

Investigation of Mechanical properties of Aluminium reinforced Fly ash with CNT

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Abstract. Metal matrix composites are gaining enormous acceptance in the recent times. This is due to their remarkable characteristic of enhancement in their mechanical properties without any compromise in their weight. This paper deals with the investigation of mechanical properties of Aluminium 6061 reinforced fly ash with CNT. Here samples of four different compositions were fabricated using stir casting method and subjected to tensile, flexural, hardness and impact tests. The result indicated no change in the impact value of the samples. On addition of 2% flyash, the hardness value increased to a value of 59.2BHN when compared with pure Aluminium and the tensile strength increased to about 147.76 MPa on addition of about 3% fly ash.

1. Introduction

Carbon nano tubes (CNTs) are being used as the most common reinforcement material in metal matrix composites (MMCs) due to its unexceptional physical and chemical properties. Many MMC have been prepared using CNT as reinforcing material. Aluminium is one of the widely reinforced metal with CNT for the preparation of the composite. This is because of the collective properties such as low density, low weight, high strength, superior malleability, excellent corrosion resistant, high thermal and electrical conductivity of the aluminium. B. Vijayaramnath et al. [1] concluded that addition of aluminium increases the tensile strength of the sample. Jinzhi Liao and Ming-Jen Tan [2] observed increase in tensile strength and hardness of the composite by the addition of CNTs (0.5 wt%) to the pure matrix. C. Parswajinan et al. [3] concluded that the hardness and tensile strength of iron increased when reinforced with CNT. A.M.K. Esawi et al. (2009) [4] determined that there was uniform dispersion at the tensile testing fracture surface of the specimen. It is also found that the CNTs act as nucleation sites during testing. D.-S. Lim et al. (2005) [5] stated that when the CNTs are added up to 12 wt.%, the wear loss decreased significantly and the friction coefficients were maintained same. H.J. Choi et al. (2010) [5] observed that, as the grain size is reduced to 150 nm and MWCNT volume increases up to 4.5 vol.%,



yield stress notably increases and hence wear resistance is significantly enhanced in the specimen. P. Naresh Narayanan [6] paper illustrates Carbon nanotubes reinforced pure Al (CNT/Al) composites and fly ash reinforced pure Al (FA/Al) composites produced by ball-milling and sintering it was indicated that the CNTs and fly ash were uniformly dispersed into the Al matrix as ball-milling time increased with increase in hardness. Oluwagbenga B. Fatile et.al [7] results show that the hardness, ultimate tensile strength, and percent elongation of the hybrid composites decrease with increase in fly ash content. B. Vijayaramnath et al. [8] concluded that the compressive strength increases with increase in CNT. Shadakshari. R et.al [9] concluded that on reinforcing CNT with metal matrix composite at about 400° C, high damping capabilities were achieved. C. Parswajinan et al. [10] concluded that addition of CNT did not have any impact on the hardness of the material, but there was an increase in compressive strength on addition of CNT. A. M. K. Esawi et al. (2010) [11] concluded in their studies that the mechanical properties were found to increase more than the expected values but fell short at 5 wt%. B. Vijaya Ramnath et al. [12] reviewed the properties of Aluminium and Magnesium matrix composites with CNT and suggested an increase in mechanical properties. C. Parswajinan et al. [13] studied the addition of CNT with iron and recommended an increase in strength of sample. Addition of reinforcements to the metal matrix increases the Mechanical Property [14,15,16,17]

2. Material selection

Aluminium (6061), CNT and fly ash are the materials used in this experiment. The aluminium powders used are of 99.5% purity with a mesh size of 200. The melting point and density of aluminium powders are 660°C and 2.70 g/cm³, respectively. The properties of CNTs used has a purity greater than 95% on trace metal basis, melting point of 3652-3697°C, density of 2 g/cm³ and dimensions of 10-30 nm of outer diameter, 2-6 nm of inner diameter and 15-30 µm of length. As per TEM analysis, the impurities present in the CNTs used are amorphous carbon of about < 3%. Fly ash, also known pulverised fuel ash is one of the combustion products of coal, composed of the fine particles that are driven out of the boiler with the flue gases. Ash that falls in the bottom of the boiler is called bottom ash. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys.

