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Characterisation of Al6063/Alumina Nano Composite

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Abstract: Aluminium metal matrix composites are one of the new materials used for various applications due to their low cost and light weight. Aluminium alloy 6063 is used for window, door, pipes & tubing, furniture, shop fittings and for high performance applications such as aerospace vehicles and racing automobiles. Low tensile strength of this Aluminium alloy however restricts its usage in various structural applications. Therefore an attempt is made to increase the tensile strength of Aluminium alloy 6063.

This paper discusses the effect of different compositions of Al_2O_3 nano particles on the tensile strength, hardness and microstructure of the Aluminium matrix nano composite made using stir casting method. AA 6063 was casted with varying mass of Al_2O_3 nano particles (3%, 5%, and 7% by weight). Tensile test specimen was prepared for testing on Universal Testing Machine. Hardness of composite material was tested on Vickers Hardness Testing Machine. For microstructure study, Binocular Inverted Metallurgical Microscope was used.

The results reflected an increase in tensile strength and hardness. Grain size was reduced and thus the hardness was increased. Variation of tensile strength and hardness with increase in amount of alumina added is discussed in detail.

Keywords: Al6063, Alumina, Stir casting, UTS.

I. INTRODUCTION

Conventional materials have limitations in having desired combination of strength, stiffness, hardness, toughness and density as per the need of modern day technology. Metal matrix composites have been promising materials of interest with improved properties such as high strength, damping capacity and high wear resistance compared to unreinforced alloys.

Aluminium offers a rare combination of valuable properties even after being one of the lightest metals due to which it is widely used in construction of buildings, food, chemical, petroleum, aircraft and automotive industries.

A composite is a multiphase material system composed of a continuous phase (the matrix) in which discrete constituent called reinforcement is distributed. By varying the nature of constituents and their volume fraction, desired properties of composites can be obtained.

There are various methods for producing composites like stir casting, powder metallurgy, etc. However, stir casting process is the simplest, cost effective and reliable process. It begins with the melting of the raw matrix material in a furnace. Thereafter reinforcement particles are added along with stirring and finally molten mix is poured into a prepared mould to obtain desired cast composite. [1,2,3,4]

Another concept of composites which further enhances the properties of commercial composites is given by the development of metals reinforced with nano particles. Due to their very small size, the nano particles are able to interact with the lattice defects (dislocations) thereby enabling new strengthening mechanisms to be activated. The nano composites exhibit high strength, good ductility, improved damping behaviour and the capability of being worked into wires. The major challenge in processing of composite materials is to get defect free microstructure and homogeneous distribution of reinforcements.[5,6]

Many trials have been done to fabricate aluminium composites using varying methods and different reinforcement materials.

K.Hemalatha et al. (2013) adopted stir casting method to produce Al 6063 composite with varying percentage by weight of Al_2O_3 particles (3%, 6% and 9%). Tensile strength of Al composite was improved due to the addition of Al_2O_3 particles (up to 6 wt. %). The percentage elongation of the composite decreased with increase in Al_2O_3 content, which confirms that alumina addition increases brittleness. Increase in hardness with increasing weight percentage of Al_2O_3 particles was mainly due to grain refinement and particle strengthening effects. [7]

H. R. Ezatpour et al. (2013) adopted a two-step mixing method by injecting particles into the melt by inert gas along with stirring to prepare AMC reinforced with Al_2O_3 particles. The samples were extruded with ratios of 1.77 or 1.56. The microstructure revealed that the application of injection and extrusion processes led to a uniform distribution of particles in the matrix. Hardness, yield and ultimate tensile strength of the extruded composites increased with increasing the particle mass fraction up to 7%. For the composites without extrusion, these properties increased with particle mass fraction up to 5%. [8]

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Alireza Fadavi Boostani et al. (2015) adopted an innovative approach to prevent agglomeration of nano particles by encapsulating SiC nano particles using graphene sheets during ball milling. Afterwards, the milled mixture was incorporated into Al 356 molten alloy using non-contact ultrasonic vibration method. Results revealed 45% and 84% improvement in yield strength and tensile ductility. [9]

II. MATERIAL SELECTION

AA6063 is an Aluminium alloy with Magnesium and Silicon as the alloying elements was used as the matrix material due to its good mechanical properties and being heat treatable and weldable.

Alumina nanoparticles were taken as reinforcement particles due to its promising results of mirco sized alumina particles being used as reinforcement in composites. It also possesses high hardness, high stability, high insulation, and transparency.

