EFFECT OF MAGNESIUM ENHANCEMENT ON MECHANICAL PROPERTY AND WEAR BEHAVIOUR OF LM6 ALUMINUM ALLOY

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Abstract: For last several decades aluminium and aluminium alloys are widely used in automotive industries because for their favourable properties like low density (about 2700 Kg/m^3), good malleability, high formability, high corrosion resistance and high electrical and thermal conductivity. High machinability and workability of aluminium alloys are prone to porosity due to gases dissolved during melting processes. However, in the engineering application pure aluminium and its alloys still have some problems such as relatively low strength, unstable mechanical properties and low wear resistance. The microstructure can be modified and mechanical properties, wear resistance can be improved by alloying, cold working and heat treatment. In this regards, the present paper reports the influences of enhancement of magnesium contents on the mechanical properties and wear behavior of LM 6 aluminum alloy.

Index Terms: LM 6 Aluminum alloy, wear rate

1. Introduction

Aluminium and aluminium alloy are gaining huge industrial significance because of their outstanding combination of mechanical, physical and tribological properties over the base alloys. These properties include high specific strength, high wear and seizure resistance, high stiffness, better elevated temperature strength, controlled thermal expansion coefficient and improved damping capacity [1]. These properties obtained through addition of alloying elements, cold working and heat treatment. Alloying elements are selected based on their effects and suitability. For the purpose of understanding their effects and importance, alloying elements for majority of alloys are best classified as major and minor elements, microstructure modifiers or impurities, however the impurity elements in some alloys might be major elements in others [2]. LM6 is one of the most important Aluminium alloy falls under Aluminium – Silicon alloying system in which aluminium is the predominant metal and high levels of silicon (4% to 13%) are added that contributes to give good casting characteristics and increases fluidity, by which we can produce castings of thick as well as thin sections according to the required design. Other typical alloying elements are Copper, Magnesium, Manganese, Silicon, Zinc, Iron, Nickel, Lead and Tin.

Engineering and consumer goods are produced by a number of techniques among which are sand casting and die casting. Lynch *et al*. (1975) observed that although sand cast parts are characterised by rough surface finishes, sand casting as a process offers a cheap means of fabrication which also allows undercuts and channels to be cast into the part and allows the casting of many small-sized parts simultaneously in the same mould, thus increasing productivity The maximum weight obtainable by squeeze casting is 19kg for aluminium-base alloys (Clegg 1991; Yue and Chadwick 1996). But the maximum weights attainable by chill casting are 70kg, 25kg, 13.6kg and 9kg for aluminium-base alloys, magnesium-base alloys, cast iron and copper-base alloys, respectively (West and Gruback 1989; Clegg 1991). Abdulkabir Raji was observed that the grain size of the microstructures of the cast products increased from those of Die-casting to sand casting. Conversely, the mechanical properties of the cast products improved from those of sand casting to Die-casting [3]. Each alternative technique is characterized by its own distinct capabilities and related costs.. we have investigated the effect of enhancementment of magnisum addition in LM6 alloy on hardness and wear resistance and compare these properties with LM6 alloy. Results revealed that hardness and wear resistance of new LM6 alloy increases with high Mg addition.

2. Material

The chemical composition and mechanical properties of LM6 alloy are shown in Table-1 and Table-2 respectively. The composition of aluminum alloy used in the present work is given in Table-3. The present work aims to investigate the effect of enhancement of Magnesium in LM 6 alloy. The percentage of Mg was increased upto to 1.18% and the effect of this enhancement on tensile strength, hardness and wear properties of LM6 alloy was studied. Aluminum alloy (LM6) & Mg was supplied by S. M. Founders (Bhopal). The oil fired furnace was used for casting the LM6 alloy.

Table-1CHEMICAL COMPOSITION OF LM6

Copper	0.1 max
Magnesium	0.10 max.
Silicon	10.0-13.0

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Iron	0.6 max
Manganese	0.5 max
Nickel	0.1 max
Zinc	0.1 max.
Lead	0.1 max.
Tin	0.05 max
Titanium	0.2 max
Aluminium	Remainder
Others: each	0.05 max.

