Evaluation of Mechanical Properties of HDPE Composite for Automobile Application

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Abstract: The Composite materials are having a widespread application in almost all aspects of daily needs. The requirement for a lightweight component in industries like aerospace and automobile is very significant. This study on short glass fiber reinforced and Silicon Carbide filled High-Density PolyEthylene composites concentrates on one such application in the automobile sector, to be specific, bumper and bonnet is the main focus. The composite was tested for its Tensile, Flexural and Impact properties. EDAX and SEM images were also considered to justify the results. The tests results showed an increasing behavior with silicon carbide particles. This study provides a novel way for replacing a conventional sheet metal components with composites

Keywords: HDPE composites, particulate fillers, Mechanical Properties, Processing, Fractography, EDAX.

1. Introduction

The growth of Automobile sector in past three decades was exponential, as the field grows a new design, innovation, automation gets added to it [1-7]. Though engine flashes first into the mind with the thought of automobile there are many other internal and external components which play an important role, chassis is one such example for that [8]. Bumpers and bonnet (hood) are mainly focused on the study [9-11]. Both of the above-mentioned components requires flexibility and there are many European norms which govern their design aspects. The composite material made of matrix HDPE, reinforced with the short glass fibers and silicon carbide as the secondary fillers is analyzed for its properties according to the ASTM standards [12-16]. In this study, the composite was fabricated by extrusion followed by the injection molding [17-19]. The percentage of the short glass fibers was kept constant and percentage of SiC and HDPE were varied accordingly. The direct imaging of SEM images gives bulk phase composition of composites. The composition was justified with the EDAX test.

2. Experimental

2.1. Materials

The HDPE of density 953 kg/m^3 is used as the matrix material, 20% wt short E- glass fibers are used as reinforcements. For the study, we have employed various filler loadings (0% wt, 8% wt, 10% wt and 12% wt). The maleic anhydride polyethylene (MAPE) is used as the compatibilizer for providing good bonding between the matrix, fibers, and particulates [20, 21].

TABLE 1
Composition and nomenclature of specimens

Specimen	HDPE (%)	SGF (%)	SiC (%)
TR-1	80	20	0
TR-2	72	20	8
TR-3	70	20	10
TR-4	68	20	12

2.2. Fabrication

After all, materials made available, the extrusion process followed by injection molding was selected. In this HDPE pellets and SGF were taken and heated to soften and later converted into a dough with proper mixing. The dough is then converted into plates and fed into a rotary extruder, the composite strips are prepared and later it is fed into the die or a mold to get required specimens. The temperature was of molten HDPE was maintained to be 160°C and the single screw type extruder was rotated at 180rpm at a pressure of 10 bar [17, 19].

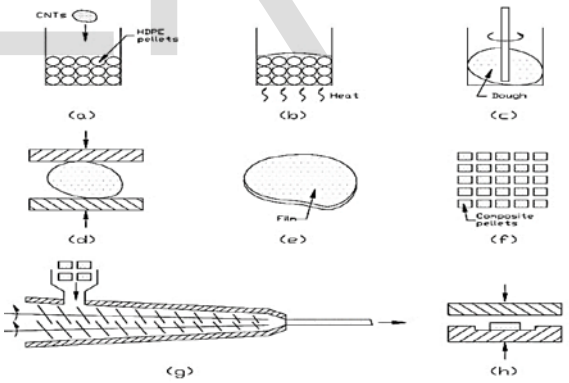

Fig 1: Process used for fabrication of composite (here in this study instead of CNT, SGF and SiC is used.)[17]

2.3. Test Procedure

2.3.1 Density

The density is the main parameter in a composite material this is first measured in a closed box containing air later on it is measured in water to get actual density. In order to measure the density, the specimen was cut into 6mm×6mm size. The ASTM D792 was used for this purpose.

2.3.2 Hardness

The hardness is measured using Shore D hardness scale. To measure the hardness the Durometer is pressed against the workpiece. The needle is deflected and stops at a position which is considered. Similarly, the readings are taken at different positions to check for precision.

2.3.3 Tensile Test

The rectangular cross-section dumbbell shape specimen was prepared with an effective span of 70mm. The test was performed according to ASTM D638-02a [12]. The 100KN UTM of Kalpak made was used for carrying out the tests. The crosshead speed of 0.5mm/min is used [22]. The load versus displacement plots were taken for further calculations.

2.3.4 Flexural Test

The specimen was 90mm long but the effective length was considered to be 60mm, the aspect ratio (length to thickness ratio) is maintained to be 16:1 [13]. The test was performed according to the ASTM D790 [13]. The crosshead speed was maintained to be 0.25mm/min. The plots of load versus deflection were taken into account for calculation.

2.3.5 Impact Specimen

The test was performed on a V-notched specimen. Various hammers were used based on the hardness values they are 2.7J, 5.4J and 10.84J. The values of energy absorbed were displayed digitally on the screen. The reason for performing the impact test is that the bumpers must undergo low velocity impact during testing time [11].