2.1. Specimen preparation

The material is prepared using Stir Casting technique, in which the Aluminium 6061-CNT-fly ash mixture is combined in various compositions. The mixture is heated inside the furnace at a temperature of 800°C for about 2 hours. The molten mixture is stirred using electric stirrer for the even distribution of all the elements throughout the material. It is again heated inside the furnace for about half an hour. The molten mixture is then poured into the die and allowed to cool in the ambient temperature for few hours.

Table 1. Composition of samples.

Samples	Composition
Sample 1	Al+2% Fly Ash
Sample 2	Al+2%Fly Ash+0.2%CNT
Sample 3	Al+3%Fly Ash+0.2%CNT
Sample 4	Al+4%Fly Ash+0.2%CNT

3. Testing conducted on the material

3.1. Tensile test

The ability of the material to resist breaking under the action of longitudinal force is defined as tensile strength of the material. From table 2 it could be inferred that the tensile strength reduces with addition of CNT but reaches a maximum strength of 147.76MPa at 3% of the fly ash. The graphical representation of tensile strength of various samples is shown in figure 1. Stress-Strain chart has been illustrated in figure 2 for the sample 3 while performing the tensile strength test. The experimented sample on which the tensile test had been performed is shown in figure 3.

Table 2. Tensile strength of samples.

Composition	Tensile Strength [MPa]
Sample 1	132.15
Sample 2	78.76
Sample 3	147.76
Sample 4	60.83

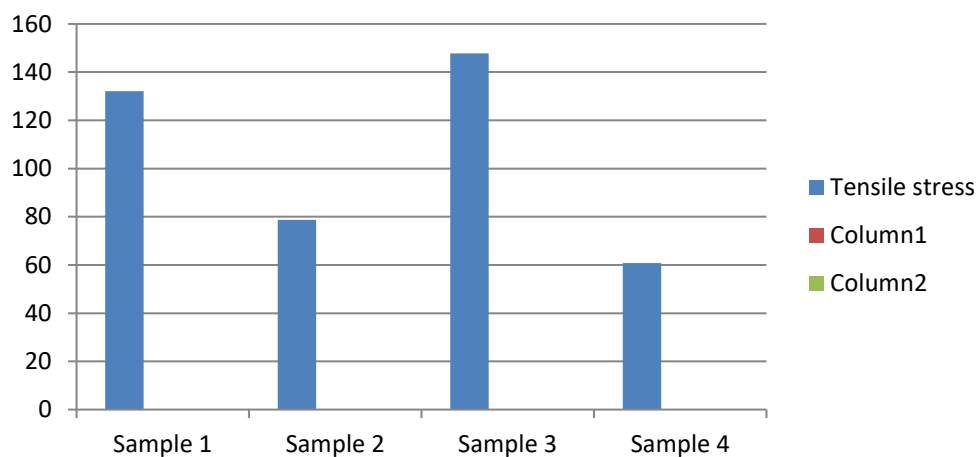


Figure 1. Graphical representation of Tensile test results.

Stress vs Strain diagram

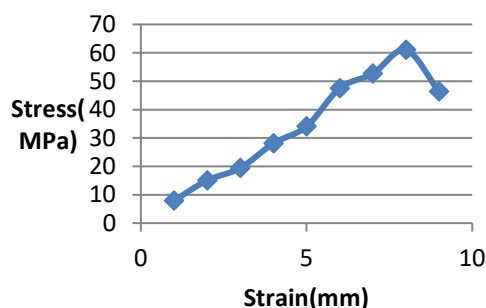


Figure 2. Stress strain diagram of sample 3.



Figure 3. Tensile sample after testing.

3.2. Flexural test

Flexural tests are generally used to determine the flexural modulus or flexural strength of a material. A flexural test is more affordable than a tensile test with a slight variation in values. The material is laid horizontally over two points of contact (lower support span) and then a force is applied to the top of the material through either one or two points of contact (upper loading span) until the sample fails as shown in figure 4. Variations of the flexural load values for different samples are tabulated in table 3. The maximum recorded force is the flexural strength of that particular sample which is 7.51 kN. The variation of the flexural strength of various samples is shown in figure 5.

