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Assessment of Tensile and Hardness Property of AA5083/Nano-Al_2O_3 Metal Matrix Composites

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Abstract
Al–Mg base composites reinforced with different mixtures of nano-Al_2O_3 particles have been fabricated by mechanical stir casting and their metallurgical and mechanical characterization has been investigated. In this investigation, the Al_2O_3 particulates were reinforced into the base matrix of aluminium fabricated with five levels of volume fraction such as Al/0 vol.% Al_2O_3, Al/2 vol.% Al_2O_3, Al/4 vol.% Al_2O_3, Al/6 vol.% Al_2O_3 and Al/8 vol.% Al_2O_3. After the Al-base-nano-composites were fabricated by stir casting, the microstructure inside the matrix has been investigated using optical microscope. The hardness and the tensile properties of the nano-composites were evaluated at room temperature by using Vickers hardness and universal tensile testers, respectively. The result confirmed that stir cast AA5083 with uniform distribution of nano-Al_2O_3 particles enhances both tensile strength and hardness. With 6 wt.% of nano-Al_2O_3 indicating sensibly reasonably high strength by 29.53% and hardness by 24.65% when compared with matrix alloy.

Keywords: *Aluminium alloy 5083, nano-Al_2O_3, Vickers hardness, strength*

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INTRODUCTION

Metal matrix composite is a fundamental class of materials with high potential for structural applications obliging high-specific modulus, strength and toughness. Metal matrix nanocomposite materials have issues as a reasonable distinct choice for defeat the constraints of metal matrix composites; however, nanocomposites are attempting to make as structural composites as a result of challenges in accomplishing a homogeneous dispersion of the nanophased particles[1]. Nanotechnology is spreading enormously in the different requesting fields of building and drugs like aviation, barrier, automotives, hardware, materials, science, imperativeness, environment, information and correspondence, purchaser stock and biotechnology. It made a high impact on improvement of new time nanomaterials with cutting edge elements and board mixture of their applications. Reinforcement of submicron or nanosized particles with aluminium matrix yields predominant mechanical and physical properties and changes morphology and interfacial element of nanocomposites[2]. The processing of AA5083 reinforced with Al_2O_3 through microwave sintering was broken down by Verma *et al.*[3]. Microwave sintering of mechanically alloyed AA5083 composites brought about great density. The hardness value enhanced with increase aluminium oxide content. The wear rate was low with increasing alumina content. Gargatte *et al.* conducted experiments on characterization of aluminium 5083 alloy composites and they reported the dry sliding wear behaviour and Brinell hardness test of AA5083 aluminium reinforced with SiC particles manufactured by stir casting method[4]. It was observed that the wear rate diminished for expanding the reinforcement rate of SiC particles. The tribological behaviour of AA5083 with micro- and nano-SiC composites made by ultrasonic helped stir casting process was explored by Rana *et al.*[5]. The particle size is furthermore one of the components which impacts wear. At low speed and low load the wear resistance of composites with nano-SiC particles is higher than the composites with micron SiC particles because of higher hardness of nano-SiC composites. Reinforced with micro (10 wt.%) SiC and nano (1, 2, 3 and 4 wt.%) SiC particulate composite. Tharik ali *et al.* led experimentation to analysis's the mechanical properties and microstructure of Al_2O_3 reinforced AA5083 matrix composite[6]. AA5083 matrix was reinforced with micron (10–5 wt.%) and nanoparticles (1–5 wt.%) of Al_2O_3. The results showed that the composites containing 2 wt.% of nano-Al_2O_3 and 8 wt.% micro-Al_2O_3 reinforcement obtained magnificent mechanical properties like microhardness and compressive strength because of its compound effect of focus and particulate scale, and the extensive isotropic behaviour was proficient by homogenous distribution of reinforcement in the matrix phase. The mechanical behaviour of LM6 aluminium alloy reinforced with nano-Al_2O_3 utilizing die-casting method was completed by Surendran *et al.*[1]. The aluminium alloy LM6 was reinforced with nano-Al_2O_3 particles 0, 1, 1.5 and 2.5 wt.% is produced by die-casting technique. Nano-Al_2O_3 particle reinforced metal matrix composite exhibits better hardness and strength when compared to micro-Al_2O_3 reinforced metal matrix composite. The tribological behaviour of LM25 aluminium alloy reinforced with nano-Al_2O_3 was inspected by Surendran *et al.*[7]. The results find that the metal matrix nano-composite thus prepared exhibits great mechanical properties like hardness; tensile strength and impact resistance and tribological properties like wear resistance contrasted with the base alloy. Further, the description of micro- and nano-Al_2O_3 particle reinforced LM25 composites was studied by Suresh *et al.*[8]. Results expressed that nano-MMCs exhibit better hardness and tensile properties compared to micro-MMCs. The goal of the present work is to characterize the properties of MMNCs, with varying proportions of nano-Al_2O_3 particle reinforced with AA5083.

