IJRAME
ISSN (ONLINE): 2321-3051

INTERNATIONAL JOURNAL OF RESEARCH IN AERONAUTICAL AND MECHANICAL ENGINEERING

# MECHANICAL BEHAVIOUR OF LM6 ALUMINIUM ALLOY REINFORCED WITH NANO ALUMINIUM OXIDE USING DIE CASTING METHOD

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## Abstract

The LM6/Al2O3 nano composites were fabricated using a die casting method .The LM6 Aluminum alloy was reinforced with Al2O3 nan particles 0 wt.%,1 wt.%, 1.5 wt% and 2.5 wt% .The composites were characterized by Wear, Tensile, Hardness and Impact tests were carried out in order to identify mechanical properties. . The results reveal that die casting could be an economical route for the production of nano composites. Increasing the volume of fraction and/or reducing the size of Al2O3 nano particulates increase both the tensile and yield strength of the nano composites and reducing the wear

***Keywords**:* MMNC, Nano Alumina, die casting, Mechanical properties.

## 1. Introduction

Metal-matrix Nano composite materials have emerged as a viable alternative to overcome the limitations of metal matrix composites; however nano composites are challenging to produce as structural components due to difficulties in attaining a homogeneous distribution of the nano phased particles.

A *nano composite* is a multiphase solid material where one of the phases has one, two or three dimensions of less than 100 nanometers (nm), or structures having nano-scale repeat distances between the different phases that make up the material. In the broadest sense this definition can include porous media, colloids, gels and copolymers, but is more usually taken to mean the solid combination of a bulk matrix and nano-dimensional phase(s) differing in properties due to dissimilarities in structure and chemistry. The mechanical, electrical, thermal, optical, electrochemical, catalytic properties of the nano composite will differ markedly from that of the component materials. Particulate reinforcement by employing double layer feeding – die casting technique proves to be a promising technique in developing MMNC.

## 2.EXPERIMENTAL PROCEDURE

### *2.1 Materials*

Aluminium Alloy LM6 and nano – $Al_2O_3$ were chosen as Matrix alloy and reinforcement respectively. LM6 is selected as the matrix alloy which has fewer tendencies to drag than with high silicon alloys containing no other alloying elements. LM6 Alloy has high Resistance to corrosion attack under normal atmospheric condition. Nano alumina particulates were reinforced with matrix alloy in different weight percentages of 0 %,1%, 1.5% and 2.5% respectively. The matrix was preheated at 200 °C and the reinforcements were added to the matrix material using double layer feeding mechanism [2]. The mix was then melted to liquidus temperature of 600°C – 700°C and motor stirrer at 90RPM. The spectro- analysis test report of the matrix alloy is given in Table 1

| Constituents | Composition % |
|---|---|
| Iron | 0.6 |
| Silicon | 10.0-13.0 |
| Copper | 0.1 |
| Manganese | 0.5 |
| Magnesium | 0.1 |
| Titanium | 0.2 |
| Nickel | 0.11 |
| Zinc | 0.14 |
| Aluminium | 84.0-86.0 |

### *2.2 Processing*

The Aluminum alloy (LM6) was heated in a graphite crucible under controlled argon environment. The furnace heating temperature was increased to 750ºC, hold for 30 minutes until Aluminum alloy melted completely

