A Study on Effect of Graphite Particles on Tensile, Hardness and Machinability of Aluminium 8011 Matrix Material

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Abstract. Industrial application point of view, metal matrix composites in general and Aluminium alloy matrix composites in particular are ideal candidates because of their favourable engineering properties. Being lightweight Aluminium matrix composites are widely used in aircraft, defence and automotive industries. In this work Aluminium 8011 metal matrix was reinforced with fine Graphite particles of 50 µm. developed by two-step Stir casting method. Graphite weight %was varied in the range 2, 4, 6 and 8%. Uniform dispersion of graphite particle is examined under optical microscope. Tensile test coupons were prepared as per standard to determine % of elongation and tensile strength for various % of graphite particle. Hardness of developed composite for various % of graphite particle and Machinability parameters were also studied for effect on surface finish. It was observed that with increase of weight percentage of Graphite particles up to 8% in Aluminium 8011 alloy matrix there was increase in tensile strength, decrease in % of elongation with increase in hardness. Machinability study revealed that, there was decrease in surface roughness with increase in Graphite content.

Keywords: Tensile, Hardness, Machinability, Aluminium 8011, Stir casting.

1. Introduction

Two or more materials with different chemical composition and essentially insoluble in each other are combined together to form a composite material. Hence it is a complex material system whose properties can be tailored as per the needs of mankind by varying its different constituents. Its classification predominantly used in industries involves metal matrix, polymer matrix and ceramic matrix composites [1]. Metal Matrix Composites (MMCs) have received considerable attention of researchers due to their high specific strength and stiffness compared to other conventional materials. They have found extensive application in automobiles and aerospace vehicles [2]. Tensile and Hardness behaviour of the composite. Stir casting technique was used to fabricate the composite as this technique is popularly known for its simplicity, flexibility, ease of mass production and being cost effective [2].Out of different matrix materials available, Aluminium Matrix Composites (AMCs) are considered as best suitable candidates due to light weight, reduced processing cost and low thermal coefficient of expansion [3]. In particular Aluminium 8011 has attractive properties such as good cast-ability, corrosion resistance and higher strength to weight ratio etc. [4].

In the present work, Tensile, Hardness and Machinability of Aluminium 8011 alloy reinforced with Graphite particles of different weight fractions was examined. Objective was to test the effect of reinforcement fractions on machinability,

2. Experimental procedure

2.1. *Matrix Material*
Aluminum alloy of 8011 is used as matrix material in this investigation .The tables 1 and 2 show chemical composition and the mechanical properties of this alloy respectively [4]. In this alloy, for proper mixing Magnesium was used as wetting agent.

Table1. Chemical Composition of Aluminum 8011

Material	Fe	Si	Mn	Zn	Cu	Ti	Cr	Mg	Al
Weight %	1	0.9	0.2	0.1	0.1	0.08	0.05	0.05	97.5

Table2. Mechanical Properties of Al 8011

Density	Elastic Modulus	Strength to Weight Ratio	Ultimate Tensile Strength	Thermal Expansion
2.72 g/cm^3	71GPa	40kN-m/kg	110Mpa	21.8µm/m-k

2.2 *Reinforcement*
Since the objective of this work was to investigate the effect of weight fraction of reinforcement on Tensile, Hardness and Machinability, proportion of Graphite powders was varied in the range 2, 4, 6 and 8% by weight. These powders were pre heated to 300 º C before mixing. Graphite powder has physical properties like good electrical and thermal conductivity, temperature stability and high purity. It acts as solid lubricant and has low density [5].

2.3 *Composite preparations*
As already mentioned Aluminium alloy 8011 was used as matrix material in this work for the production of the composites which was reinforced with 2, 4, 6 and 8% by weight Graphite particles of 50µm. The composite was fabricated by the two step stir casting method. The tiny ingot of Aluminium 8011 alloy was kept in Graphite crucible and melted in resistance furnace at 680 °c above its melting point (660 °c) to remove entrapped gases, degassing tablet was used. While melting Magnesium was added to improve wettability between molten metal and graphite partials and to facilitate the dispersion of particles into the alloy during melting. The metal was stirred continuously using Zebrine coated steel stir. Stirring is done for about 300sec, the stirring speed is increased gradually up to 300rpm. Initially 2% by weight of Graphite was added and later it was incremented by 2% till it reached 8%. The melt was then poured to a prepared cylindrical mould box of mild steel material of 150mm length and 22mm dia at about the same melting temperature. The figures 1 and 2 show the preheater and resistance furnace. The melt in the mould box was then cooled in still air. The tensile test specimens were then cut to the required dimensions as per ASTM standards.

