابة ومقاومة البلى للسبيكة. تبين أن إضافة الألومينا أسفرت عن زيادة كبيرة في الصلابة المجهرية وزيادة مقاومة التآكل عن السبائك الأصلية. مقاومة التآكل والصلابة المجهرية تزداد بزيادة نسبة مسحوق الألومينا بسبب ترسب حبيبات الألومينا البلورية على الحدود وفي أطوار السبيكة أثناء عملية التجميد.

Abstract

Magnesium alloys have extensive application in industries. The range of physical properties that can be imparted to them is remarkable. Magnesium–Aluminium binary alloys generally possess good castability and good mechanical properties. The objective of the present investigation is to study the effect of varying weight percentage of alumina (Al_2O_3) on the hardness and wear resistance of the Mg–Al alloy. The addition of alumina resulted in a considerable increase in the Vicker's microhardness number and wear resistance of the original alloy. Wear resistance and Vicker's microhardness number increase with the increasing proportion of alumina powder addition because of the deposition of crystalline alumina granules on the border and in the phases of remnant alloy during freezing process.

Keywords

Mg–based alloy, Mg–6Al alloys, Alumina, Microhardness and Wear.

Introduction

Pure Magnesium lacks sufficient strength and ductility for most structural applications. These properties are improved through the selective addition of alloying elements. The major commercial alloying elements used so far in Mg–alloys include aluminium (Al), zinc (Zn), zirconium (Zr), manganese (Mn), silicon (Si), rare earth metals (RE) and alumina (Al_2O_3). One of the most important things for the world is to reduce the fuel costs for vehicles and to further the reduction of emissions to lower our growing environmental impact. Magnesium (Mg) alloys are attractive for light–weight applications due to their high strength–to–weight ratio. In consumer electronics and power tools, it is important to reduce weight for carrying convenience [1, 2]. In the automobile and aerospace industry, weight reduction directly decreases fuel consumption and CO_2 emissions, which are of significance in the current era. The utilization of magnesium and its alloys in the automotive industry has therefore significantly increased in past few years. However, only a few magnesium alloys are used because of having lower mechanical properties and wear resistance than aluminum alloys [3–8]. In general, magnesium alloys are based on Mg–Al systems which are relatively cheap compared with other magnesium alloys

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available. It is well known, Al containing Mg alloys include the β-$Mg_{17}Al_{12}$ compound that detrimentally influences the mechanical properties such as tensile strength and impact resistance [6, 9–12]. One of the most efficient ways to decrease the detrimental effect of the β -$Mg_{17}Al_{12}$ phase on the mechanical properties is to addition third alloying element [13–15]. Besides, wear properties are also significant when magnesium alloys are to be applied for critical automobile applications. However, few studies on wear properties of magnesium alloys have been reported. Hence, their wear properties are not understood much in detail compared to other structural components. These studies were observed that the reduction of grain size of magnesium alloys is positively affected for their wear properties [4–7, 16]. What is more, the wear behavior of magnesium alloys can be affected by the hardness of the base alloys under constant sliding and dry loading conditions [17, 18].

Alumina is one of the most cost effective and widely used materials in the family of engineering ceramics. The raw materials from which this high performance technical grade ceramic is made are readily available and reasonably priced, resulting in good value for the cost in fabricated alumina shapes. With an excellent combination of properties and an attractive price, it is no surprise that fine grain technical grade alumina has a very wide range of applications because of its high hardness, excellent chemical stability, oxidation resistance and abrasive resistance [19–21].

The aim of the present study is to investigate the hardness and wear properties of Mg–6Al alloyed with Al_2O_3.

Materials and Experimental Methods

The Mg–6Al–xAl_2O_3 (wt.%) (x = 0, 1.5, 2.8, 4.1 and 5.3) alloys were prepared from commercial pure (>99.9%) Mg, Al, α–alumina powder with granules sizes less than 25 µm, by melting in an electronic resistance furnace protected by CO_2–1%SF_6. Preheat the oven to 750 ^oC, when the Crucible was left for a quarter of an hour with good mixing of components to ensure homogeneity of the alloy composition. Switch off the oven and cooling the alloy in the furnace until the arrival of the alloy to room temperature was cutting alloy. Then add the alumina powder (granules less than 25 µm) to Mg–6Al alloy and as wt. % (1.5, 2.8, 4.1 and 5.3). Put all in the crucible in the oven and repeat casting process again, with Mg–Al alloy and batching operation manual for half an hour to ensure homogeneous distribution of alumina powder granules in composition of the alloy. The melt was poured into the cast iron molds. After the alloy has been cooling and was awaiting the arrival of the alloy to room temperature, it was cut into samples for testing hardness and wear. The samples for testing are in the form of tablets (10 mm in diameter and 3 mm in thickness). The microhardness was measured using Vicker's microhardness and pin–on–disc to measure wear resistance at sliding speed 3 m/s under load 30 N for 20 min.