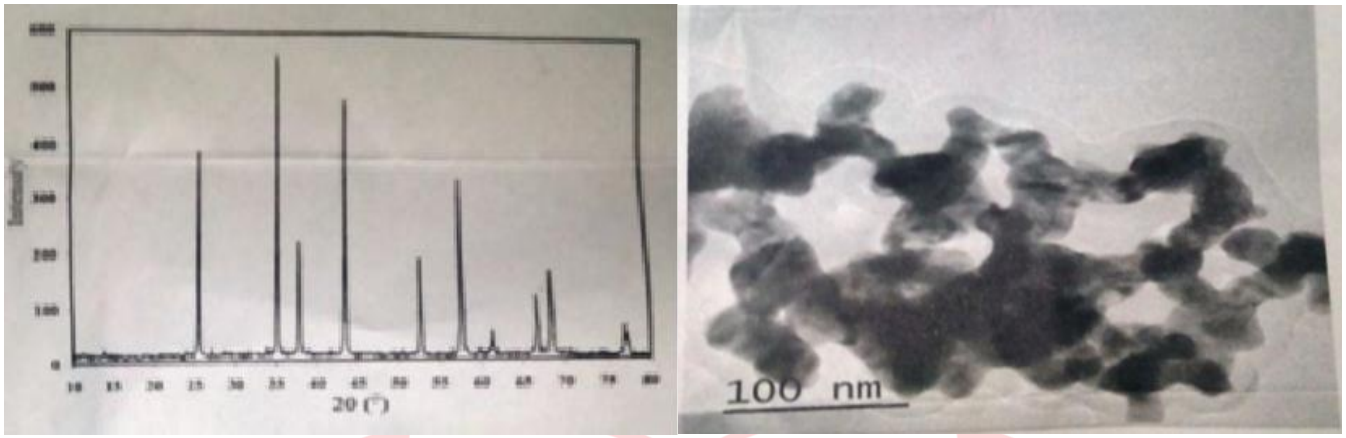

Fig. 1 XRD analysis and TEM for Alumina nanoparticles

III. EXPERIMENTAL PROCEDURE

Automatic Stir casting apparatus was used to make the composites. For enhancing the effectiveness of mixing od reinforcement and matrix, a stirrer of stainless steel was designed with rod diameter 12 mm and blade angle of 45 degrees to serve the purpose of mixing of the matrix during the addition of nano particles.

Sand casting was used to prepare the composites. Patterns were prepared using mild steel. The patterns were designed in a manner so as to compensate all losses occurring during casting such as shrinkage. The first pattern was 162 cm long with a diameter of 14.1 cm to produce a workpiece meant for the study of microstructure and change in hardness of the composite. Second pattern was 222 cm long with a diameter of 30.8 cm to produce a workpiece meant to perform tensile test.

AA 6063 obtained in raw form was cut into randomly sized pieces and put into the ceramic crucible. Crucible was then put in an automatic stir casting furnace setup which was set to reach a temperature of 700˚C.

The stirrer was then started to rotate at 150 rpm. The alumina nanoparticles were then poured into the crucible with a hopper while stirring was continued till 15 minutes. The molten material was then poured into prepared mould to obtain the nano composite.

The mixing mass of alumina and AA 6063 as per the decided ratios are given in the table 1.

Table 1 Mass of Alumina and Al6063 used

Experiment	Mass of Al2O3 nano particles taken	Mass of AA6063 taken (including the wastages)	Total mass of stir casting obtained
1	18 g (3 %)	582 g (97 %)	600 g
2	30 g (5 %)	570 g (95 %)	600 g
3	42 g (7%)	558 g (93 %)	600 g

Composite were extracted from the mould and were machined to remove extra material. Then the specimen were prepared for the mechanical testing. Two specimen of each nano composite were prepared, one for tensile test and another for microstructural analysis and hardness test.

Universal testing machine (UTM) was used to test the tensile strength Ultimate tensile strength was calculated using the following formulae:

UTS of the specimen under testing = Load applied that resulted in fracture (P)/Initial area of cross−section of the specimen

Table 2 Fracture load obtained by UTM

S. No	Composition of specimen	Initial diameter (mm)	Initial length (mm)	Fracture load (KN)
1.	AA6063 – 100% by wt.	12.71	182.1	17.725
2.	AA6063 – 97% by wt. Al2O3 – 3% by wt.	13.42	179.2	21.851
3.	AA6063 – 95% by wt.	13.62	180.1	23.825

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	Al2O3 – 5% by wt.			
4.	AA6063 – 93% by wt. Al2O3 – 7% by wt.	12.52	181.3	19.089

Fig. 2 Specimen after tensile test

The Vickers Hardness testing machine was used to find out the hardness of the samples. The Vickers hardness indenter was having square base and an angle of 136 degrees between opposite faces subjected to a load in the range 1gf and 100kgf. The full load is normally applied for 10 to 15 seconds.

