[NCIME: October 2016]
ISSN 2348 – 8034
Impact Factor- 4.022

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

INVESTIGATION OF MECHANICAL STRENGTH AND THERMAL PROPERTIES OF A PULTRUDED CFRP WITH MWCNT

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ABSTRACT

In this investigation, carbon fiber reinforced, multiwall carbon nanotube (MWCNT) filled polymer composite rods are produced (pultruded) using Primaset BTP 6020S resin as matrix material. The samples out of the pultruded rods were tested for their mechanical and thermal properties. The results obtained shows the improvement in the tensile strength on addition of MWCNT and improvement in glass transition temperature on postcuring of the pultruded samples.

Keywords- *Polymer Composites, Carbon fiber, BTP 6020S, Pultrusion, Tensile test, , MWCNT, tg.*

I. INTRODUCTION

Varieties of composites based on thermosetting matrices, strengthened with suitable reinforcements have been developed in recent times and assessed for their specific technological characteristics and the results of these activities are encouraging. Scientific analysis backed up by technological advancements have paved the way for developing novel processing methods such as Pultrusion - offering itself as a candidate technology to fabricate some really exotic and performing composites.

They offer many attractive mechanical and thermal characteristics. Extensive studies have been conducted on pultrusion process.[7-12] Pultrusion is a process in which dry, continuous fibers are pulled through a bath of resin and then through a die. The objective of this article is to develop and characterize carbon fiber/Lonza Primaset BTP 6020S cyanate ester composite rods manufactured by pultrusion process. Experimental plan, experiments, results and discussion are given in the following sections.

II. PULTRUSION PROCESS

The typical pultrusion process starts with racks or creels holding spools of bundled continuous fiber (roving). Most often the reinforcement is fiberglass, but it can be carbon, aramid, or a mixture. This raw fiber is pulled off the racks and guided through a resin bath or resin impregnation system. The raw resin is almost always a thermosetting resin, and is sometimes combined with fillers, catalysts, and pigments. The fiber reinforcement becomes fully impregnated (wetted-out) with the resin such that all the fiber filaments are thoroughly saturated with the resin mixture. As the resin rich fiber exits the resin impregnation system, the un-cured composite material is guided through a heated steel die. Precisely machined and often chromed, the die is heated to a constant temperature, and may have several zones of temperature throughout its length, which will cure the thermosetting resin. The profile that exits the die is now a cured pultruded Fiber Reinforced Plastic (FRP) composite. This FRP profile is pulled by a gripper system. Either caterpillar tracks or hydraulic clamps are used to pull the composite through the pultrusion die on a continuous basis. At the end of this pultrusion machine is a cut-off saw. The pultruded profiles are cut to the specific length and stacked for delivery[4]. The actual photograph and the schematic diagram of the pultrusion machine are shown in figure 2 and figure 3 respectively.

Figure 2: Actual Photograph of the Pultrustion Machine

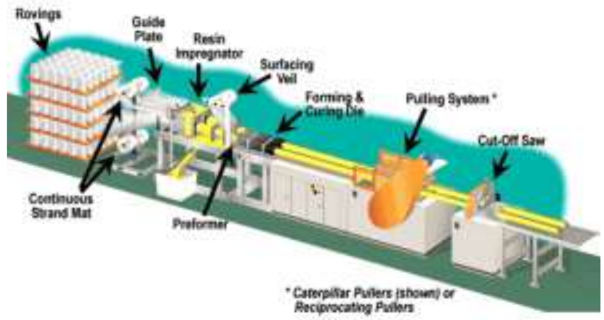

Figure 3: Schematic Diagram of the Pultrusion Process

III. MATERIALS USED FOR PULTRUSION

The materials considered are 6mm filament diameter and 9200 Tex (linear weight) carbon fibers supplied by Indian Petrochemicals Corporation Limited, India form the Basis for the CFRP Composite Material, which is shown in Figure 4. The matrix material used is Primaset BTP 6020 S[6] (liquid), which is supplied by Lonza Inc, Basel is shown in figure 5. The filler material used is MWCNT, which is supplied by Quantum materials corporation, Bangalore is shown in figure 6. The carbon nanotubes (CNT) are a new form of carbon made-up of graphene layers rolled-up into a cylindrical form. Extensive studies have been carried out on CNT[14-17]

Figure 4: Carbon Fiber Reinforcement of having 9200 Tex

Figure 5: Primaset BTP 6020S

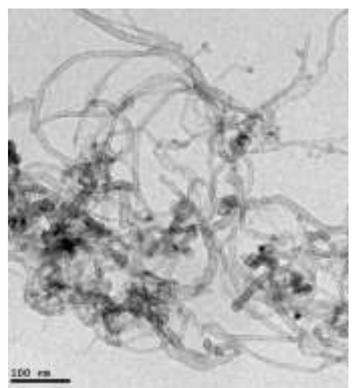

Figure 6: TEM Image of Multiwall Carbon Nano Tubes[4]

IV. EXPERIMENTAL

In this study, rods with 3mm diameter with 6m Length are pultruded at a temperature of 160^0C and at the rate of 125 – 135 mm/min. The calculation for number of carbon fiber rovings required to pass through the die for 65% of the fiber is as shown below.

