Investigation of the effects of Magnesium Content and Cooling Rate on the Mechanical Properties of Aluminium-Magnesium Alloys Refined with Titanium-Boride Master Alloy

Fatai Olufemi ARAMIDE[1], Samuel Ademola IBITOYE[2] and Obafunmilola Oluwatosin FAGADE[2]

[1] *Metallurgical and Materials Engineering Department, Federal University of Technology, Akure, Ondo State, Nigeria.*
[2] *Materials Science and Engineering Department, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria.*
E-mails: fat2003net@yahoo.com; sibitoye@0auife.edu.ng
[*] Corresponding author: Phone: +2348038509288

Abstract

Investigations into the effects of magnesium content and cooling rates on the mechanical properties of aluminium-magnesium alloys refined with titanium-boride master alloy was conducted. Experimental samples were produced from melt with Mg content ranging from 0% to 8%, poured and cooled in air, water and oil. Standard sample dimensions were produced for tensile and hardness tests. It was observed that both the Mg content and the cooling rate affect the mechanical properties; elongation (ductility) reduced with increased Mg content while the hardness of the samples increased with the Mg content. It was concluded that the sample poured and cooled in water possessed the optimum mechanical properties (combination of ductility and hardness) within the range of composition of maximum ultimate tensile strength (UTS).

Keywords

Magnesium content; Cooling rates; Ductility; Master alloy.

Introduction

The use of aluminium and magnesium alloys in the automobile industry is continuously increasing. The driving force is reduced green house gas emissions resulting from light weighting of the vehicles and efficient scrap recycling. The present consumption of aluminium and magnesium in passenger cars is 120-140 kg and ~5 kg per vehicle respectively; these figures are expected to rise further in the next decade. In order to maintain this momentum it is necessary to pay attention to all processing (solidification, mechanical and thermal) aspects of the alloys and optimize the properties. Grain refining plays an important role in this context [1]. Many people have worked on grain refinements; Kowatschewa et al [2] reported that depending on the constitutional and heat flow conditions in a solidifying aluminium alloy, two different grain morphologies are possible, namely, equiaxed and columnar. The formation of a fine equiaxed grain structure is always desired due to its inherent uniform mechanical properties, reduced ingot cracking, improved feeding, enhanced fluidity and fabric ability, improved mach inability, and better surface finishing. Various reports have been submitted by various researchers on grain refinement, influence of cooling rate on grain refinement and so on [3-13], but none of them have actually focused on the combined effects magnesium contents and cooling rates on the mechanical properties of aluminium-magnesium alloy.

This aim of the research was directed towards exploring the combined effects of magnesium contents and cooling rates on the mechanical properties of aluminium-magnesium alloy refined with titanium boride master alloy.

Material and Method

The materials used for this research work are commercially pure aluminium metal, Magnesium metal and titanium boride obtained from Aluminium Rolling Mills, Otta; a division of Tower Aluminium (Nig.) Plc.

Test Specimen Preparation

The melt was produce in a cast iron crucible placed in an electric furnace, after charging it with required proportions as shown in Table1.

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Table 1. Composition range use for preparing the alloy

Alloy Type	Composition (%)		
	Al	Mg	Ti-B
A	100	0	0.1
B	98	2	0.1
C	96	4	0.1
D	94	6	0.1
E	92	8	0.1

The electric furnace was set at 700°C and then switched on. For all the produced castings, the molten metal was poured into metal moulds made of steel. For the samples that cooled in normal still air, the melt was poured into the steel mould in still air and left to cool. For those samples that cooled in water or oil the steel mould was immersed in the cooling media inside a special container that allowed the cooling media to flow so as to carry heat away outside the container as fresh cooling media is flowing into the container while the melt is being poured into the mould.

The cast rods were machined to standard dimensions for the impact and tensile test samples on a lathe machine. Samples were also cut for hardness tests.

Tensile Testing

The tensile tests were performed on various samples using Monsanto tensometer. The fracture load for each sample was noted as well as the diameter at the point of fracture and the final gauge length. The initial diameter and initial gauge length for each sample was noted before uniaxial load. From the generated data the ultimate tensile strength and percentage elongation of each sample was calculated.

Hardness Test

The hardness test was carried out on the various test samples using the Hounds Field Tensometer with a compression die and the Brinell ball bolster attached, having adjusted the mercury level to zero.

Results and Discussions

Tables 2-4 show the effects of magnesium content on; the UTS of the samples quenched in different media, the percentage elongation of the samples quenched in different media and the Brinell hardness of the samples quenched in different media respectively. Similarly, figures 1-3 show the effects of magnesium content on; the UTS of the samples quenched in different media, the percentage elongation of the samples quenched in different media and the Brinell hardness of the samples quenched in different media respectively.