EXPERIMENTAL PROCEDURE

Material

Matrix

Aluminium alloy 5083 has been used as matrix alloy for synthesis of MMCs.

The chemical composition of the candidate metal AA5083 and the reinforcement nano-Al_2O_3 employed in the fabrication process is represented in Tables 1 and 2.

Table 1: *Chemical Composition of AA 5083 Alloy (wt.%).*

Element	**Zn**	**Fe**	**Ti**	**Cu**	**Si**	**Mn**	**Mg**	**Cr**	**Al**
wt.%	0.25	0.4	0.15	0.10	0.40	0.70	4.50	0.15	Balance

Table 2: *Chemical Composition of Nano-Alumina (Al_2O_3).*

Element	**CaO**	**Fe_2O_3**	**MgO**	**SiO_2**	**Al_2O_3**
wt.%	≤0.017	≤0.35	≤0.001	≤0.050	≤99

Reinforcement

Nanosize aluminium oxide particulates have been used as reinforcement material. Alumina size particles with average particles size of 30–50 nm and purity $Al_2O_3 \geq 99\%$ were used.

Fabrication of Aluminium Matrix-Al_2O_3 Composites

In the present study, metal matrix composites were prepared by stir-casting method. Aluminium alloy 5083 as matrix phase and nano-Al_2O_3 powder is used as reinforcement with varying proportions such as 0, 2, 4, 6 and 8 wt.%. A special care has been taken to produce castings of nanocomposite specimens for the purpose of achieving uniform distribution of nanoparticles in the matrix phase (Figure 1).

***(a)** Stirring Process.* ***(b)** As-Cast Specimen.*

***Fig. 1:** Preparation of Metal Matrix Nanocomposites. **(a)** Stirring Process, **(b)** Specimen.*

Methods: Mechanical Testing

The specimens were tested for the characterization of hardness and tensile properties.

Microhardness

The microhardness of the surface composite was measured by utilizing Vickers microhardness tester (Make: Wilson Wolpert; Germany). The tests were conducted at constant loading of 0.5 kg load for 30 sec at environment temperature. In every example, three trails were made and the mean value was taken to avoid from the higher deviation of results.

Tensile Test

Tensile specimens were prepared to evaluate ultimate tensile strength, yield strength and percentage elongation as per ASTM E8M-13 standards, as shown in Figures 2 and 3. Tensile test was conducted using Universal Testing Machine.

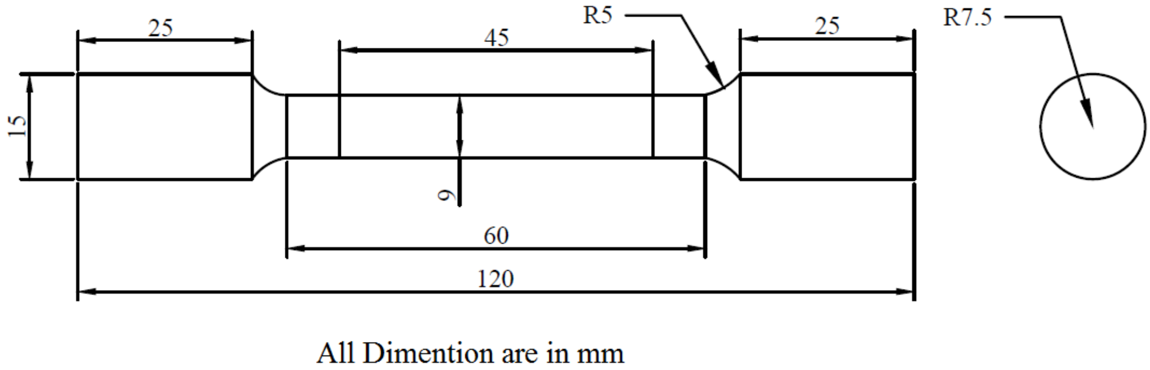

***Fig. 2:** Tensile Test Specimen.*

Fig. 3: *Tensile Sample in UTM of MMNC Specimen.*

Microstructural Characteristics of Al/Nano-Al_2O_3 Composites

The micro-structural characterization of the fabricated composites was carried out using optical microscopy. The specimen was polished as per standard metallographic procedure and etched with keller's reagent.

