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Effect of Pouring Temperature on Mechanical Properties and Microstructures of Aluminium Matrix Composite Strengthened by CNT with Stir Casting Method

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Abstract. Aluminium matrix composite reinforced Carbon Nano Tubes are widely developed because it can increase mechanical strength without reducing its ductility. One of the AMC / CNT manufacturing processes is through the stir casting method. The challenge of the Al / CNT manufacturing process is the occurrence of agglomeration and CNT not homogeneous so that the right casting parameters are needed to obtain optimal results. The purpose of this study was to analyse the effect of pouring temperature on the mechanical strength and microstructure of AA6061 by adding Carbon Nanotube (CNT) through the stir casting method. The CNT is added by 0.1% wt and pouring temperature at 700 °C, 730 °C and 760 °C. Mechanical tests carried out were tensile test, hardness test, and impact test. The highest value of hardness and tensile strength was obtained at the pouring temperature of 700 °C are78 HV and 80.97 MPa. Lower pouring temperature causes smaller grain size so that it has higher strength. The distribution of hardness values at the top, middle and bottom of the specimen is not evenly distributed, but does not differ greatly for all pouring temperatures. The highest value of impact strength is obtained at the pouring temperature of 760 °C which is 0.128 J/mm^2. Microstructure was shown the addition of CNTs caused the size of primary silicon and aluminium grains to be small which would increase the mechanical properties.

Introduction

Light metal needs continue to increase, especially for structural, automotive and aviation industries. Aluminium is a lightweight metal with high corrosion resistance, high tenacity, and low melting point that is widely applied in various industries [1]. The mechanical performance that is still low causes aluminium applications to be limited to be developed. Various studies were developed to improve the mechanical properties of aluminium. In the past, increasing the strength of aluminium was done by adding various alloys.

The development of Nano materials opens up new avenues for improving the mechanical properties of aluminium with Nano-reinforced aluminium composite matrix . Research on metal matrix composites is increasing, especially regarding Al/CNT composites [2-4]. The CNT reinforced aluminum matrix composite has great potential to be applied in the industry because of its high specific strength, high thermal conductivity, and good coefficient of thermal expansion. These properties are advantageous because light weight material leads to savings in energy.

Homogenous dispersion of CNTs in the Al matrix is a mayor challenge to effectively producing mechanical strength of aluminum matrix composite. Therefore stir casting method have been proposed to produce aluminum matrix composite. Another advantage is low cost [5]. However effect of casting temperature has not been widely studied. In this study, we made CNT composites using AA6061 as a matrix using the stir casting method to produce a homogeneous CNT dispersion in the AA6061 matrix with varying pouring temperatures. The aims of this study are to analyse effect pouring temperature on Mechanical Properties and Microstructures of Aluminium Matrix Composite Strengthened by CNT.

Organization of the Text

The matrix used in this study is AA6061 alloy in the form of rod. The chemical composition characterize by XRF can be seen in Table 1. MWCNT is used as reinforcement with outer diameter> 50 nm, length 0.5-2.0 'mm, purity> 97%. The stir casting method use as shown in Figure 1. The casting process is done by melting AA6061 in the crucible, after melting argon gas is given to clean the slag. Then the metal liquid is stirred at a speed of 500 rpm while entering CNT powder 0.1wt%. Furthermore, molten aluminium was poured into metal moulds heated at 400ºC. The pouring temperature varied from 700.730 and 760 ºC.

Table 1. Chemical Composition of AA6061

Element	Al	Mg	Si	Fe	Cu	Cr	Zn
Wt%	Bal.	0.9	0.7	0.6	0.3	0.25	0.2

Figure 1. Stir Casting Method

The results of the castings can be seen in Figure 2. Specimens of hardness test dimension (20 mm x 20 mm x 5 mm), tensile test specimens tensile machined from casting results according to ASTM E-8 standards and impact test specimens according to ASTM E-23 standards. Specimens that have been cut according to standards can be seen in figure 3. Material characterization is carried out through various tests, including: Testing of hardness, tensile test, impact test, and microstructure observation using Optical Microscope.