Table 2. Effect of Magnesium content on the UTS of the samples quenched in different media

Magnesium Content (%)	Ultimate Tensile Strength (UTS) (Nmm^{-2})		
	Air	Water	Oil
0	8.52		
2	13.58	12.69	13.24
4	14.19	15.23	15.17
6	10.28	11.35	11.99
8	7.95	9.75	11.30

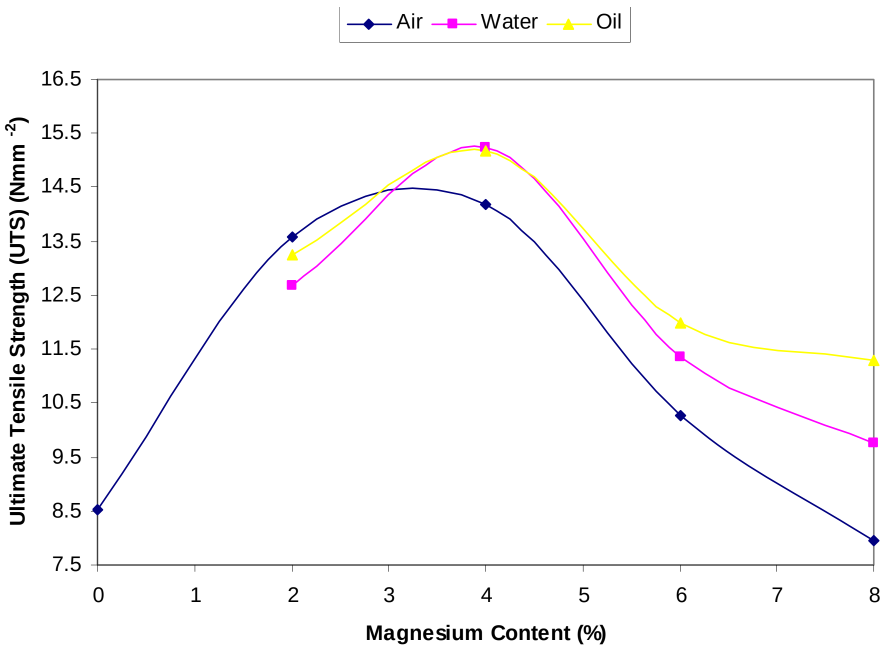

Figure 1. *Effect of Magnesium content on the UTS of the samples quenched in different media*

From Figure 1 the effect of magnesium content on the ultimate tensile strength of the sample is conspicuously seen; for all the samples, the UTS initially increased with increase in the magnesium content, the maximum UTS is achieved at 4% magnesium content, further increase in the magnesium content results in reduced UTS [14]. For the samples poured and cooled in air, the UTS at 2% Mg content was higher than those of other samples poured and cooled in other cooling media while the UTS of the other samples poured and cooled in other media were higher at 4% and above Mg content.

Table 3. Effect of Magnesium content on the percentage elongation of the samples quenched in different media

Magnesium Content (%)	Elongation (%)		
	Air	Water	Oil
0	17.17		
2	25.19	34.67	23.94
4	25.09	19.52	14.93
6	21.82	13.39	9.32
8	15.95	6.73	8.51

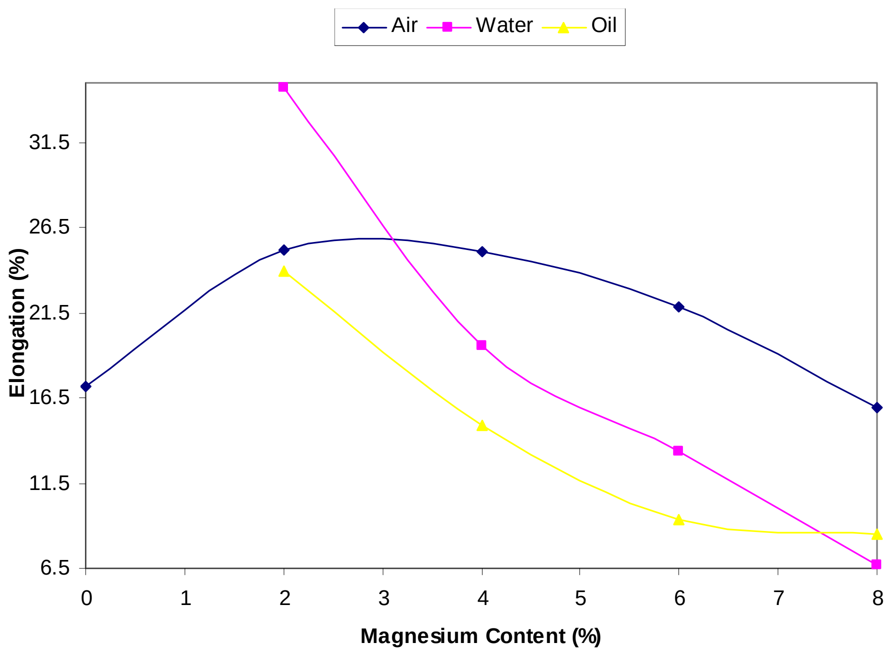

Figure 2. *Effect of Magnesium content on the percentage elongation of the samples quenched in different media*