RESULTS AND DISCUSSIONS

MMNC Samples

The composite AA5083 reinforced with Al_2O_3 was successfully fabricated using mechanical stir casting process.

Hardness

The microhardness of composites was measured using Vickers microhardness tester with the load of 500 gm for 30 sec. The average hardness of as-received AA5083 was 73 Hv. Average of three readings was calculated and tabulated in the Table 3 (Figure 4).

Higher hardness was recorded with 6 wt.% nano-Al_2O_3 reinforced composites. As the percentage of composition increases from 0 to 6 wt.%; correspondingly hardness increases. It has been found from histogram that the hardness of composite decreases behind 8 wt.%. Hence, the presence of 6 wt.% nano-Al_2O_3 in AA5083 is found to be optimal percentage in order to enhance the hardness. This is concurrence with the previous investigations. Increase in hardness may be due to the toughness characteristics of the nano-Al_2O_3.

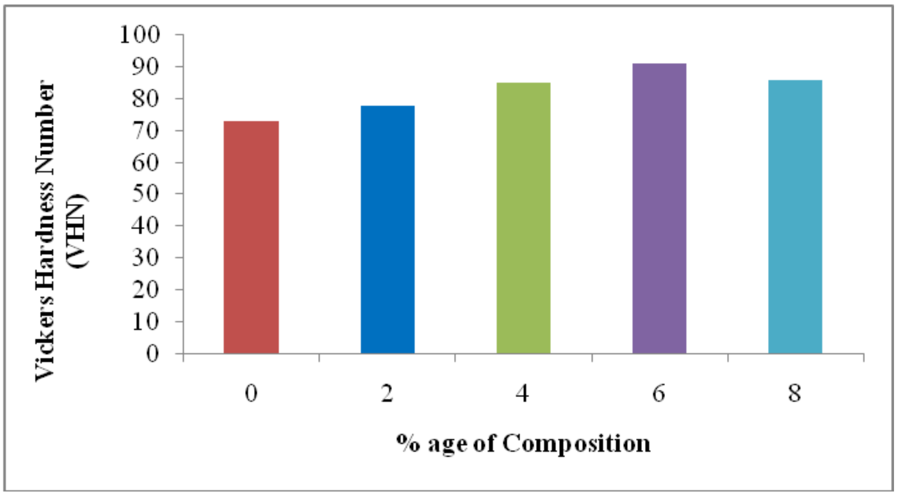

Fig. 4: *Hardness Verses Composition in wt.%.*

Tensile Strength

The tensile properties of the AA5083 alloy with addition of nano-Al_2O_3 particle materials are summarized in Figures 5 and 6. Three samples were tested for each trial. The average values of ultimate tensile strength and ductility in terms of elongation were calculated.

Table 3: *Mechanical Properties of Al-Nano-Al_2O_3 Composite.*

Composition wt.%	Tensile Strength (N/mm^2)	Yield Stress (N/mm^2)	%Age of Elongation	%Age of Increases in Tensile Strength	Microhardness/HV
0	157.45	139.26	2.6	–	73
2	168.42	156.39	2.18	6.96	78
4	179.29	159.41	1.98	13.87	85
6	203.95	180.62	1.87	29.53	91
8	194.84	176.98	1.62	23.74	86