Figure 2. Casting result produced by stir casting method with metal mold

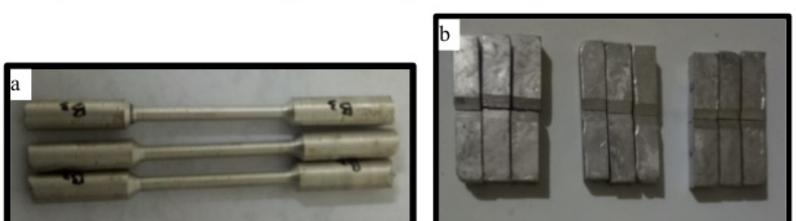

Figure 3. a) Specimen for tensile test b) specimen for impact test

Result and Discussion

Effect of pouring temperature on hardness. The effect of pouring temperature variation on the hardness of AA6061 with CNT can be seen in Figure 4. It can be seen that the addition of CNT increases the hardness value of each variation of pouring temperature by 18.29% at pouring temperature 700 °C, 14.85% at pour temperature 730 °C and 12.91% at pour temperature 760 °C. This is because CNTs spread in aluminium matrices which will increase the value of aluminium mechanical strength causes Addition of CNTs causes a reduction in grain size [6].

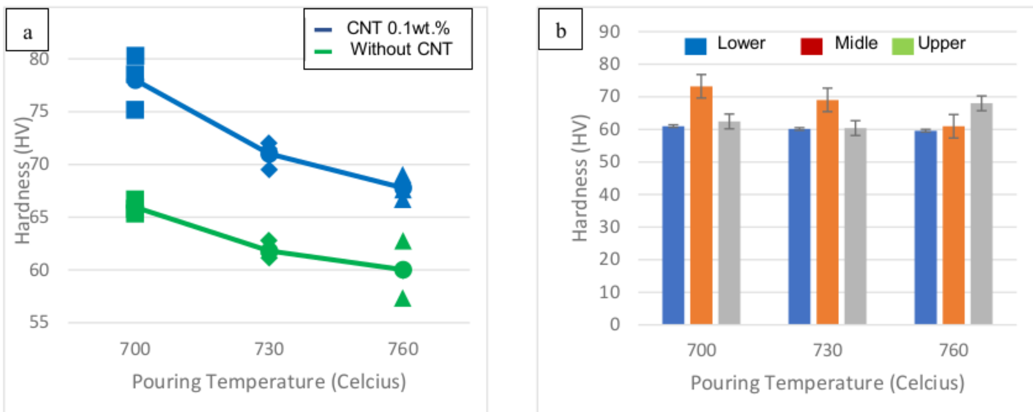

Figure 4. a) Effect of pouring temperature on hardness b) Hardness value in different area

It can be seen also that the effect of pouring temperature also affects the hardness of aluminium both without CNT and CNT additions. The highest hardness value is found in aluminium which has a pour temperature of 700 °C and the lowest hardness value is found in aluminium which has a pour temperature of 760 °C. This is because the high pouring temperature undergoes a slow cooling process so that grain growth is greater so that the hardness is lower [7]. In figure 6 shows the value of hardness based on the area of casting results. From the graph, it can be seen that in the three conditions there are differences in the value of hardness between the upper, middle and lower regions. Based on the value of hardness, it can be seen that there is no agglomeration in certain regions. The difference in the value of this hardness is caused by the uneven distribution of CNT when process by stir casting. Although the differences the value of hardness is not significant. It can be seen also that pouring temperature did not affect CNT distribution.