The Vicker's hardness is calculated by evaluated by using the formula:

$$HV = 1.8544F/d^2$$

where F is in kgf and d is in millimetres

Table 3. Diagonal length of indentation in Vicker's hardness

S. No	Composition of specimen	Load applied (kgf)	Length of diagonal of indentation mark (mm)
1.	AA6063 – 100% by wt.	5	0.36
2.	AA6063 – 97% by wt. Al2O3 – 3% by wt.	5	0.3324
3.	AA6063 – 95% by wt. Al2O3 – 5% by wt.	5	0.3176
4.	AA6063 – 93% by wt. Al2O3 – 7% by wt.	5	0.304

IV. RESULT AND DISCUSSION

Microstructure Examination

Grain growth is the increase in size of grains in a material at high temperature. If the grain size increases, accompanied by a reduction in the actual number of grains per volume, then the total area of grain boundary will be reduced. If there are additional factors preventing boundary movement, such as pinning by foreign particles, then the grain size may be restricted to a much lower value than might otherwise be expected. The nucleation sites increase in number due to breaking of the dendritic arms at the solidification front. Initially when the sample is pure, the grains are coarser. The reason being that the grains get sufficient time to grow. After the solidification has started at various nucleation sites, it progresses towards the remaining molten metal. Since there is no hindrance created due to foreign particles, coarser grains are observed.

On addition of nano particles in 3 % by wt., the number of nucleation sites increased and as a result the grain formation started at the multiple sites. The grains obtained in this sample were therefore not much coarser. However, when the percentage of nano particles were increased to 5 % by wt. then for the same reason even finer microstructure was observed.

In the sample containing percentage of nano particles equal to 7 % by wt., finest microstructure was seen. Dark regions in the image shown below indicate the agglomeration of nano particles.

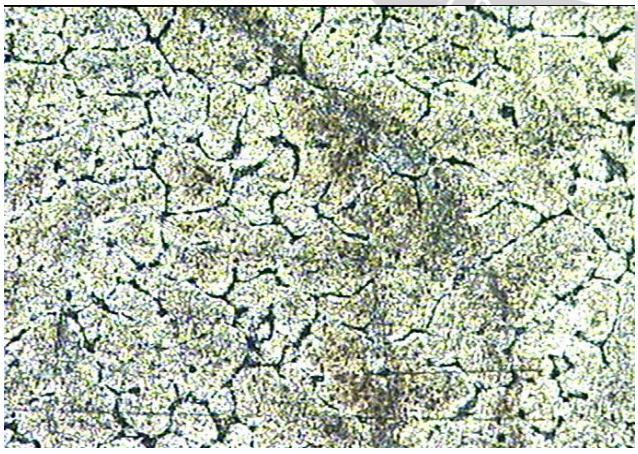

Fig 3 Pure AA6063

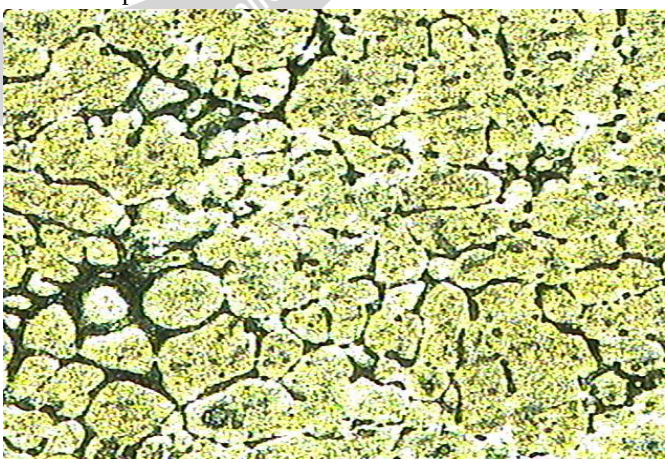

Fig.4 AA6063- 97 wt. % & alumina- 3 wt.%

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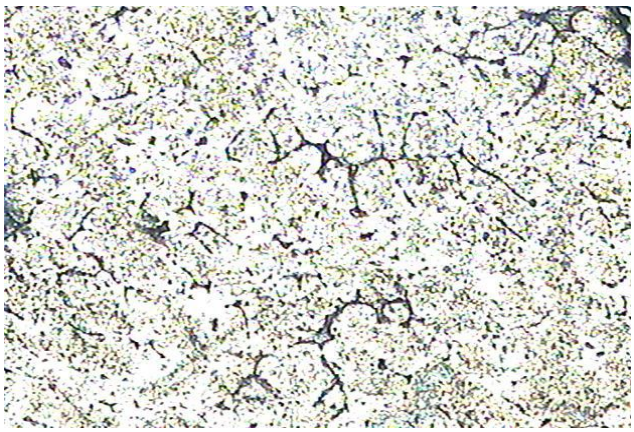