Table2 Mechanical properties of die cast lm 6 alloy

Tensile Stress (N/mm^2)	Elongation (%)	Brinell Hardness	Endurance Limit ($5x10^7$ cycles; N/mm^2)	Modulus of Elasticity ($x10^3$ N/mm^2)
280	2-5	55-60	70-100	71

Table 3 Composition of aluminum alloy used in the present work

Sr. No.	**Material**	**% Wt.**
1.	Al	88.48
2.	Cu	0.06
3.	**Mg**	**1.18**
4.	Si	9.52
5.	Fe	0.425
6.	Ni	0.005
7.	Mn	0.048
8.	Zn	0.044
9.	Sn	0.006
10	Ti	0.043
11.	Cr	0.170
12.	V	0.019

3. Experimental Methods: LM6 alloy was placed in graphite crucible and heated in Oil fired furnace. For aluminium alloy the overall furnace temperature was about 700⁰C to 750⁰C. The consumption rate of the oil in the furnace was 13-20 liters /hour. Molten metal was poured in mild steel die which is preheated to about 200⁰C. No external source of cooling the die was used. The cooling was done by the natural convection & conduction process. The **die casting** process was used to cast the specimen because this process is best suited for speedy production of bulk metallic parts, and it requires minimal secondary operations like machining. Figure 1 shows the Die casting process used for casting the test specimens. Others equipments used in the present work include wear analysis apparatus, Precision electron balance, Brinell hardness testing machine and Universal testing machine for further investigation of cast product.

Figure 1 Die casting process used for casting the test material

4. Testing of Properties: The mechanical properties like tensile strength, Hardness and tribological properties like wear resistance were investigated in the present work.

4.1Tensile test: Dimensions of tensile specimen is shown in figure 2. Specifications and norms for tensile test specimen were used as per ASTM standard. Dimensions of specimen used: Overall Length = 200 mm, Parallel length = 57 mm, Grip section = 50 mm, Width of grip section = 20 mm, Gauge diameter = (a) 13 mm, (b) 12.3 mm.

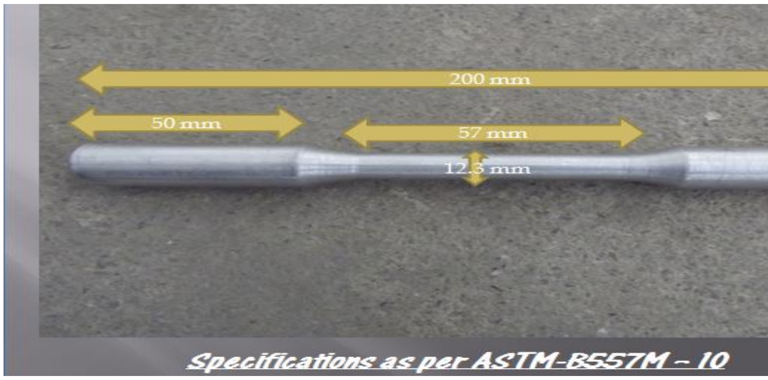

Figure 2 Dimensions of tensile specimen

Tensile test were performed on UTM of the specimen having gauge diameter 13 mm and 12.3 mm. The test results were summarized in the table 4 and table 5 for the

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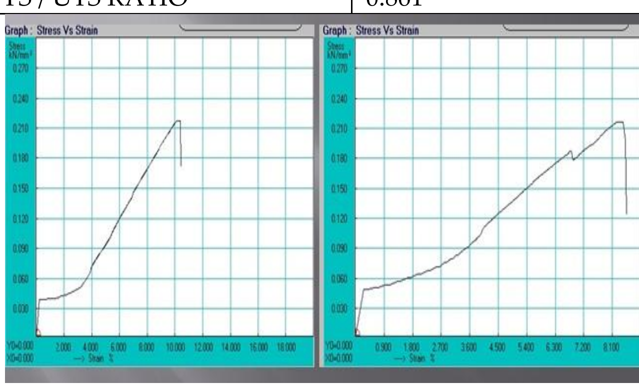
diameter of the specimen 13 mm and 12.6 mm respectively. Stress vs strain curve were shown in the Figure 3. The value of Young's Modulus was found to be 3.036 GPa on the basis of this stress and strain curve.