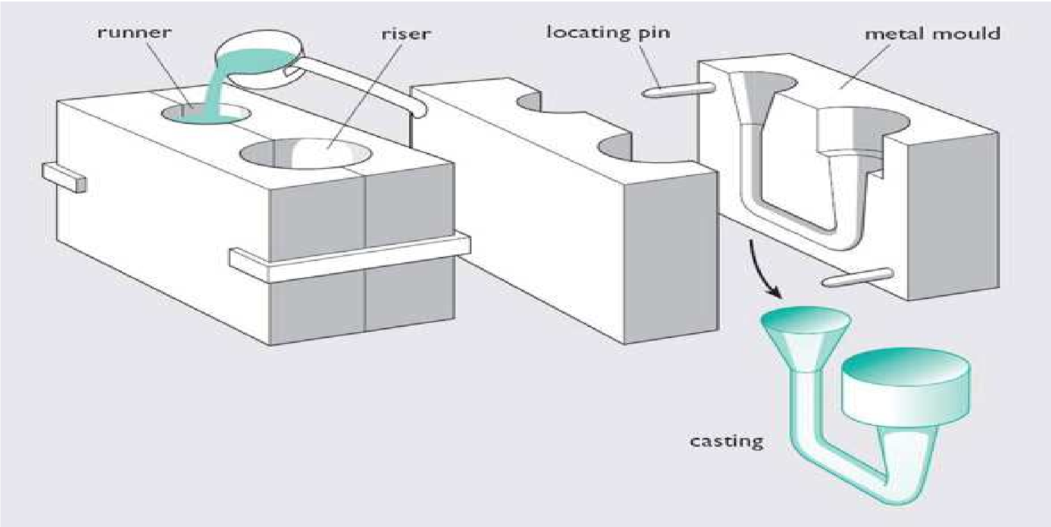



Fig 1

Aluminum dross then removed from the surface of the molten metal. Weighted amounts particulate of zirconium oxide preheated to 750º were added continuously to the molten metal through the side of vortex created by mechanical stirring by the stir impeller. The optimum stirring speed of 450 rpm was determined and selected prior to this experiment. This is to avoid excessive gas content that resulted from over agitating of melts, which led to unacceptable porosity content in the casting product (Hashim et al., 2002). The impeller and stirring rod was coated with liquid alumina so as to avoid any metals contamination to the molten metal. Stirring was carried out to facilitate both incorporation and uniform distribution of particulate Aluminium Oxide in the molten metal. The composite melt was stirred for 5 minutes then immediately cast into a permanent mould in gravity die. The solidified Al/ $Al_2O_3$ metal matrix composites (MMC), which were taken out from the mould. Separate samples for tensile strength, hardness, wear resistance, impact and corrosive resistance at 0 wt.%, 1wt. %, 1.5wt. % and 2.5 wt. % were produced

### 2.3 *Wear Testing*

Wear tests were performed using a DUCOM pin on disc tribometer. The pin was an 8mm diameter single crystal $Al_2O_3$- LM6 MMNC ball which was held down stationary on the flat face of the test piece disc under a 10 N load initially. The disc velocity is maintained at 0.1 m/s in unlubricated, open air environment. Before and after each test, the specimen and the discs were cleaned using the acetone and dried up in the open air to avoid any contaminations. Experimental parameters were tabulated in Table 2. Also the temperature change in the specimens at the ends of the wear test was measured using the digital temperature indicator with 0.1° C accuracy.

TABLE II
EXPERIMENTAL PARAMETERS OF WEAR TEST

| | |
|---|---|
| Pin Length | 30 mm |
| Pin Diameter | 8 mm |
| Load | 10 – 20 N |
| Track Diameter | 60 – 90 mm |
| Sliding speed | 3.665 s (1000 RPM) |

### *2.4 Mechanical Testing*

The mechanical behaviour of the materials, specimens were prepared for tensile tests. A cylindrical rod specimen of Ø15 is subjected to a tensile load using the Universal Testing Machine (UTM). Test data were used to find the breaking and the ultimate load corresponding to the MMNC samples.