Table 3. Flexural test results.

Composition	Flexural load in kN
Sample 1	5.55
Sample 2	6.76
Sample 3	5.41
Sample 4	7.51



Figure 4. Flexure sample after testing.

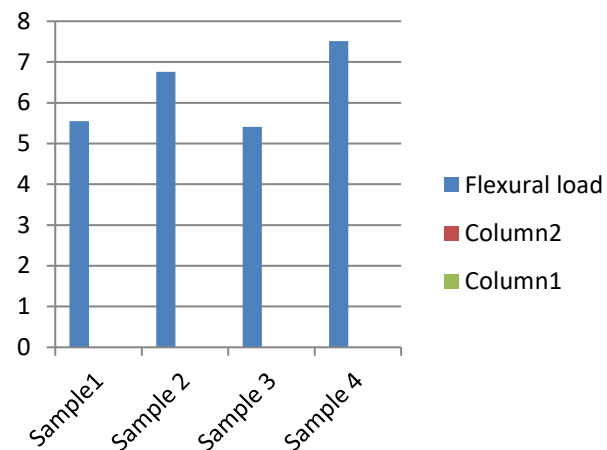


Figure 5. Graphical representation of flexure test results.

3.3. Impact test

The impact test is a method for evaluating the toughness and notch sensitivity of engineering materials. It is usually used to test the toughness of metals to determine its ability of being strong enough to withstand adverse conditions or rough handling. This test conducted on various samples with different composition gave a constant result. The tested sample is shown in figure 6.



Figure 6. Impact sample after testing.

3.4. Hardness test

The measure of resistance to indentation is termed as hardness of the material. The hardness information facilitates to effectively use the material in the place of requirement. Hardness of these specimens are measured using Brinell method in which tungsten carbide indenter is used to produce the indentation with a force of 3000kgf which is then tabulated in the sequence of the samples in table 4. It is noticed that the hardness of the specimen with fly ash content of 2% along with 0.2% of CNT is much more than the other specimens. The tested sample is shown in figure 7. The variation of hardness values with various composition have been graphically represented in figure 8.

Table 4. Hardness of samples.

Composition	Hardness [HBW]
Sample 1	53
Sample 2	59.2
Sample 3	55.3
Sample 4	49.8



Figure 7. Hardness sample after testing

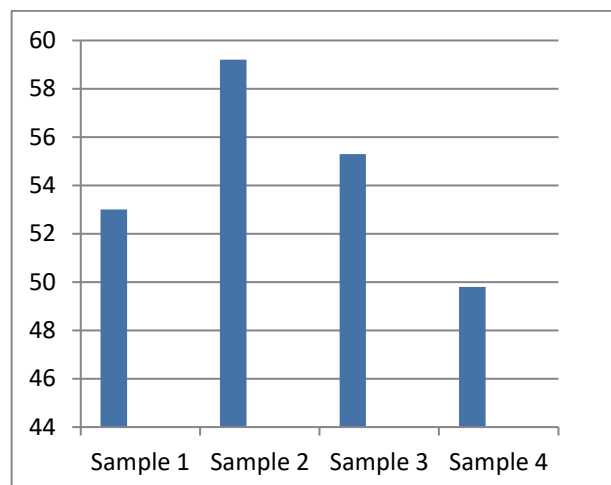


Figure 8. Graphical representation of Hardness test results.

4. Conclusion

The work done could be summarized as, Aluminium 6061, Fly ash, CNT are combined together performing stir casting technique and the results of various compositions are compared along with the effects on pure Aluminium. The results are as follows:

- 1) The tensile strength of the material has the highest value at 3% of flyash with 147.76 kN.
- 2) The flexural ability of the composite specimen seems to increase to a highest value on addition of 3% of fly ash and 0.2% of CNT.
- 3) The impact strength of the specimen remains the same without any variation.
- 4) The hardness of the material increases with decrease in the percentage of fly ash.

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