Fracture Testing of Aluminium 7079 Metal Matrix Composites Reinforced with Nickel Coated Carbon Fibres

Shreepannaga[1], B Vishwash[2]

Abstract— The material unavailability demands for new materials to be produced with various combinations of materials. In the world, to create the new materials one need to combine various materials to achieve some intended properties that differ from the other. This led to development of a newer material called Composite materials. Now a day's the development of metal matrix composite has become a major innovation in the materials. The present study deals with the fabrication of Nickel coated Carbon fibre reinforced to Aluminium alloy metal composites (Al7079). The Al7079 metal matrix composite has been fabricated using stir casting method with 0, 4 and 8 wt. % nickel coated carbon fibres. Then the cast composite was machined to prepare a specimen for Fracture characterization as per the ASTM standards.

Index Terms— Metal matrix composites, Nickel coated carbon fibre, ASTM.

1 INTRODUCTION

Engineering support has always been on the lookout for newer materials which would fit all types of service conditions. It needs progressive discoveries by engineers. The unaviability of many materials demands for new materials need to be created from various combinations of other compatible materials. In the real world, various materials have been combined to achieve some intended properties that differ from the other This concept leads to the generation of new materials called composites, where in various types of matrices and reinforcements may be combined with enhancement in its properties. (1) A composite material is the combination of two or more different materials when combined together to form a newer material, which has the properties different from the matrix materials. The constituent which forms a continuous phase is called as the matrix. The other major constituent is called as the reinforcement phase. Reinforcement can be in the form of fibre or a particulate and they are added to the matrix material in order to improve matrix properties. (2) Metal Matrix Composites (MMCs) have emerged as a class of materials due to their several advantages over the conventional materials. The most popular Metal Matrix Composite used nowadays is Aluminium Metal Matrix Composite. Aluminium MMC are very attractive due to their good mechanical properties and the low costs. The Aluminium metal matrix composites can be produced by different comprising solid or liquid state processing method. (3)

Fracture mechanics is primarily concerned with the strength of cracked structures or components of a machine. It deals with the analysis of prediction and prevention of structural failures originating from cracks. The central difficulty in designing against fracture in high-strength materials is that the presence of cracks can modify the elastic stress analysis carried out by he designers is rendered insufficient. When a crack reaches a certain critical length, it can propagate catastrophically through the structure, even though the gross stress is much lesser than what would normally cause yield or failure in a tensile specimen. (4)

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2 FABRICATIONS AND EXPERIMENTAL DETAILS

In this particular work undertaken, the Aluminium alloy metal matrix composite was prepared by using Stir casting technique. The schematic representation of Stir casting process is shown in Figure 1. Blend throwing is a fluid state technique for composite materials creation, in which a scattered stage (short filaments) is blended with a liquid grid metal by mechanical mixing method. It is then trailed by cementing of the melt containing suspended particles and the coveted appropriation of the scattered stage is accomplished. The fluid composite material is then thrown by traditional throwing strategies and may also be prepared by customary metal shaping advances. The mix throwing process has some critical favorable circumstances like wide choice of materials, better lattice molecule holding, less demanding control blend structure, basic handling, adaptability to expansive amount creation and fantastic profitability for close net formed parts. It is additionally alluring in light of the fact that, on a fundamental level, it permits a customary metal handling course to be utilized and consequently minimizes the last cost of the item. Blend throwing is one of the procedures in which different materials are blended by mixing process. This strategy is likewise called as vortex method. It serves to make good wetting between the fortification and the fluid Al melt.

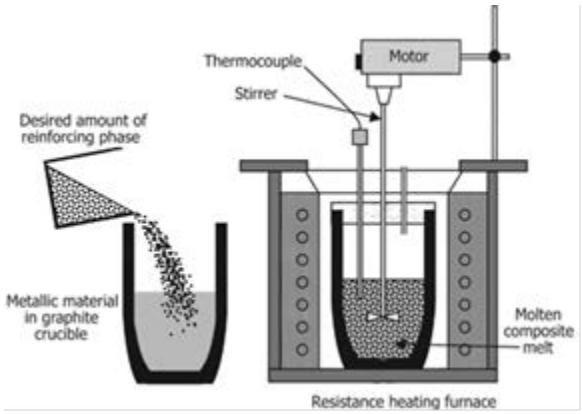

Fig.1 Schematic of Stir Casting

This will prompt a decent holding between the fortification and network material. Mix throwing is reasonable for assembling composites with up to 30% volume divisions of fortification. A huge concern associated with the blend tossing system is the seclusion of bracing particles which is realized by the surfacing or settling of these particles in the midst of the softening and tossing shapes. The last scattering of the particles in the solid depends on upon material properties and system parameters, for instance, the wetting condition of the particles with the melt, nature of mixing, relative thickness and rate of solidifying.