Fig 5 AA6063- 95 wt. % & alumina- 5 wt. %

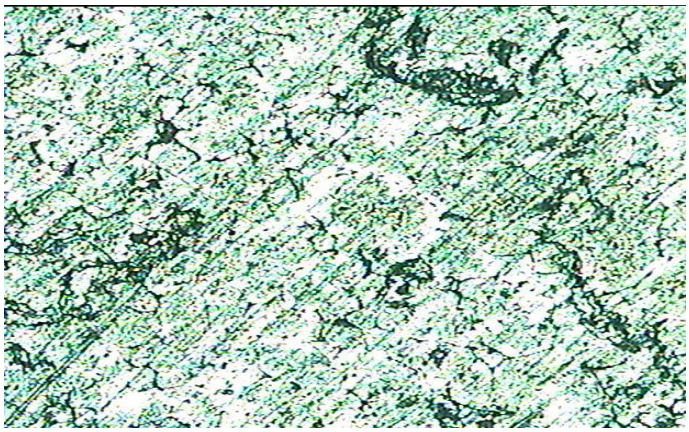

Fig 6 AA6063- 93 wt. % & alumina- 7 wt.

Mechanical Testing:

UTS of pure AA6063 was recorded as 139.703 Mpa. Addition of nano particles in 3% by wt. has increased the UTS to 154.48 Mpa. A further rise of UTS to 163.527 Mpa was observed if the content of reinforcement was increased up to 5% by wt. However, UTS decreased if percentage of the particles was increased beyond 5 % by wt. (i.e. 7% by wt.) probably due to agglomeration of the nano particles. The variation is documented in table no. 4 and compared using a bar chart in fig 7.

Table 4. Ultimate Tensile Strength of samples

S NO.	COMPOSITION	ULTIMATE TENSILE STRENGTH (= FRACTURE LOAD / AREA OF CROSS-SECTION)
1.	AA6063 – 100% by wt.	139.703
2.	AA6063 – 97% by wt. Al2O3 – 3% by wt.	154.48
3.	AA6063 – 95% by wt. Al2O3 – 5% by wt.	163.527
4.	AA6063 – 93% by wt. Al2O3 – 7% by wt.	155.056

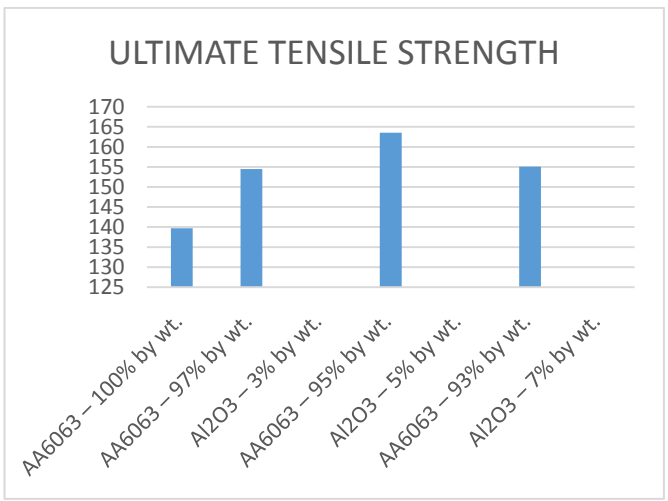

Fig. 7 Bar graph for Ultimate Tensile strength of samples

Hardness was found to be directly related to the percentage of nano particle addition. It increased with the increase in the percentage of alumina nanoparticles added. VHN of pure Al-6063 was found to be 71.5. Addition of 3% by weight of nano particles increased the hardness to 83.899. A further rise of hardness to 91.9 was observed by increasing the content of reinforcement up to 5% by weight. The hardness increased to 100.307 VHN for 7% addition of nanoparticles but the tensile strength decreased. The increasing hardness values obtained from samples are given in table no. 5 and compared in bar chart in fig 8.