Effect of pouring temperature on tensile strength. Figure 5.a shows the tensile strength of AA6061 with variations in pour temperature and addition of CNT. It can be seen that the addition of CNT 0.1% increases the maximum stress at each pouring temperature variation by 8.66% at a pour temperature of 700 °C, 7.43% at a pour temperature of 730 ° C and 12.32% at a pour temperature of 760 °C. This is because the dislocation movement is inhibited by the CNT which leads to curvature of the dislocation between the CNTs, this result in a back pressure which will prevent further dislocation migration and produce an increase the strength [8]. It can be seen also that the effect of pouring temperature also affects the tensile strength of both aluminium without CNT or with CNT additions. The highest tensile strength is found in aluminium which has a pour temperature of 700 °C and the lowest maximum stress value is found in aluminium which has a pour temperature of 760 °C. This is directly proportional to the value of the hardness. This is because the high temperature of aluminium causes the size of the aluminium grain to be larger and decreases the tension value, whereas if the pouring temperature is low then the grain size of aluminium will be smaller and increase the value of its strength [8].

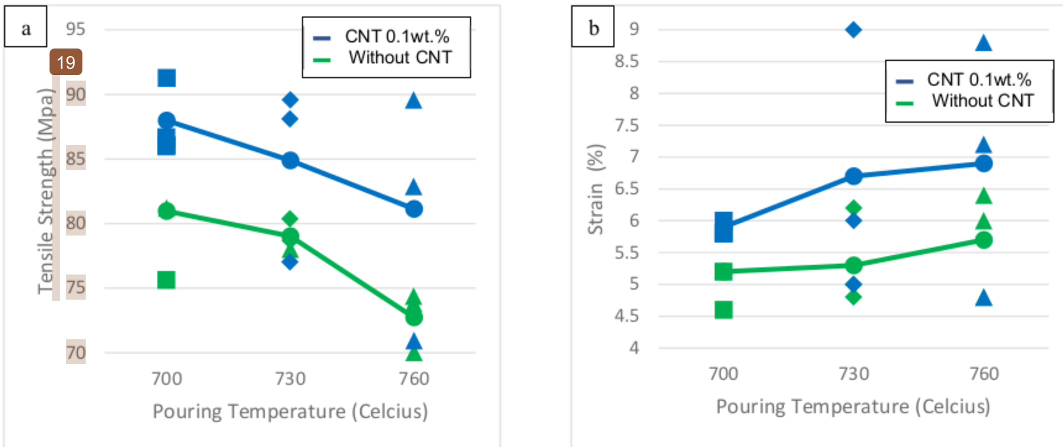

Figure 5. Effect of pouring temperature on (a) Tensile Strength (b) Strain

Figure 5.b shows the strain both of AA6061 pure and addition of CNT with variations in pour temperature. It can be seen that the addition of CNT increases the strain value in each variation of pour temperature by 13.46% at a pour temperature of 700 ° C, 26.41% at a pour temperature of 730 ° C, and 21.05% at a pour temperature of 760 ° C. This is due to the CNT strengthening behaviour, namely grain boundary reinforcement where the material is strengthened by changing the average grain size due to the interaction between dislocation and grain boundary [7].It can also be seen that the effect of pouring temperature also affects the strain value of aluminium both without CNT and CNT additions. The highest strain value is found in aluminium which has a pour temperature of 760 ° C and the lowest strain value is found in aluminium which has a pour temperature of 700 °C. This is because the high pouring temperature makes the cooling rate slow so that the castings result are ductile when the cooling rate is fast the castings become brittle [9].