Experimentation Details:

A very common and simple method to test for Fracture toughness is using a Universal Testing Machine. Among the various kinds of available specimen configurations, C-T specimen was selected due to its fabrication simplicity. C-T specimen consumes less material and while testing it does not demand any special fixtures while mounting on the jaws of testing machine. The CT specimen is prepared in T-L orientation as per ASTM E399-90 standard is as shown in Fig. 2. Initially a straight through type notch is introduced till a length of a_0=10mm by CNC using wire cutting machine. Later a plastic zone is generated at the vicinity of the notch by applying fatigue loading by using Dynamic testing machine. In order to obtain fracture toughness parameters, it is essential that fracture toughness test satisfies three important requirements such as firstly, the specimen geometry must be such that K_{IC} can be estimated with the sufficient accuracy. Secondly, the value of the load and crack length at the onset of the cracking must be measured accurately. Finally, pre-cracking must be done so as to ensure that the crack introduced is a sharp one.

The pre-cracked specimen is mounted on UTM for testing. Then the specimen is loaded to obtain load v/s Crack Opening Displacement (COD) curve by pulling it in a tensile machine through loading points.

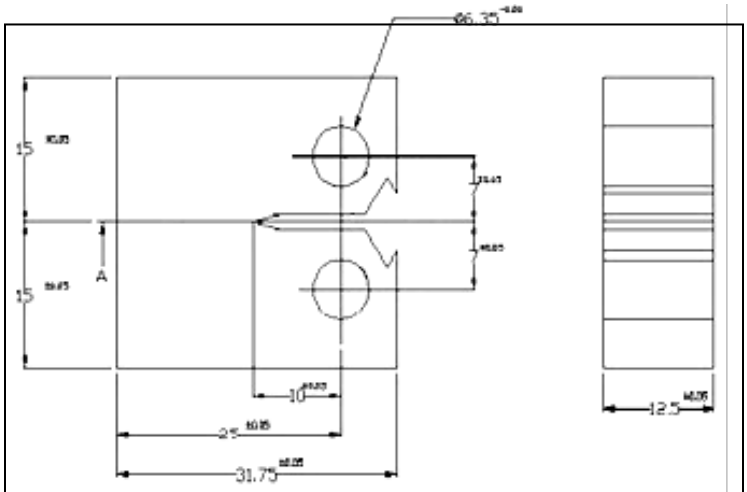

Fig. 2 Dimensions of CT Specimen

The general expression of the plain strain fracture toughness for a CT specimen made up of Aluminum 7079,

$$K_q = \frac{P_q}{B \times \sqrt{w}} f\left(\frac{a}{w}\right) \quad (1)$$

Check for validity constraints,

i) For plate thickness,

$$B \geq 2.5 \times \left(\frac{K_{Ic}}{\sigma_y}\right)^2 \quad (2)$$

ii) For crack length,

$$a \geq 2.5 \times \left(\frac{K_{Ic}}{\sigma_y}\right)^2 \quad (3)$$

iii) For Width,

$$w \geq 5.0 \times \left(\frac{K_{Ic}}{\sigma_y}\right)^2 \quad (4)$$

iv) For load ratio

$$P_{max} \leq 1.1 \times P_q \quad (5)$$

3 RESULTS AND DISCUSSION

Under the plane strain condition and opening mode loading Fracture toughness test is conducted according to the ASTM E399 standard with the aid of UTM. Compact Tension (CT) specimens are prepared according to the standards. Fatigue pre-crack is measure as per the ASTM E 647 standard. The load versus COD for each material is shown graphically. The Load versus Crack Opening Displacement (COD) curve is generated digitally in UTM.

Case I: Aluminium 7079 composites with 0% Carbon Fibre

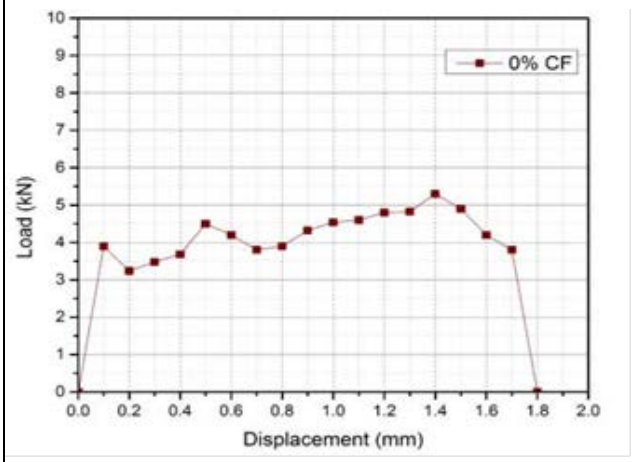

Fig.3 Load vs COD curve for Al7079 with 0% CF

From the Fig. 3, the values of critical load 'Pq' and 'Pmax' is found to be Pq= 4.82kN and Pmax = 5.3kN. For the non-dimensional term, a/W=12.994/25.4=0.511, the corresponding geometrical correction factor recommended by ASTM E399 standard table (Appendix A) was found to be 9.96. By using the equations 1 to 5 for plain strain fracture toughness, the value of Kq is tabulated in the table 1.