Table 5. Hardness of samples

S. No	Composition of specimen	VHN
1.	AA6063 – 100% by wt.	71.5
2.	AA6063 – 97% by wt. Al2O3 – 3% by wt.	83.899
3.	AA6063 – 95% by wt. Al2O3 – 5% by wt.	91.9
4.	AA6063 – 93% by wt. Al2O3 – 7% by wt.	100.307

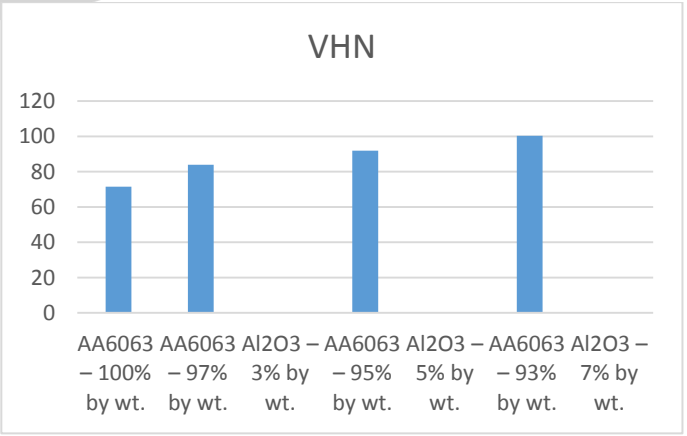

Fig.8 Bar chart for VHN of samples

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V. CONCLUSION

With the addition of nano particles, grain refinement occurs since the particles provide extra nucleation sites at the time of solidification. So the addition of particles up to 7 % by weight resulted in grain refinement. Ultimate Tensile Strength was found to increase with the nano particles reinforcement. It increased with the increase in percentage of alumina nanoparticles by weight till 5% addition. However, further addition of the nanoparticles decreased the Ultimate tensile strength. Hardness was found to increase due to refinement of grain structure. The hardness increased with increase in percentage of nano particles added. The sample containing 5 % by weight of nano particles was the best since increase in UTS with the simultaneous increase in hardness was obtained. If increase in hardness is the only concern and the tensile strength can be considered at a lower value, then the sample containing 7 % by weight of nano particles is the most suitable one.

REFERENCES

[1] Mathur S, Barnawal A, 2010, Effect of Process Parameter of Stir Casting on Metal Matrix Composites. International Journal of Science and Research. Vol. 2, Issue 12, pp. 395-398.

[2] Kumar M, Kumar A, 2014, Mechanical Behavior of Al 6063/ MoS2/ Al2O3 Hybrid Metal Matrix Composites. International Journal of Scientific and Research Publications. Vol. 4, Issue 12, pp. 1-4.

[3] Hassan MA, 2014, Development of Aluminium Metal Matrix Composite using Stir Casting Method. The International Journal of Engineering and Science. Vol. 3, Issue 8, pp. 36-39.

[4] Ma ZY, Li YL, Liang Y, Zheng F, Bi J, Tjong SC, 1996, Nanometric Si3N4 particulate-reinforced Aluminium composite. Materials Science and Engineering. Vol. 219, Issues 1-2, pp. 229-231.

[5] Girisha KB, 2013, Preparation, Characterization and Mechanical Properties of Al356.1 Aluminium Alloy Matrix Composites Reinforced With MgO Nanoparticles. Journal of Innovative Research in Science, Engineering and Technology. Vol. 2, Issue 10, pp. 5593-5600.

[6] Mendoza-Ruiz DC, Esneider-Alcala MA, Estrada-Guel I, Miki-Yoshida M, Lopez-Gomez M, Martinez-Sanchez R, 2008, Dispersion of Graphite Nanoparticles in a 6063 AA by Mechanical Milling and Hot Extrusion, Vol. 18, pp. 280-283.

[7] Hemalatha K, Venkatachalapathy VS, Alagumurthy N, 2013, Processing and Synthesis of metal Matrix Al 6063/Al2O3 Metal Matrix Composite by Stir Casting Process. International Journal of Engineering Research and Applications. Vol. 3, Issue 6, pp. 1390-1394.

[8]Ezatpour H R, Torabi-Parizi M, Sajjadi SA, 2013, Microstructure and mechanical properties of extruded Al/Al2O3 composites fabricated by stir-casting process. Trans. Nonferrous Met. Soc. China. Vol. 23, pp. 1262−1268.

[9] Boostani AF, Tahamtan S, Jiang ZY, Wei D, Yazdani S, Khosroshahi RA, Mousavian RT, Xu J, Zhang X, Gong D, 2015, Enhanced tensile properties of Aluminium matrix composites reinforced with graphene encapsulated SiC nanoparticles. Applied Science and Manufacturing. Vol. 68, pp. 155-163.

 DOI : 10.18231/2454-9150.2018.0364