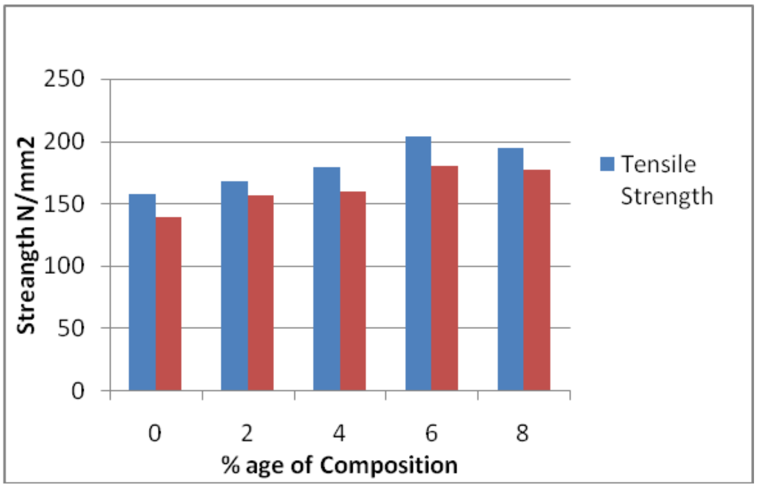

Fig. 5: *Effect of Nano-Al_2O_3 Particle Addition on Ultimate Tensile Strength (UTS) of Produced Composite Materials.*

The materials that have Al_2O_3 content of 6 wt.% show higher ultimate tensile strength than that of base metal as indicated in Figure 5. This can mainly be attributed to the strengthening effect of the reinforcing phases. The increases in percentage of nano-Al_2O_3 composite in AA5083 alloy increase the tensile strength between 6.62 and 23.74% for variable percentage of composite.

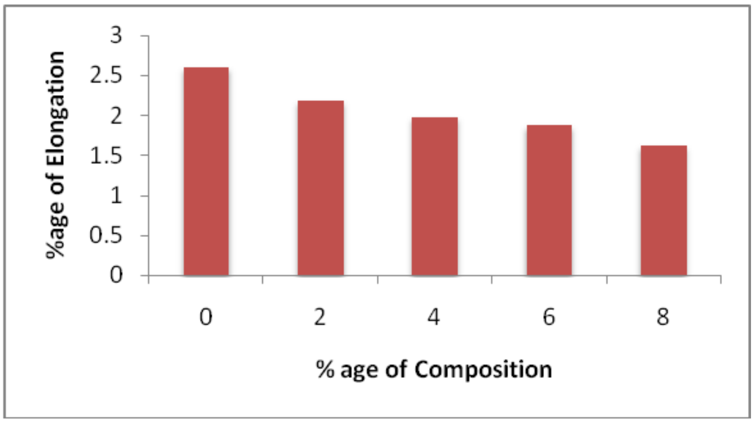

Fig. 6: *Variation of %Age of Elongation with Varying %Age of Nano-Al_2O_3.*

As percentage of composite increases from 0 to 8 wt.% it decreases ductility of the material as shown in Figure 6. The reason behind the above phenomenon may be increase in hardness of the AA5083.

The maximum tensile strength indicates that material can with stand stress for longer period of time. Increases in hardness and ultimate strength indicate the toughness of material.

