AN EXPERIMENTAL STUDY ON EFFECT OF SHORT GLASS FIBER REINFORCEMENT ON CHARACTERISTICS OF POLYMER MATRIX (POLYCARBONATE)

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ABSTRACT:

Polycarbonate (PC) has been reinforced with glass fibers of different weight ratios viz., 10%, 20% & 30%. All reinforced and unreinforced polycarbonate composites have been fabricated using twin screw extruder and characterized for physico-mechanical properties such as density, surface hardness, impact strength, tensile behavior and the microstructure property relationship of glass filled polycarbonate composites has been performed using scanning electron microscope (SEM). Also the thermal properties like heat distortion temperature (HDT), vicat softening temperature (VST) and chemical resistivity to evaluate the influence of glass fiber reinforcement on polycarbonate. It has been observed that the values are considerably higher than the base material as a result of incorporation of high strength glass fiber.

Keywords: Polycarbonate, glass fiber, physical properties, mechanical properties, microstructure, thermal properties.

1. INTRODUCTION

The role of the materials in the development of the modern technology need not be emphasized. At least 40% of the cost of the materials is used for its construction. As the technology becomes more and more sophisticated, the materials used also have to be correspondingly more efficient. Several performance characteristics are also expected from these materials. The materials to be used in the sophisticated applications are expected to have higher performance efficiency and reliability.

Polymer matrix composites have shown the ability to balance traditional polymer properties such as low weight and ease of process ability with the strength and stiffness of reinforcing agents. Fiber reinforced thermoplastic composites have become an area of increased interest due to their shorter cycle times and greater potential recyclability compared to thermosetting polymers. Additionally, thermoplastic polymers display large elongation to break which can be particularly beneficial in unidirectional fiber composites. Fillers, in the form of particulates and fibers, are often added to polymeric materials to improve their stiffness and strength. Polycarbonate is a most important technical thermoplastic because of its excellent heat resistance, outstanding impact strength and good dimensional stability.

The most widely known and recognized reinforcing fiber in today is glass. However, carbon and polyaramid fibers are also finding ever-increasing usage. The presence of reinforcing glass fibers lends added strength and stiffness to the final composite, permitting applications not normally associated with resinous plastics. The application of any new class of composite depends mainly upon the characteristics of that composite. These include behavior at high temperature, maximum stress the composite can withstand, fatigue characteristics, impact strength, wear resistance, corrosion behavior and other machinability parameters.

So the investigation of the above said characteristics is important for any composite. The investigation of physical, mechanical, thermal and chemical properties of Polycarbonate (PC) as the matrix material and glass fiber as the reinforcement at different percentages (10%, 20% and 30%) is the aim of the present paper.

2. EXPERIMENTAL

2. 1 MATERIAL

Polycarbonate was obtained from M/s. SRF, New Delhi, India. The Polycarbonate T_m 280 ^{0}C, density 1.20 g/cc and E-glass short fiber with 4mm length was used. Polycarbonate is a most important technical thermoplastic because of its excellent heat resistance, outstanding impact strength and good dimensional stability. Acetal resin and polycarbonate both resulted from research on pure formaldehyde. Bisphenol A, which was produced for the epoxy resins, opened the door for Acetal resin and polycarbonate. Polycarbonate was the first of the rigid thermoplastics to offer good temperature stability up to 130^{O}C and impact strength.

E-glass is the most common form of reinforcing fiber used in polymer matrix composites having lower alkali content and stronger than a glass (alkali). Good tensile, compressive strength and stiffness, good electrical properties, but relatively low (poor) impact resistance.

2.2 FABRICATION OF COMPOSITE SPECIMENS

The short glass fiber of 4mm length is incorporated to Polycarbonate with different weight ratios, viz., 10%, 20% and 30% using twin-screw extruder [13]. Glass fiber filled Polycarbonate pellets were predried at 280^{O}C for 24hrs prior to Moulding. The dried pellets were then transferred to steel mould, which was placed in preheated mould at 290

± 5^{O}C. The mould was kept under pressure using hydraulic press for 10min at the same temperature and cooled to room temperature. The composite specimens were removed from the mould.