Figure 1: Preheater

Figure 2: Electrical Resistance Furnace

2.4 *Experimental work*

2.4.1 Microstructural characterization
To examine the specimens for microstructure, the surfaces of the specimen were metallo-graphically prepared by series of polishing steps to get mirror surface finish. The samples were later etched with Keller's reagent (95 ml water, 2.5 ml HNO3, 1.5 ml HCl, 1.0 ml HF). Once the specimens were ready Microstructural examination was performed. Microstructures of different composites were shown on figure 4.

2.4.2 Tensile test
The prepared cylindrical specimens were brought down to final dimensions as per ASTM E8 Standard by machining the specimens using conventional lathe machine. Tensile test was carried out using Universal Testing Machine. The Tensile load was applied gradually from initial value of 0.5 KN till failure load. Ultimate tensile strength and % elongation obtained from tensile test are provided in table 3.

2.4.3 Hardness test
First the cylindrical specimens were cut to the required dimensions of 1.5x20mm. The samples were polished by 400, 800, and 1200 grit paper, to get fine surface before testing their hardness. The hardness of prepared composite was measured by Rockwell hardness test and figure 3 shows the Rockwell Hardness Tester. 1/16 inch steel ball was used as indenter and 100Kgf pressure was exerted for dwell period of 20secs. The hardness values were measured in 5 different locations over the surface of the samples, average value were calculated and are shown in table 4.

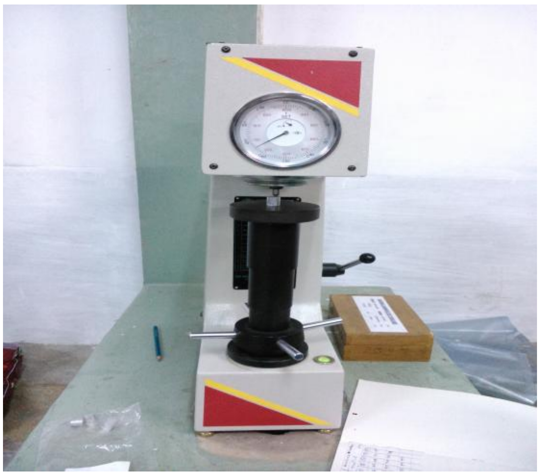


Figure 3: Rockwell hardness tester

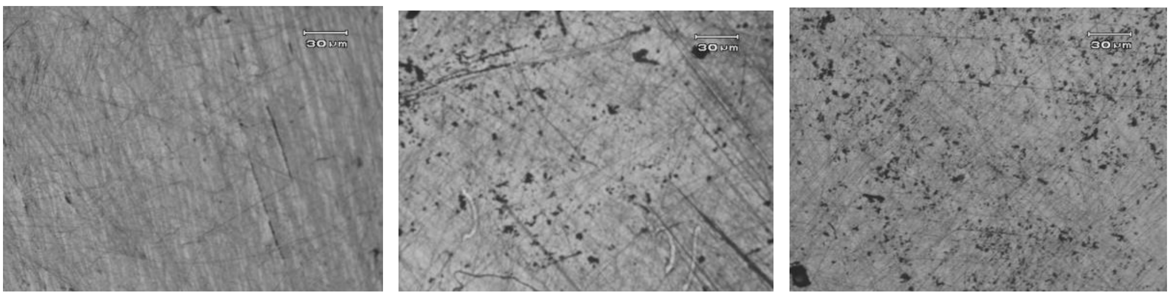
2.4.4 Machinability

Machinability testing aims at evaluating how the work material responds to the cutting process. A material is said to have good machinability if it is cut with good surface finish, long tool life, low force and power requirements. To evaluate the machinability of a particular material, it is enough to asses any one of the following five parameters: (i) tool life or wear, (ii) surface finish of test piece, (iii) cutting force requirement, (iv) power requirement, and (v) cutting temperature. Hence cutting speed, feed rate and depth of cut are important parameters in the investigation of machinability [6]. In this work, conventional lathe was use for dry turning and after machining, surface roughness was checked by using Surface Roughness Tester. Surface Roughness is considered as parameter to evaluate the machinability.

3. Results and discussion

3.1 *Microstructure*

Optical micrographs of Aluminium 8011 alloy and Graphite composite are depicted in figure 4. It is observed that reinforcement particles of Graphite are visible and uniformly distributed in Aluminium 8011 alloy. This indicates that two step stir casting fabrication process adopted gives fairly good results.