Microstructural Characteristics of Al/Nano-Al_2O_3 Composites

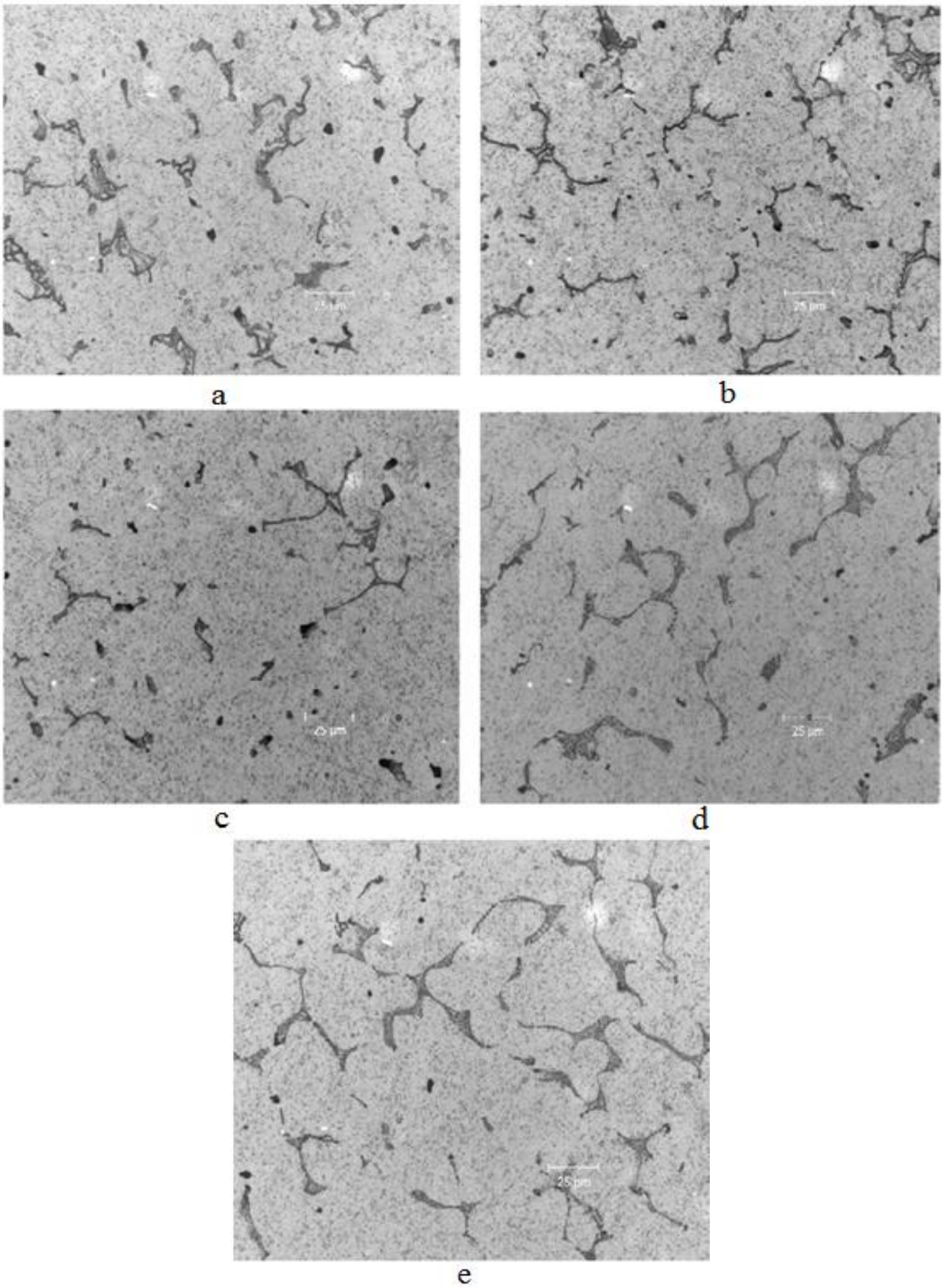

Fig. 7: *Optical Photomicrograph of AA5083/Nano-Al_2O_3 MMCs Containing Nano-Al_2O_3:* ***(a)*** *0 vol.%,* ***(b)*** *2 vol.%,* ***(c)*** *4 vol.%,* ***(d)*** *6 vol.% and* ***(e)*** *8 vol.%.*

Figure 7(a–e) indicates the microstructural characteristics of the specimens. Fine precipitation of alloying element dispersed along the grain boundary in the matrix of aluminium solid solution at 6 wt.% nano-Al_2O_3 composite in AA5083 alloy.

The distribution of alloying element in matrix of aluminium solid solution is responsible for increasing the hardness and tensile strength of the AA5083 alloy.

CONCLUSIONS

In this work, aluminium-based nanocomposites were manufactured with five levels of volume fraction of nano-Al_2O_3 particles (0, 2, 4, 6 and 8 wt.%) through stir casting. Microstructure perceptions were performed on all specimens. The microhardness was also measured with a Vickers hardness tester. Tensile strength and percentage of elongation were assessed by utilizing universal testing machine. The obtained results are summarized as follows:

- Aluminium-based metal matrix nanocomposites have been successfully produced by stir-casting technique and further the optical images clearly indicate uniform distribution of nano-Al_2O_3 particles.
- The results confirmed that stir cast AA5083 with uniform distribution of nano-Al_2O_3 particles enhances both tensile strength and hardness. With 6 wt.% of nano-Al_2O_3 showing reasonably high strength by 29.53% and hardness by 24.65% when compared to matrix alloy.
- Well dispersed alloying elements along its grain boundary are responsible for increasing the toughness of the material.

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