Table4 Results of the tensile test for gauge diameter of 13 mm

ULTIMATE BREAKING LOAD	28.880KN
MAXIMUM DISPLACEMENT	6.810 mm
ULTIMATE STRESS	0.217 kN/mm^2
ELONGATION	7.692 %
REDUCTION IN AREA	14.793 %
YIELD STRESS	0.187 kN/mm^2
YS / UTS RATIO	0.861

Table 5 Results of the tensile test for gauge diameter of 12.3 mm

ULTIMATE BREAKING LOAD	25.720KN
MAXIMUM DISPLACEMENT	5.280 mm
ULTIMATE STRESS	0.216 kN/mm^2
ELONGATION	12.821 %
REDUCTION IN AREA	4.819 %
YIELD STRESS	0.187 kN/mm^2
YS / UTS RATIO	0.861



For d = 13 mm For d = 12.3_ mm

Figure 3 Stress vs strain curve obtained during tensile test

Crake Surface Analysis: The structure and type of crack in the tensile test specimen shown in figure 4 is highly resembles to that of a brittle material. The cup-and-cone fracture as in the case of ductile material (LM6) was nt seen. Thus, brittleness of the material has increased tremendously. In brittle fracture, no apparent plastic deformation takes place before fracture. In brittle crystalline materials, fracture can occur by cleavage as the result of tensile stress acting normal to crystallographic planes with low bonding (cleavage planes). In amorphous solids, by contrast, the lack of a crystalline structure results in a conchoidal fracture, with cracks proceeding normal to the applied tensile load.

Figure 4 Photograph of the fractured tensile test specimen

4.2 WEAR TEST: Wear test was performed on Pin-on-Disc wear testing machine at 120 rpm, track radius 50 mm and for 10 minute time duration in dry sliding condition at atmospheric temperature. Three readings were taken at 20N, 30N and 40N applied load. Weight of the specimen was measured before and after each reading. Dimensions of test specimen for wear test are as follows (Figure 5):
Diameter of specimen = 10 mm
Length of specimen = 30 mm.

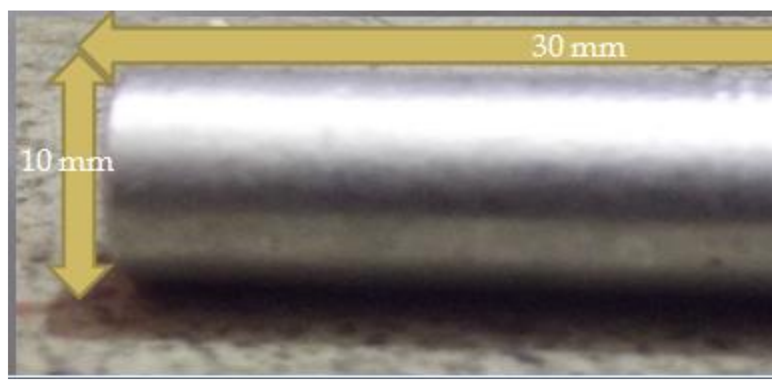


Figure 5 Photograph of the wear test sample

The following formula was used to to calculate the Wear Rate which is equal to the Volume removed/unit distance of sliding/unit loading:
Wear Rate = $(dW)/(\pi \varrho DPNt)$
Here, dW = weight lost after test,
ϱ = density of material = 2.65617 g/cm^3

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D = track radius,
N = average rotating disc speed,
t = time duration of test,
P = applied load,

On the basis of test results shown in Table 6, the average wear rate was found to be 1.2762 x 10^{-13} m^3/Nm. For load =30 N the trends of wear, frictional force and coefficient of friction with respect to time is shown in figure 6.