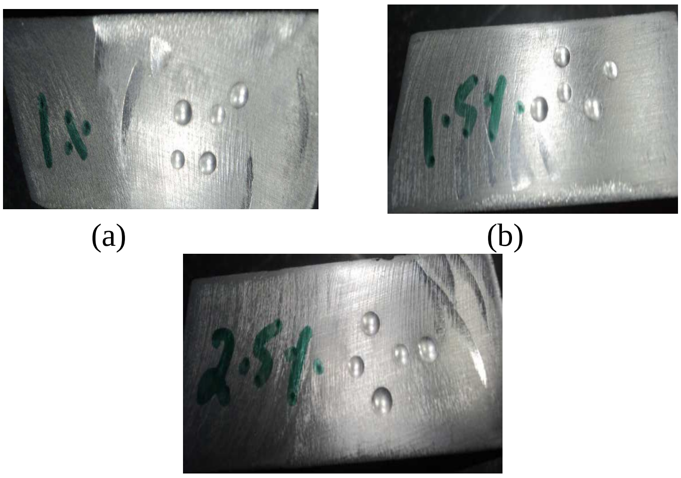
The specimens were prepared for measuring hardness tests by polishing them with suitable grades of emery and etching them finally. Rockwell hardness test was carried out with 1/16” steel ball indenter with minor load of 10kgF and major load of 90 kgF. The specimens were prepared for measuring the impact strength of LM6 and reinforcement of Aluminium Oxide

## 3.RESULTS AND DISCUSSIONS

### *3.1MMNC Samples*

The MMNC samples prepared shows presence of porosity reduces with increase in the percentage of reinforcement. The presence of porosity reduces as the reinforcement increases since the interfacial bonding between the aluminium matrix and the $Al_2O_3$ particulates is high for higher percentage of reinforcements.

### *3.1.1Hardness samples*




(a) (b) (c)

Fig. 2 Hardness samples (a) MMNC with 1% $Al_2O_3$, (b) MMNC with 1.5% $Al_2O_3$, (c) MMNC with 2.5% $Al_2O_3$

### *3.1.2 Tensile test samples*

Fig 3

### *3.1.3 Impact samples*

Fig 4

### *3.1.3 Wear samples*

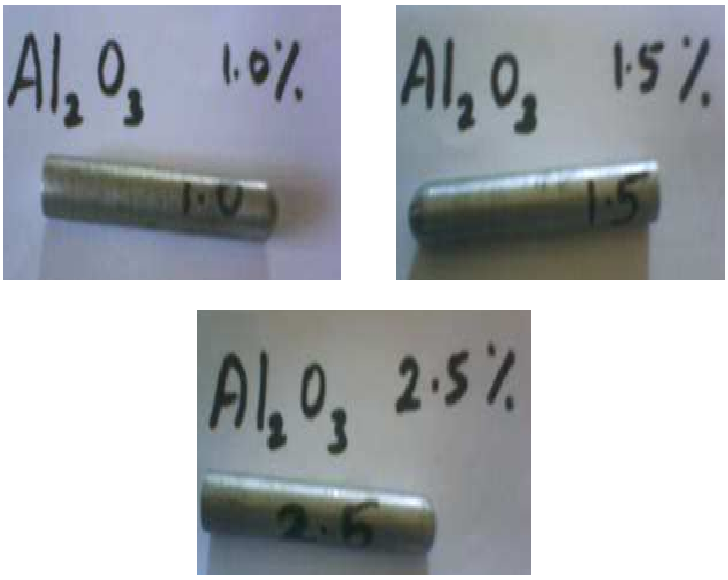



Fig 5

## *3.2 Wear Characteristics*

Pin-on-disc dry sliding wear test results with pins of pure Aluminium reinforced with up to 1%, 1.5% and 2.5% weight of (40nm) nano-sized alumina showed that wear rate decreases with increasing percentage of reinforcement. The volumetric wear rates of Aluminium and its composites are plotted against the time to the wear in micrometer. It is immediately apparent that there is consistent improvement in wear resistance with increasing amounts of reinforcement. This corresponds directly to the rise in hardness and strength of the composites with reinforcement level, and agrees with Archard's equation that the wear of a material is inversely proportional to its hardness. The 2.5 %$Al_2O_3$ -reinforced MMNC, being the best performer shows an improvement in the wear resistance of 1.2 times at the lowest speed of 1 m/s, and more importantly, up to 1.9 times under the higher-speed, and thus, more severe sliding conditions.