2.3 MEASUREMENTS

All properties were measured at room temperature 26^{O}C. At least six specimens (replicates) were taken for each of the properties measured and the average values are reported. The Densities of the glass fiber reinforced

polycarbonate (GFRPC) has been determined by ASTM method D-792 using Electrical Balance, Mettler Toledo AG204, The Surface Hardness test was performed as laid down by ASTM D-2240 using Shore D tester, Hiroshima 0-100 Shore D. The Izod Impact Strength was measured according to ASTM D-256.Tensile Strength, Young's modulus has been measured using ASTM D-638M using Universal Instron Testing Machine Model 4301, with standard and dumbbell shaped specimens. The structure property relationship of GFRPC composites has been performed using scanning electron microscope (SEM). The Heat Distortion Temperature (HDT) and Vicat Softening Temperature (VST) were measured according to ASDM-648
and ASDMD-1525 respectively. Resistance to chemical reagents was also estimated by ASTM D543-67.

3. RESULTS AND DISCUSSION

3.1 PHYSICO-MECHANICAL PROPERTIES

The densities of GFRPC were determined and the results obtained are given in Table 1. The density values of GFRPC lie between 1.27g/cc to 1.31g/cc. The improvement in the density was observed with increase in the glass fiber amount increased the densities by 5.83%, 8.0%, 9.6% for 10%, 20%, 30% GFRPC respectively, it can be clearly observed from cross sectional view of GFRPC microphotographs shown in Figure 5,7 & 9.

Table 1 – Density, Hardness and Impact Strength results of GFRPC

GFRPC	Density (g/cc)	Hardness	Impact strength (J/m)
10%	1.27	87	66.56
20%	1.29	90	37.25
30%	1.31	93	31.52
Base Resin	1.20	70	123

The Surface Hardness of GFRPC results were obtained by the Shore-D Type Durometer is given in Table 1. The Surface Hardness values of GFRPC lie between 87 to

93. The improvement in the Surface Hardness were observed as increasing the glass fiber amount increased the Hardness by 24.3%, 28.6%, 30% of the specimens with 10%, 20%, 30% GFRPC respectively. The surface view of GFRPC microphotograph reviles that the surface roughness increases as increase in the glass fiber amount shown from Figure 4, 6 & 8.

In case of Impact strength of GFRPC, the strength decreased with increase in weight percentage of glass fiber, this is due to the increase in critical length of the glass fiber. The Impact strength of GFRPC results obtained by pendulum impact tester is given in Table 1. The Impact strength values of GFRPC lie between 66.56 J/m to 31.52 J/m. The reduction in Impact strength is more in case of GFRPC compared to base material casts.

Table 2 – Mechanical (Tensile) Properties of GFRPC

GFRPC	Tensile strength (MPa)	Young's Modulus (MPa)	Percentage of Elongation (%)

10%	80.07	1600.48	9.027
20%	98.12	2134.63	8.621
30%	107.49	2966.45	7.035
Base Resin	62		

The results obtained for Tensile Strength properties of GFRPC are given in Table 2. The Tensile Strength values of GFRPC lie between 80.07 MPa to 107.49 MPa. The Tensile Strength is higher for GFRPC than for base material casts. This is due to increase in high modulus glass fiber content in the polycarbonate matrix.