4. (a) 4. (b) 4. (c)

Figure 4. Microstructures of different composites.
(a) Al 8011 (b) Al 8011+4% Gr (c) Al 8011+8% Gr

3.2 *Tensile properties*

The tensile test results furnished in table 3 show an increasing trend in the values of ultimate tensile strength with increase in reinforcing graphite % by weight. Hence it can be concluded that the presence of greater amount of Graphite increases strengthening effect till 8%. The opposite trend is observed in case of % elongation. As the Graphite content increases % elongation decreases. This is because Graphite content increases the tensile strength. This shows that addition of Graphite influences ductility levels of composites. Figure 5 shows Scatterplot of Ultimate Tensile Strength vs Graphite % wt. and figure 6 shows Scatterplot of % elongation vs Graphite % wt.

Table 3. Tensile test results

Sl No	Composition	Ultimate tensile strength (Mpa)			% of Elongation		
		1	2	Average	1	2	Average
1	Aluminium- 8011	61.03	72.08	66.55	12.66	13.83	13.24
2	Aluminum+2% graphite	95.04	143.41	119.22	7.16	7.54	7.35
3	Aluminum+4% graphite	113.71	152.57	133.14	5.53	5.83	5.68
4	Aluminium+6% graphite	131.76	139.68	135.72	3.66	5.50	4.58
5	Aluminium+8% graphite	190.51	190.58	190.54	1.90	3.30	2.60

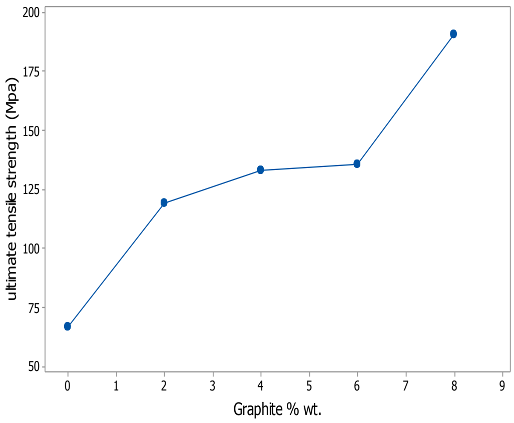


Figure 5. Scatterplot of Ultimate Tensile strength (Mpa) vs Graphite % wt.

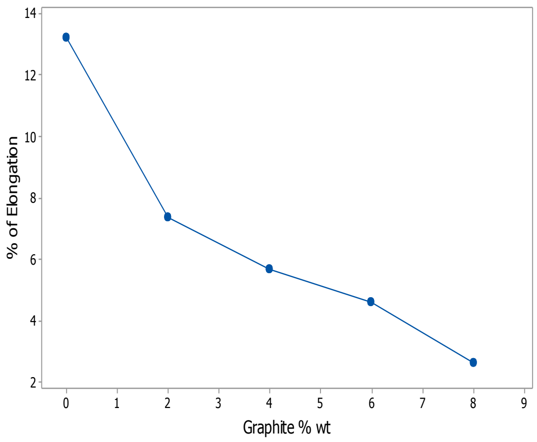


Figure 6. Scatterplot of % of Elongation vs Graphite % wt.

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3.3 Hardness

The values given in table 4 reveal that hardness of the composite increases proportionately with increase in the weight % of graphite particles in composite. This is depicted in Scatterplot drawn in figure 7.

Table 4. Hardness Test Results

Material	Load KGF	Indenter	Scale	Indentation time in sec	Hardness number
Aluminium- 8011	100	1/16” ball	B	20 sec	49
Aluminum+2% graphite	100	1/16” ball	B	20 sec	65
Aluminum+4% graphite	100	1/16” ball	B	20 sec	68
Aluminium+6% graphite	100	1/16” ball	B	20 sec	77
Aluminium+8% graphite	100	1/16” ball	B	20 sec	86

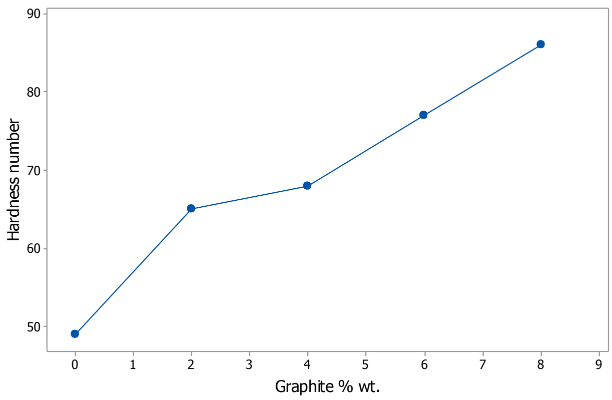

Figure 7. Scatterplot of Hardness number vs Graphite % wt.