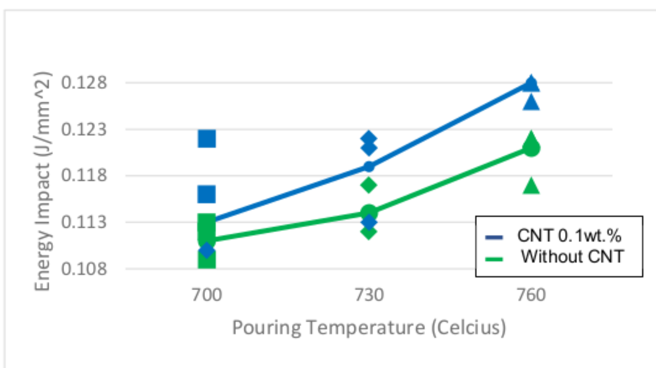

Figure 6. Effect of pouring temperature on Energy Impact

Effect of pouring temperature on Impact Strength. In figure 6 shows the value of impact strength, it can be seen the value of impact strength of each specimen has different values. The difference in the value of impact strength from each specimen was associated with variations in pour temperature and addition of CNT. It can be seen that the addition of CNT increases the impact strength value of each variation of pour temperature by 1.8% at pour temperature of 700 ° C, 4.39% at pour temperature 730 ° C and 5.79% at pour temperature 760%. This is because CNTs that are dispersed singly in composites tend to spread along the grain boundary which results in a much better grain size [7].

It can also be seen that the effect of pouring temperature also affects the value of impact strength of aluminium both without the addition of CNTs and the addition of CNTs. The highest impact strength value is found in aluminium which has a pour temperature of 760 ° C and the lowest impact strength value is found in aluminium which has a pour temperature of 700 ° C. This is because the higher the temperature of the pouring the cooling rate will be slower and the results of the castings will be resilient, on the contrary the lower the temperature of the castings the result will become brittle [9]

Effect of pouring temperature on Microstructure. Aluminium structure shows a difference. Overall the structure of the metal castings has a microstructure in the form of a dendrite structure which is a characteristic of the microstructure of Al-6061 alloy metal. The difference in Figure 10 above is in the figure (a), it looks black and black aluminium grain in aluminium is large while in figure (b) silicon and aluminium grains become smaller. This is because the addition of CNT to aluminium 6061 can affect the microstructure of aluminium and increase the mechanical strength of the aluminium [10].

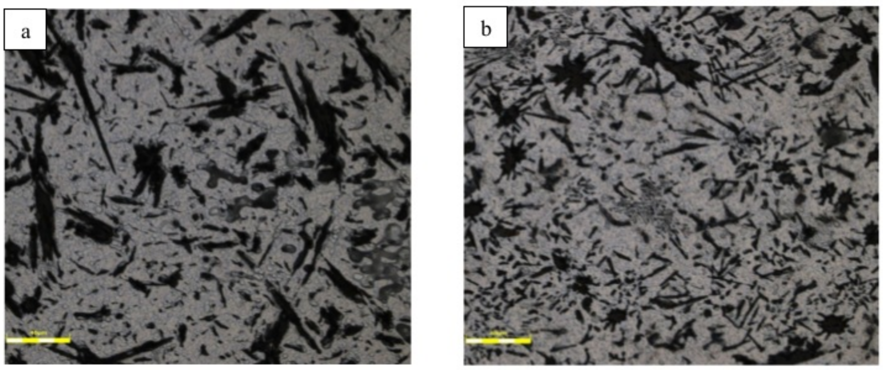

Figure 7. a) Microstructure of pure AA6061 b) Microstructure of AA6061+CNT 0.1 wt.%

Conclusion

Based on the results of the study, the author can draw conclusions:

1. Addition of CNT 0.1% increases hardness by about 13% from pure AA6061. The highest hardness value was obtained at 700oC pouring temperature and the higher the pouring temperature the lower the hardness value. This is caused by a slow cooling process so that the grain size becomes larger
2. Tensile strength is directly proportional to hardness. The strain value is inversely proportional to the tensile strength. The lower the pouring temperature, the smaller the grain size causes the strain to be lower. The value of impact strength increases with the addition of CNT. Increasing pouring temperatures also increase material toughness
4. The addition of CNT to AA6061 will affect the microstructure of aluminium which causes the size of silicon and aluminium grains to be small which will increase aluminium mechanical strength.

Acknowledgment

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