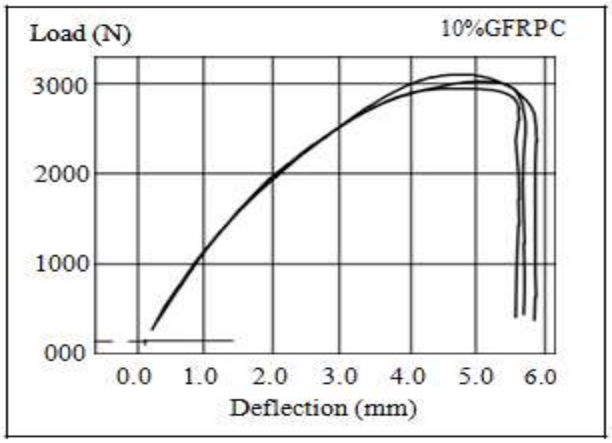

Figure 1 Load-Deflection Curve for 10% GFRPC

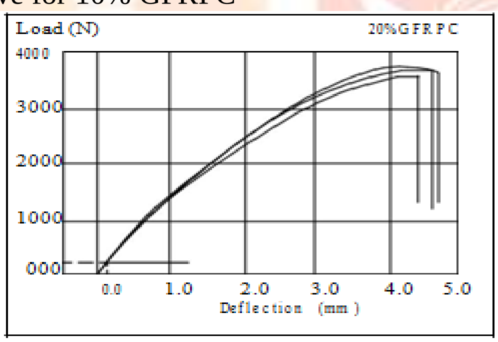

Figure 2 Load-Deflection Curve for 20% GFRPC

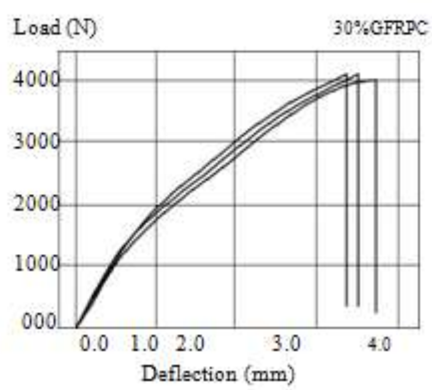

Figure 3 Load-Deflection Curve for 30% GFRPC

The Load-Deflection curves for different composition of GFRPC are shown in Figure 1, 2 and 3. The improvement in the tensile strength was observed as increasing the glass fiber amount increased the tensile strength by 29.15%, 58.25%, 73.38% of the specimens with 10%, 20%, 30% GFRPC respectively.

A marginal increase in 7.81%, 53.59% physical and mechanical properties of GFRPC respectively were found compared with base resins. Incorporation of glass fiber altered the mechanical properties of the composites significantly.

3.2 MICROSTRUCTURE PHOTOGRAPHS

The structure property relationship of GFRPC composites has been performed using scanning electron microscope (SEM). To probe the adhesion between polycarbonate and glass fiber the scanning electron microphotographs of surface and brittle fractured are given in Figure 4 – 5, Figure 6 – 7, and Figure 8 – 9 for 10%, 20% and 30% GFRPC respectively.