2.3.6 Fractography

The best two specimens from tensile test and impact test were carefully cut, for procuring images the JSM-IT300 instrument was used. The samples were thoroughly cleaned, air-dried and thick gold particles of 10nm were coated and cut specimens were subjected to SEM images of 100x, 250x and 500x magnification to visualize the picture more clearly. On the same base, the specimens were subjected to EDAX which gives the composition of the specimen. The energy for EDAX was from 0keV to 13.0keV with the time duration of 50 seconds [23].

3. Results and Discussion

3.1. Mechanical Properties

3.1.1 Density

The density of matrix is found to be 0.953 g/cc that of the Short glass fibers and the SiC were quoted as 2.46g/cc and 3.1g/cc respectively. The variation of density followed an increasing path as expected this is shown in table.

3.1.2 Hardness

Shore D hardness tester is used to measure hardness. When the durometer is pressed against the HDPE it shows less hardness similarly when indented on to SiC shows a high hardness. Hardness is measured at 15 points on each specimen to have uniformity in the results.

TABLE 2
Density and Hardness values of the composite

Specimen	Density (g/cc)	Hardness Shore-D
TR-1	1.0811	45.7
TR-2	1.0942	50
TR-3	1.1121	55
TR-4	1.1156	57

3.1.3 Tensile Test

The specimen showed an acceptable behavior under tensile loading conditions. The TR-1 specimen is with the highest peak load and with the addition of the SiC the peak load decreased initially at TR-2 and increased later on. The main reason for this is SiC particles, at lower concentration instead of acting as a stress bearer, it acts as a stress raiser, due to which the specimen showed the increase in the tensile strength. Specimens that have undergone testing is shown in fig 2.

Fig 2: Tensile specimen after testing

TABLE 3
Shows the tensile testing results of composites.

Specimen	Tensile Peak Load (N)	Tensile Strength (MPa)	Elastic Modulus (MPa)
TR-1	1047.10	26.94	449.90
TR-2	989.34	25.00	385.39
TR-3	995.98	26.02	411.52
TR-4	1026.00	26.53	421.01

3.1.4 Flexural Test

In the flexural loading condition the flexural strength and flexural modulus follow the same trendas in case of tensile test. The failure of the specimen is not observed, but the specimen will be stretched a little bit. The results obtained is a direct outcome of matrix- fiber adhesion. The improper bonding leads to the less load carrying capacity. Table 4 shows the flexural strength and flexural modulus of the compsite materials under discussion.

TABLE 4
Flexural Strength and Modulus.

Specimens	Flexural Peak Load (N)	Flexural Strength (MPa)	Flexural Modulus (MPa)
TR-1	55.57	35.63	1426.08
TR-2	45.19	27.22	747.68
TR-3	47.63	29.91	878.14
TR-4	49.21	30.44	1327.7

3.1.5. Impact Test

The Impact Strength of the specimens followed same patterns as observed in tensile and flexural. The impact specimen that were tested is shown in fig 3.

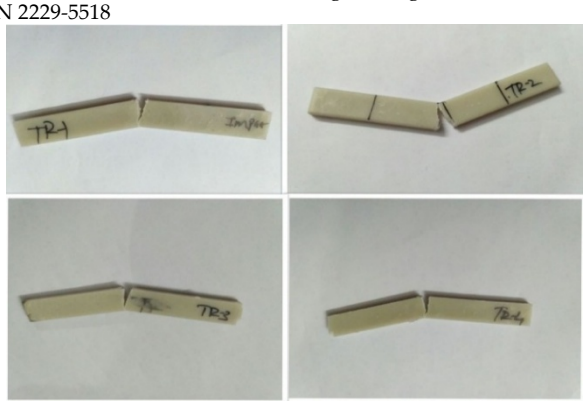

Fig 3: Tested impact Specimens.

Reason for sudden decrease in impact strength was found by investigation of SEM images. The propagation of crack was almost linear.

TABLE 5
Impact strength of Composites.

Specimen	Impact Strength J/m
TR-1	154.00
TR-2	120.00
TR-3	134.7
TR-4	159.5

3.2. Fractography

Fractographic methods are routinely used to determine the cause of failure in engineering structures. It also helps in studying the morphological aspects of the specimens under testing. For the present study the two specimens with best results were taken for SEM and EDAX analysis. The microscopic images were taken for different magnifications.

3.2.1. Scanning Electron Microscopy

SEM image of tensile specimens TR-1 and TR-4 where the images of 250x and 500x are compared as in fig 3(a). In case of tensile specimens, since the matrix is sort of elastic it still retained some of its elastic behavior due to the low cross head speed used for testing. Some fibers are not oriented in axial direction, presence of these kinds of fibers do not help in carrying the load.