3.4 Machinability:

3.4.1 *Surface roughness*

In this study, effect of Graphite reinforcement to Aluminium 8011 alloy composite at different fractions on surface roughness was investigated at various depths of cut and cutting speed keeping feed rate fixed at 0.111 mm/sec. The figure 8 shows the relation between Surface Roughness and Cutting Speed during turning at constant feed rate of 0.111 mm/sec at different depths of cut of 0.2mm, 0.4mm and 0.6mm for base metal and base metal with 4 and 8 % Graphite by weight reinforcement. It can be observed from this figure that Surface Roughness decreases as the Cutting Speed increases at different depth of cut and constant feed rate. Also Surface Roughness decreases with increase in Graphite weight % reinforcement.

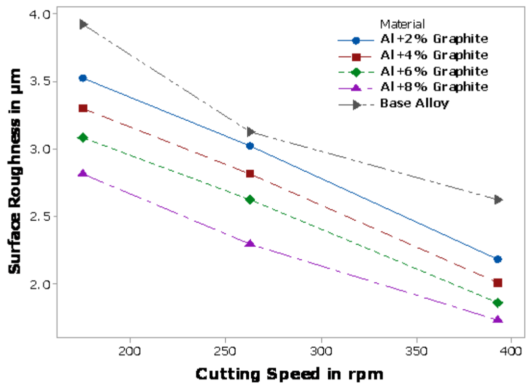

Figure 8 (a)

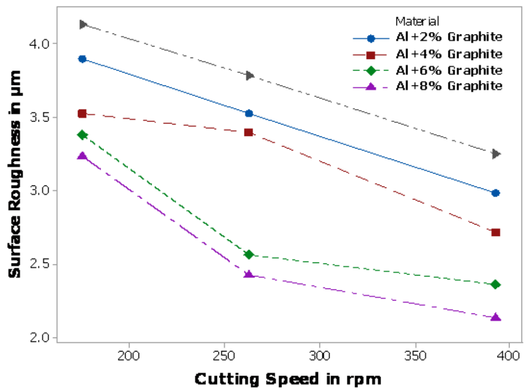

Figure 8 (b)

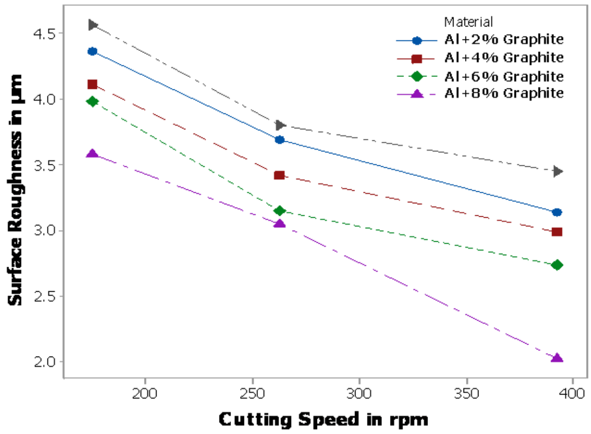

Figure 8 (c)

Figure 8 Effect of Cutting Speed on Surface Roughness at constant feed rate i.e. 0.111 mm/sec
(a) Depth of cut = 0.2mm
(b) Depth of cut = 0.4mm
(c) Depth of cut = 0.6mm

4. Conclusion:

From the present experimental investigation the following conclusions may be drawn.

- Aluminium 8011 alloy based metal matrix composite reinforced with fine particles of Graphite were successfully fabricated by two step stir casting method.
- The uniform distribution of reinforcement in metal matrix was ensured by examining optical micrographs.

- Incorporation of Graphite as reinforcement increases Ultimate Tensile Strength of Aluminum 8011 metal matrix composite when compared with base metal. And this strengthening is consistently increasing till 8% of Graphite. Accordingly % elongation decreases with increases in graphite %.
- Compared to base metal, addition of Graphite as reinforcement has positive effect on Hardness. Also as Graphite content increases, Hardness also increases proportionately.
- During turning operation at different Cutting Speeds and fixed feed rate, surface roughness increases with the increase in the depth of cut. On increasing the weight % of Graphite the surface roughness of AMC decreases and adding Graphite content up to 8% results in better surface finish when compared to base metal.

5. Reference

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