From Figure 2 it is clear that the percentage elongation which is a measure of ductility of the samples reduces with increase in magnesium content. It is also observed that the ductility of the samples cooled in air was higher than those of the samples poured and cooled in other media at all the concerned Mg content except at 2% Mg when the sample poured and cooled in water had the highest ductility. Moreover, for air cooled samples, within the Mg content range of 2 to 6%, ductility was higher than what was obtainable at 0% Mg content;

while for water cooled samples, higher ductility was achieved within 2 to 4% Mg content and also for oil cooled samples higher ductility was obtained only at 2% Mg content. The reduction in ductility is as result of the precipitation of the β-phase Al_8Mg_5 at the gain boundaries as the magnesium content of the alloy increases above a certain threshold [14].

Table 4. Effect of Magnesium content on the Brinell hardness of the samples quenched in different media

Magnesium Content (%)	Brinell Hardness		
	Air	Water	Oil
0	23.8		
2	18.6	40.2	18.6
4	31.2	34.4	29.8
6	38.1	38.1	36.2
8	50.3	42.4	44.9

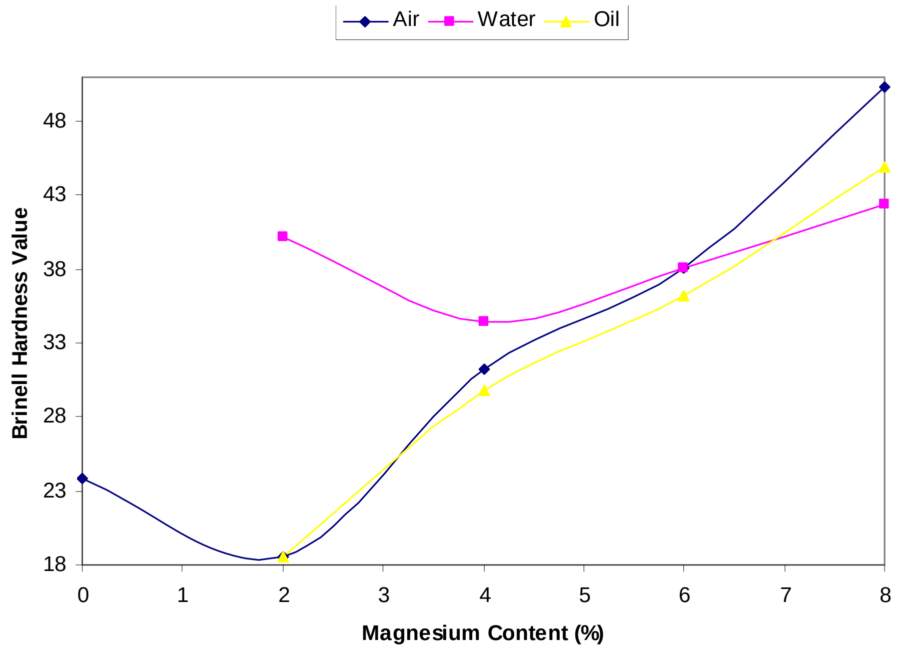

Figure 3. *Effect of Magnesium content on the hardness of the samples quenched in different media*

From Figure 3, it is observed that contrary to what was observed in Figure 2, the Brinell hardness value of the samples increases with increase in the Magnesium content of the samples for all the sets of samples considered [15]. The hardness of the samples poured and cooled in water being the highest while that of the samples poured and cooled in oil was the least within the magnesium content range of 2% to 6%. But at the magnesium content of 8%, those samples poured and cooled in air possessed the highest hardness while those poured and cooled in water possessed the least hardness.

Conclusions

From the discussion so far it is concluded that:

- Increase in magnesium content improves the UTS of the sample up to a certain threshold, thereafter, further increase in the magnesium content results in reduction in the UTS.
- Increase in magnesium content results in reduction in the ductility and increase in the hardness of the resulting alloy.
- The sample poured and cooled in water possessed the optimum mechanical properties (combination of ductility and hardness) within the range of composition of maximum UTS.

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