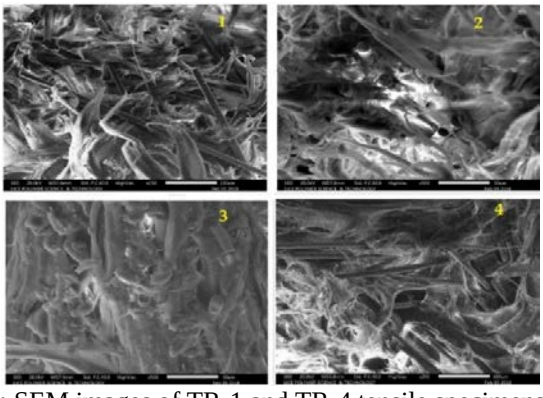

Fig 4: SEM images of TR-1 and TR-4 tensile specimens.

The fractographic study of impact specimens showed the fiber pullouts, which implies that the fiber-matrix adhesion is not high enough to hold fibers intact with the matrix. These sort of bondage will reduce the impact strength of the specimen there by reducing its application.

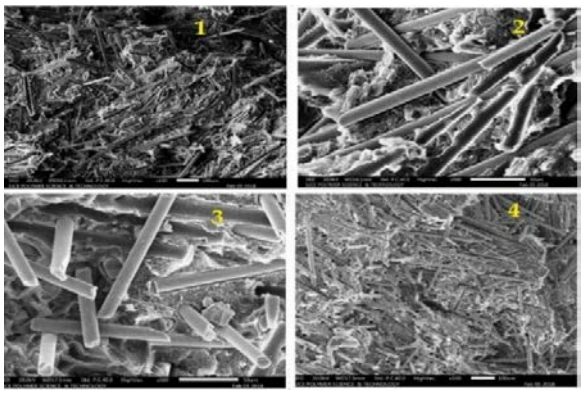

Fig 5: SEM images of TR-1 and TR-4 impact specimens.

These SEM images were printed to a required scale the dimensions of the fibers were measured, these measured dimensions got matched to actual dimensions specified by manufacturer with an error of 2.1%-4.36%. The range is due to the measurement errors which gets added when we go for lesser resolution images.

3.2.2. Energy Dispersive Analysis of X-rays

EDAX analysis was done for gaining relevant information about the constituents of the composite materials, it shows different elements and their percentage presence. The presence of carbon and hydrogen confirms the presence of the polymer and silicon, calcium and aluminium confirms the presence of SGF and silicon along with carbon confirms the presence of SiC particles.

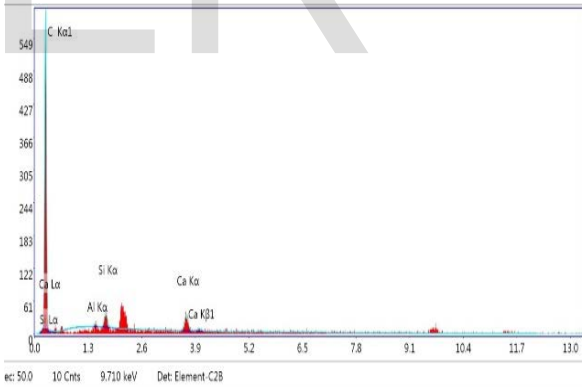

Fig 6: EDAX images of TR-1 specimen.

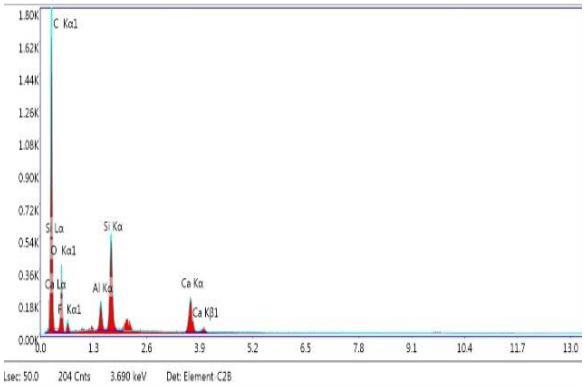

Fig 7: EDAX images of TR-4 specimen.

4. Conclusion

The above study gives a realistic approach in replacing the present day sheet metal bonnets and bumpers by a HDPE based composite materials. The bonnets and bumpers as we all know should be soft enough to save the pedestrian from head injuries and damages to body parts as well. These bonnet and bumper designs are governed by some European norms which directs the manufacturer to provide safety to pedestrian along with the automobile occupant. These material fail themselves by taking loads rather than transmitting to the major portion of the chassis. The density of material is less, with convincing tensile, flexural and impact properties the material samples named TR-1 and TR-4 can be suggested for the quoted applications. Further study have to be made to replace some more components with less expensive, more strength and sustainable materials. To have a more accurate values of the effects of agglomeration is to be considered. Mean values of the results are quoted in this text.

5. Acknowledgementss

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