There is a gradual reduction in the wear rates of all the specimens over a fairly wide range of sliding velocities, from 1 to 7 m/s. In this series of tests under a 20 N load, the optimum speed for these materials appears to be around 7 m/s, beyond which, the wear rates begin to rise.

The results of this study have shown that nano-sized alumina particulates 1%, 1.5% and 2.5% volume are able to bring appreciable improvement to the wear resistance of pure aluminium matrix alloy, especially under higher sliding speeds.

## *3.3 Mechanical test results*

It was observed that the MMNC samples with higher percentage of reinforcement shows higher hardness, higher tensile strength and lower wear strength. The tensile test, Hardness test and wear test results plots were shown in Fig. 6.Fig 7.Fig 8

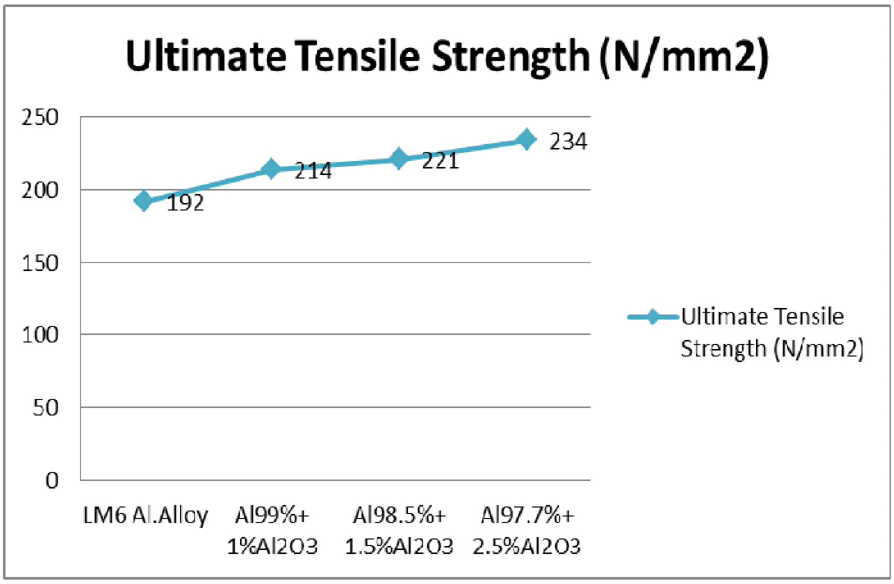



Fig. 6 Tensile test plots results of LM6 and MMNC

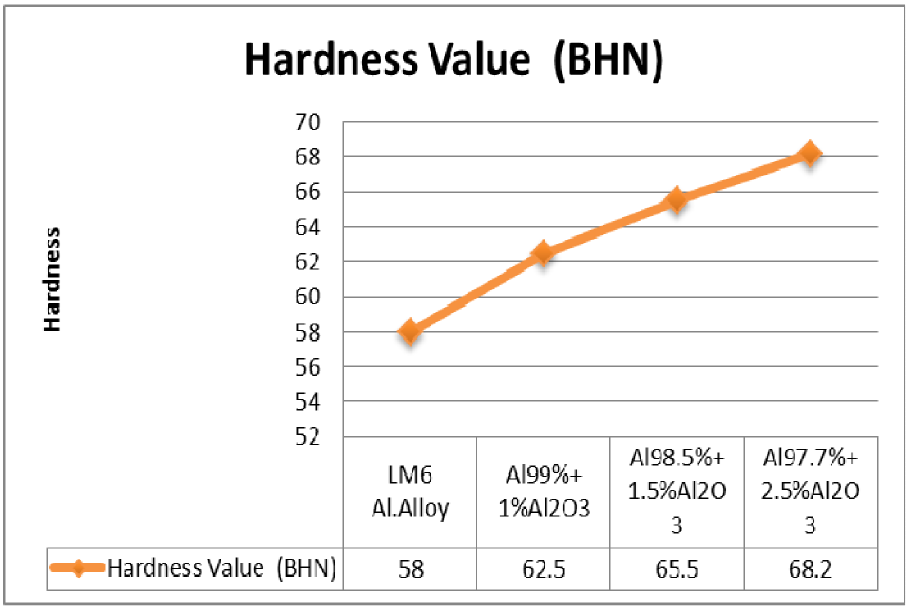



Fig. 7 Hardness survey results of LM6 and MMNC

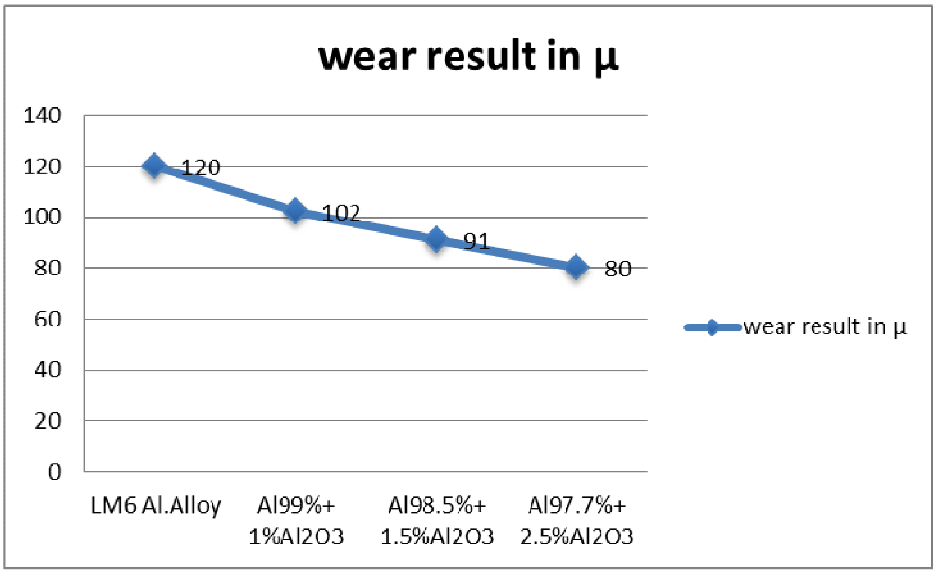



Fig. 8 Volumetric Wear rates of matrix alloy and MMNC

## 4. CONCULSION

0%, 1%, 1.5% and 2.5 Nano Alumina reinforcement are fabricated and the MMNC are prepared in the form of Blanks, Rods and Billets from these the test specimen has been produced and examined for Hardness test, Impact test, Tensile test and wear test

From these results The MMNC thus prepared exhibits good mechanical properties like hardness; Tensile strength and impact resistance and tribological properties like wear resistance compared to the ethnic materials.

The LM6 Al. Alloy reinforced with 2.5 % of $Al_2O_3$ MMNC gives the better results when compared to the all other types of metal matrix composites thus produced and tested. And the Combined results were tabulated in the below table

Table -3 Mechanical properties of LM6 Al. Alloy reinforced with 2.5% Alumina

| **Mechanical properties** | **LM6 Al. Alloy** | **LM6 Al. Alloy Reinforced with 2.5% of $Al_2O_3$** |
|---|---|---|
| Hardness | 55 BHN | 68.2 BHN |
| Ultimate Tensile Strength | 192 N/mm2 | 234 N/mm2 |
| Impact strength | 9 Nmm | 34.62 Nmm |
| Wear rate | 120 µm | 80 µm |

Vol.2 Issue.4,
April 2014.
Pgs: 1-8

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