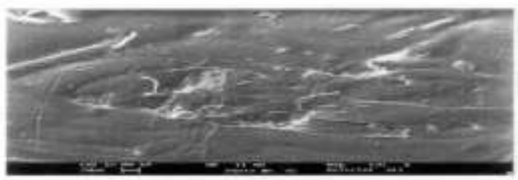

Figure 4 Surface view of 10% GFRPC

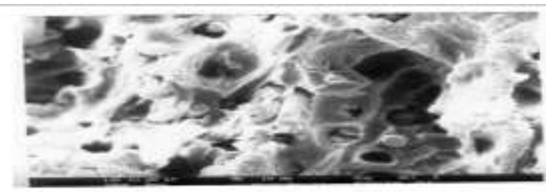

Figure 5 Cross-sectional view of 10% GFRPC

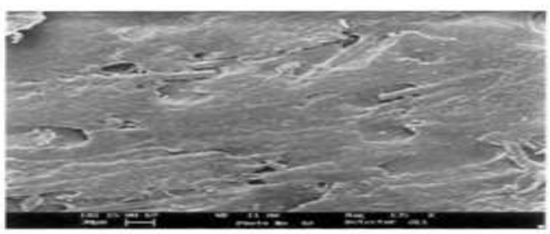

Figure 6 Surface view of 20% GFRPC

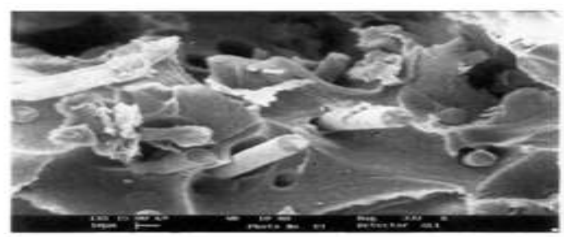

Figure 7 Cross-sectional view of 20% GFRPC

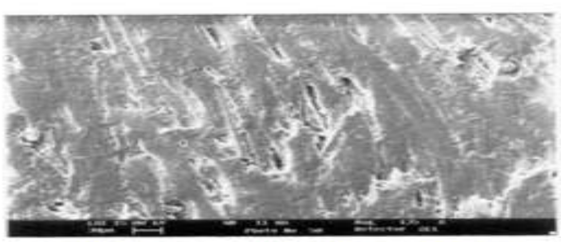

Figure 8 Surface view of 30% GFRPC

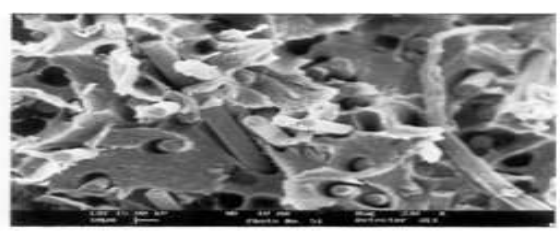

Figure 9 Cross-sectional view of 30% GFRPC

The surface morphology was recorded to know the fragmentation of the fiber. But SEM microphotographs reveal that fiber length was not reduced drastically. SEM microphotographs also revealed that uniform distribution of short glass fiber in the matrix of polycarbonate.

As a result, the composite specimens reinforced by GFs present some regions characterized by weak interfacial adhesion and some holes as a consequence of fiber pullout phenomenon. The adhesion and improved interaction between glass fibers and polycarbonate were observed in SEM photographs by examining the fracture surfaces. Due to the dispersed particle size becomes smaller and more uniform, the mechanical and thermal properties are improved more.

3.3 THERMAL PROPERTIES OF GFRPC

Heat Distortion Temperature (HDT) is the temperature at which a standard test bar deflects 0.25mm under a stated load of 455kPa and Vicat Softening Temperature (VST) is the temperature at which a flat ended needle of 1sq-mm circular cross section will penetrate a thermoplastic specimen to a depth of 1 mm under specified load and uniform rate of temperature raise. The values of HDT & VST are given in Table 3. Which lies between 130-140^{0}C & 156-160^{0}C, were considerably higher than the base material (PC=130^{0}C) as a result of incorporation of high strength glass fiber.

3.4 CHEMICAL RESISTIVITY OF GFRPC

After exposure to 10 different chemical reagents for 7 days, the composite specimens were examined for changes in physical properties, such as discoloration, loss of gloss, changes in weight and thickness. Examination of the specimens showed neither loss in gloss nor change in colour. However, a slight change in weight and thickness data of GFRPC specimens were observed and shown in Table 4.

Table 4 – Chemical Resistivity Test Results in terms of Weight & Thickness for GFRPC

Chemical Name	**GFRPC**					
	Change in Weight (gm)			**Change in Thickness (mm)**		
	10%	20%	30%	10%	20%	30%
NaOH	0	0.02	0.01	0.04	0	0.02
$KMnO_4$	0	0.06	0.06	0.02	0.02	0.04
NaCl – 10%	0.01	0	0	0.01	0.01	0.04
NaCl – 20%	0.01	0.01	0.02	0.02	0.02	0.04
NaCl – 30%	0.02	0.03	0.05	0.02	0.02	0.04
H_2O_2	0	0	0	0	0	0.02
Benzene	0	0	0	0.02	0	0.02
Ethyl Acetate	0	0.01	0.05	0.02	0.01	0.04
HCl	0	0	0	0.01	0	0.04
HNO_3	0	0	0	0.01	0.01	0.04

4. CONCLUSION

The research carried out made it possible to conclude that glass fiber reinforcement enhances the properties of GFRPC composites, i.e., specific gravity, hardness, tensile strength, strain at break, and young's modulus. The increased strain value at the break point, improved the interface allowing more ductile behaviour. The Heat distortion and Vicat softening temperature values were considerably higher than the base material as a result of incorporation of high strength glass fiber. Also from chemical resistivity test, it may be concluded that, all the composites are highly resistance to the above chemicals. These composites may be need in the chemical industries without loss of any performance.

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