Results and Discussions

In comparison with primary alloy, so that adding alumina to the alloy reduces the susceptibility of aluminium melt being either after adding alumina will deposited in addition to be phase containing alumina deposits within minutes of phase and will deposited simultaneously with alumina are the arms developed in the first phase of freezing.

Hardness

Fig. 1 shows an increase in the hardness with the increase in the percentage of Al_2O_3, when compared with the Mg–6Al alloy. For instance, the hardness was found to be 60, 65, 69, 102 and 107 Hv for 0.0, 1.5, 2.8, 4.1 and 5.3%

alumina respectively. A significant increase in hardness of the alloy can be seen with addition of Al_2O_3 granules. A hardness reading showed a higher value of hardness indicating that the existence particulates in the matrix have improved the overall hardness of the composites.

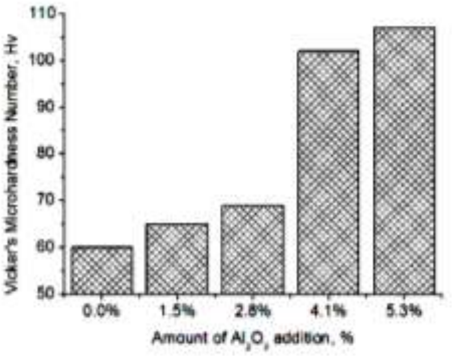

Fig. 1: The hardness of Mg–6Al alloy with different wt % of Al_2O_3 granules.

The presence of stiffer and harder Al_2O_3 leads to the increase in constraint to plastic deformation of the matrix during the hardness test. Thus increase of hardness of composites could be attributed to the relatively high hardness of Al_2O_3 itself. Through examination of the hardness in Vickers hardness testers and results table shows increase in hardness with increasing the proportion of added alumina into ingot and due to reduced deposition phase $Mg_{17}Al_{12}$ as well as the deposition of alumina on the border of the crystalline phase β–$Mg_{17}Al_{12}$ and in the arms of phase $Mg_{17}Al_{12}$ during dendritic casting process.

Wear Properties

Wear is a process of material removal phenomenon. The prepared alloys with varying weight percentage of Al_2O_3 composites were subjected to wear test under dry sliding condition. The test was conducted on 10 mm diameter and 3 mm thickness.

Fig. 2 shows that the wear rate of the alloys decreases after addition of Al_2O_3 granules compared to Mg–6Al base alloy, so the wear resistance increases. This is due to the incorporation of hard Al_2O_3 particles in the Mg–6Al alloy restricts and improves the wear resistance due to reduced deposition phase $Mg_{17}Al_{12}$ as well as the deposition of alumina on the border of the crystalline phase β–$Mg_{17}Al_{12}$ and in the arms of phase $Mg_{17}Al_{12}$ during dendritic casting process.

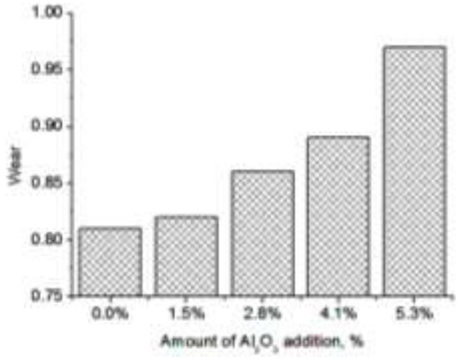

Fig. 2: The wear resistance of Mg–6Al alloy with different wt % of Al_2O_3 granules.

Conclusions

To enhance the properties of Mg–6Al alloys, Al_2O_3 powder with granules sizes less than 25 μm was added. The effect of the Al_2O_3 contents on the hardness and wear resistance was investigated. The following results are obtained:

1. Mg–6Al–xAl_2O_3 composites have shown higher hardness when compared to the hardness of Mg–6Al alloy due to reduced deposition phase as well as the deposition of alumina on the border of the crystalline phase and in the dendritic arms during the casting process.
2. Higher wear resistance was observed in as cast Mg–6Al–xAl_2O_3 when compared to Mg–6Al based alloy. The resistance to wear is increased with increasing proportion of alumina powder addition because the deposition of crystalline alumina granules on the border in phases, a remnant of the alloy during freezing process.

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