Case II: Aluminium 7079 composites with 4% Carbon Fibre

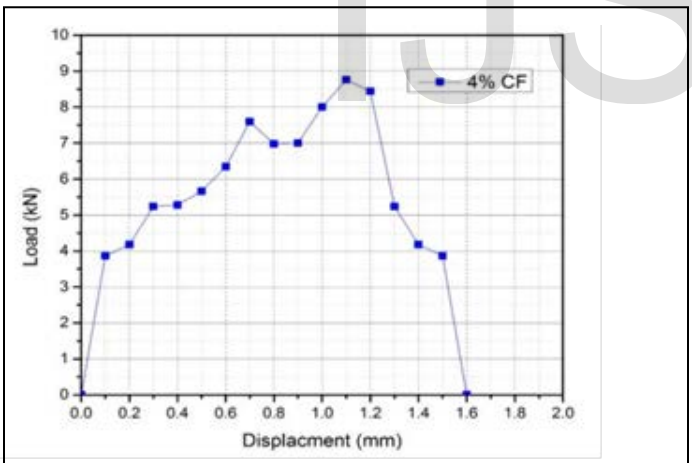

Fig. 4 Load vs COD curve for Al7079 with 4% CF

From the Fig. 4, the values of critical load Pq= 8.0kN and Pmax = 8.76kN. For the non-dimensional term, a/W=12.994/25.4=0.511, the corresponding geometrical correction factor recommended by ASTM E399 standard table (Appendix A) was found to be 9.96. The value of Kq is tabulated in table 1.

Case III: Aluminium 7079 composites with 8% Carbon Fibre

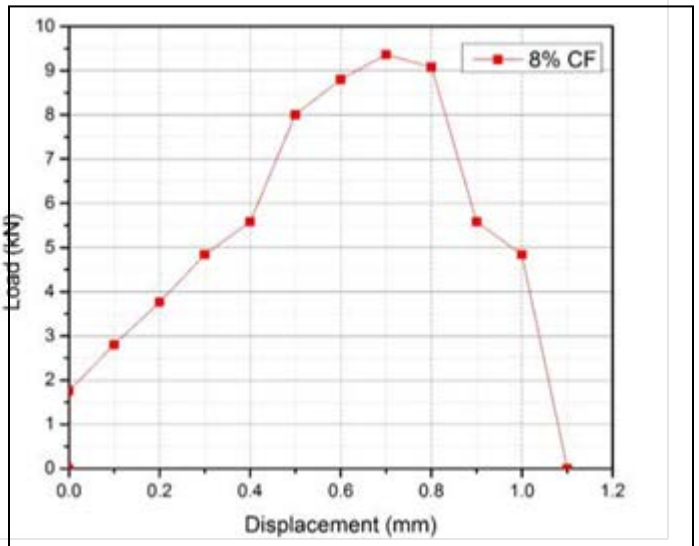

Fig.5 Load vs COD curve for Al7079 with 8% CF

From the Fig. 5, the value of critical load and maximum load is Pq = 8.8kN and Pmax = 9.36kN. For the non-dimensional term, a/W=12.994/25.4=0.511, the corresponding geometrical correction factor recommended by ASTM E399 standard table (Appendix A) was found to be 9.96. The value of Kq is tabulated in table1.

Table 1 Fracture Toughness Test Results

Sl. No	MMC	a_o mm	a_p mm	a mm	$\left(\frac{a}{w}\right)$	$f\left(\frac{a}{w}\right)$	K_q Mpa $\sqrt{m}$	K_{IC} Mpa $\sqrt{m}$
1	Al7079, 0%CF	10	2.99	12.9	0.511	9.96	24.07	24.07
2	Al7079, 4% CF	10	2.99	12.9	0.511	9.96	39.96	39.96
3	Al7079, 8% CF	10	2.99	12.9	0.511	9.96	43.88	43.88

Fracture tests have been conducted using UTM with the help of special jigs and fixtures. Fracture test is performed on the cast composites with 0%, 4% and 8% nickel coated short carbon fibres. From the fracture test results, it is observed that fracture toughness increases with the increase of the carbon fibre. Nickel coated carbon fibre reinforced with Aluminium 7079 MMC with 8% carbon fibre will exhibit higher Fracture toughness.

4 CONCLUSIONS

Based on the observations during the fabrication of the composites using the stir casting technique, it has been concluded that, the mixture ability of Al7079 with the coated carbon fibre can be improved with the addition of Magnesium Metal Powder. From the fracture test results, it was observed that the fracture toughness of the nickel coated short carbon fibres reinforced with Al7079 MMC is found to increase with increase

in reinforcement content. Also, the maximum fracture toughness value of nickel coated short carbon fibres reinforced with Al7079 MMC is 43.88 $MPa\sqrt{m}$ as experimentally witnessed. This maximum value is observed for the Al7079 MMC reinforced with 8% of CF.

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