Table 6 Results of the wear test

Sr. No.	Load	Weight before test	Weight after test	Wear rate(m^3/Nm)
1	20 N	5.851g	5.850g	9.986*10^{-14}
2	30N	5.844g	5.842g	1.332*10^{-13}
3	40N	5.838g	5.835g	1.498*10^{-13}

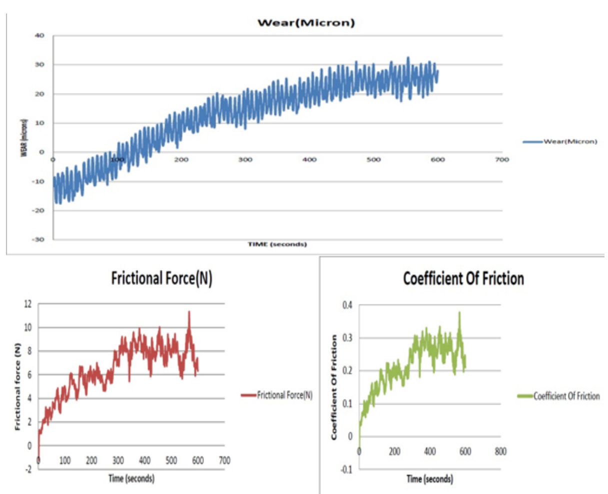

Figure 6 The graph of the wear rate, friction force and coefficient of friction obtained during wear test

4.3 BRINELL HARDNESS TEST: Brinnel hardness test were performed on the polished sample of the aluminum alloy. The dimension of specimen for hardness test was 75 mm x 23 mm x 10 mm. Hardness test were conducted on test specimen for the three set of load applied 3000 kgf, 1500 kgf, 500kgf for a given time period and indenter diameter was 10 mm. the test result were shown in the Table 7. The average hardness of test material was found to be 98.25 BHN.

Table 7 Results of the hardness tests

Sr. No	**Value of (P/D^2)**	**Load P (kgf)**	**Diameter of indenter (mm)**	**Time for which load was applied (Seconds)**	**Diameter of indentation mark (mm)**	**BHN**
1.	30	3000	10	30	6.2	88.66
2.	30	3000	10	15	6.0	95.49
3.	30	1500	10	30	4.1	108.62
4.	30	500	10	180	2.5	100.24

5. RESULTS AND DISCUSSIONS:

(a)Tensile test was performed on specimens with diameter 13 mm and 12.3 mm, in which we got mean Ultimate Tensile Strength = 217 N/mm^2, mean Yield Strength = 187 N/mm^2 and Young's Modulus = 3.036 GPa. Ultimate Tensile strength has decreased with Mg addition.

(b)Wear test was done on the specimen of diameter 10 mm in which we got mean Wear rate = 1.2762 x 10^{-13} m^3/Nm .Wear rate has decreased with Mg addition.

(c)Brinell hardness test was done and the mean BHN 98.25. Hardness has increased with Mg addition.

(d)The comparison of Mechanical properties and wear behaviour of LM6 and LM6alloy with higher Magnesium contents was done and is shown in Table 8.

Table8

Criteria	LM6 Alloy	LM6 alloy with higher Mg contents
ULTIMATE TENSILE STRENGTH	230 N/mm^2	217 N/mm^2
YOUNG'S MODULUS	64.2 GPa	3.036 GPa
YIELD STRENGTH	198 N/mm^2	187 N/mm^2
DENSITY	2.65 g/cm^3	2.65617 g/cm^3
WEAR RATE	10^{-10} m^3/Nm	1.2762×10^{-13} m^3/Nm
HARDNESS	55- 60 BHN	98.25 BHN

6. Conclusions:

From experimental study on the LM6 alloy, hardness was found to increase with increase in Mg content while the yield strength and ductility was found to decrease with increase in Mg content due to brittleness of the material. Wear rate was also found to decrease with increase in Mg content. This is due to softening of the material at the warm surfaces due to higher temperature at the contact surface.

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