Calculation for number of rovings:

Here is the calculation for number of rovings to get the required volume fraction of reinforcement material.
For Carbon Fiber Reinforcement :
Consideration: Diameter of the Wire D=3mm
Volume of Fiber =65%
Area of cross section of composite wire, $A = (\pi d^2 / 4) = (\pi / 4)\ (0.65 \times 3)^2 = 2.9864\ mm^2$
Area of carbon fiber, $A_f = n(\pi d^2 / 4) = \{9200 \times \pi\ (6 \times 10^{-3})^2\ \}/4 = 0.24033 mm^2$
Formulae for no. of roving

ISSN 2348 – 8034
Impact Factor- 4.022

Area of composite wire = N * Area of carbon fiber, where N= number of rovings
[2.9864 = N x 0.24033] i.e., N = 12.4 ≈ 13rovings

Initially, the rods are pultruded without using CNT. The photograph of the pultruded rod is shown in figure 7. To pultrude next samples using CNT, carbon nanotubes are dispersed in a resin and ultrasonicator is used to achieve effective dispersing. CNT is mixed with resin mechanically by stirring and the mixture kept for 90 minutes in an ultrasonicator at an 80^0 C and the mixture is poured in to the resin bath to mix with fibers. The schematic representation of the ultrasonicator is shown in figure 8. Now rods are pultruded using 0.2% CNT and 0.4% CNT.

Figure 7: Photograph of the Pultruded CFRP

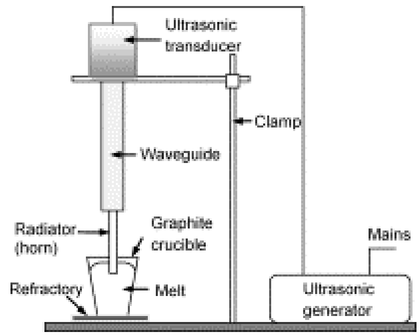

Figure 8: Schematic Representation of Ultrasonicator

Then the samples are observed in scanning electron microscope (SEM). The microscopic image is as shown in figure 9. Distribution of the fibers can be observed in the image.

Volume fraction of the pultruded composite rod is determined by using crucible furnace.

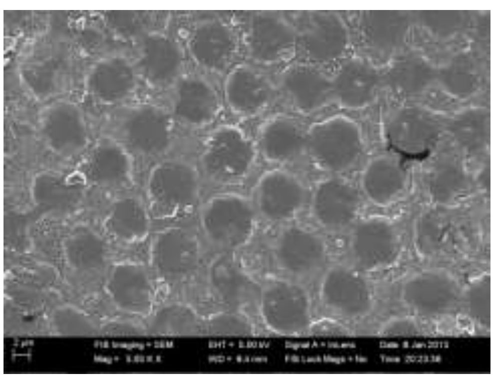

Figure 9: SEM Image of Pultruded CFRP

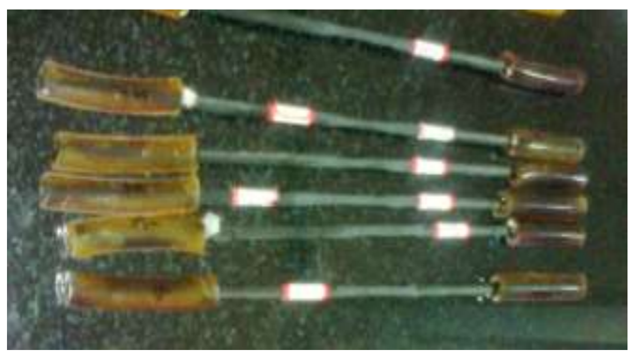

Figure 10: Tensile Test Samples

For CFRP rods, the tensile test procedure is carried out as per ASTM D 7205 - 06[13]. Literature for testing polymer matrix composite materials is referred [18, 19]. Samples are prepared for tensile test as per ASTM standards using dynamic tensile test facility.

Electrical conductivity test is carried out for both all the CFRP samples. The length of the sample taken for the test is one meter. Electrical conductivity test is carried out by digital megahmm meter.

The Glass Transition Temperature (T_g) is one of the most important properties of any polymer composite is the temperature region where the polymer transitions from a hard, glassy material to a soft, rubbery material. T_g is test is carried out before and after curing as per ASTM E1356 using differential scanning calorimetry (DSC).

ISSN 2348 – 8034
Impact Factor- 4.022

V. RESULTS AND DISCUSSIONS

Volume fraction test

The results from the crucible furnace for carbon fiber with Primaset BTP6020S are shown in table 2.

Table 2: Volume of the fiber and the matrix for all the samples

Primaset BTP 6020 S Resin based CFRP + MWCNT (%)	V_f (%)	V_m (%)
0	64.824	35.176
0.1	64.896	35.104
0.2	64.943	35.057
0.3	64.968	35.032
0.4	65.009	34.991
0.5	64.884	35.116

Tensile test

Tensile test results obtained from the theoretical calculations and dynamic testing machine are tabulated in table 3\

Table 3: Theoretical and Experimental Tensile Test Results

CFRP Test Samples + MWCNT (%)	Tensile strength (N/mm^2) x 10^3	
	Theoretical	Experimental
0	1.33	1.18
0.1	1.38	1.22
0.2	1.44	1.29
0.3	1.49	1.35
0.4	1.55	1.50
0.5	1.60	1.50

T_g test results

Glass transition temperature for the CFRP rod is measured using DSC and is tabulated in table 4.

Table 4: Glass Transition temperature Results (Before and after curing)

BTP 6020 S Resin based CFRP + MWCNT (%)	BTP 6020 S Resin	
	Post Cure (^{0}C)	Post Cure (^{0}C)
0	220.36	256.56
0.1	220.46	256.85
0.2	220.41	256.60
0.3	220.47	256.71
0.4	220.50	256.72
0.5	220.27	256.81

ISSN 2348 – 8034
Impact Factor- 4.022

VI. CONCLUSION

It is clear from the SEM image that the distribution of the fibers in the composites are uniform. The results of the tensile test shows that the CFRP composites has more tensile strength than the one without MWCNT. The t_g test results shows that temperature range is 256^0C - 257^0 C.

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