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Study On Mechanical & Cryogenic Properties of Carbon Epoxy Composites

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Abstract. Carbon-fiber-reinforced polymers are composite materials. In this case the composite consists of two parts: a matrix and reinforcement. In CFRP the reinforcement is carbon fiber which provides the strength. The matrix is usually a polymer resin such as epoxy to bind the reinforcements together. The material properties depend on these two elements. The reinforcement will give the CFRP its strength and rigidity measured by stress and elastic modulus respectively. Unlike isotropic materials like steel and aluminium CFRP has directional strength properties. The properties of CFRP depend on the layouts of the carbon fiber and the proportion of the carbon fibers relative to the polymer. This paper deals with the studies done on cryogenic treatment (Liquid Nitrogen) of composites having different fiber and matrix composition. In this work studies are done to find the effects caused by the liquid nitrogen on composites mechanical properties and change in properties due to different fiber and matrix composition in composites. It was observed that due to cryogenic treatment there was changes in the physical properties of the specimens. The specimens had deformed in their shape. The more deformation was seen in 60:40 specimen which was treated for 48 hrs and tensile strength of the composites at cryogenic temperature had higher values than that normal temperature for 70:30 specimen which was treated for 24hrs. The flexure strength of the composites at cryogenic temperature had higher values than the normal temperature for all the specimens. The flexure strength is more for 70:30 specimen which was treated for 48hrs.

1. Introduction

In the current quest for improved performance which may be specified by numerous criteria comprising less weight, more strength and lower cost currently used materials frequently reach the limit of their utility. Thus material researchers, engineers and scientists are always determined to produce either improved traditional materials or completely novel materials [12]. Composites have already proven their worth as weight-saving materials; the current challenge is to make them cost effective. The hard work to produce economically attractive composite components has resulted in several innovative manufacturing techniques currently being used in the composites industry. The composites industry has begun to recognize that the commercial applications of composites promise to offer much larger business opportunities than the aerospace sector due to the sheer size of transportation industry [13]. The biggest

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advantage of modern composite materials is that they are light as well as strong. By choosing an appropriate combination of reinforcement material and matrix, a novel material can be made that exactly meets the requirements of a specific application. Composites also give design flexibility because many of them can be moulded into complex shapes [17].

Carbon fiber alternatively graphite fiber carbon graphite or CF is a material consisting of fibers about 5–10 µm in diameter and composed mostly of carbon atoms. To produce carbon fiber the carbon atoms are bonded together in crystals that are more or less aligned parallel to the long axis of the fiber as the crystal alignment gives the fiber high strength-to-volume ratio (making it strong for its size). Several thousand carbon fibers are bundled together to form a tow which may be used by itself or woven into a fabric [15].Figure 1.1 shows a carbon fiber fabric.

The properties of carbon fibers such as high stiffness, high tensile strength, low weight, high chemical resistance, high temperature tolerance and low thermal expansion make them very popular in aerospace, civil engineering, military, and motorsports, along with other competition sports. Composites made from carbon fiber are five times stronger than grade 1020 steel for structural parts yet are still five times lighter.

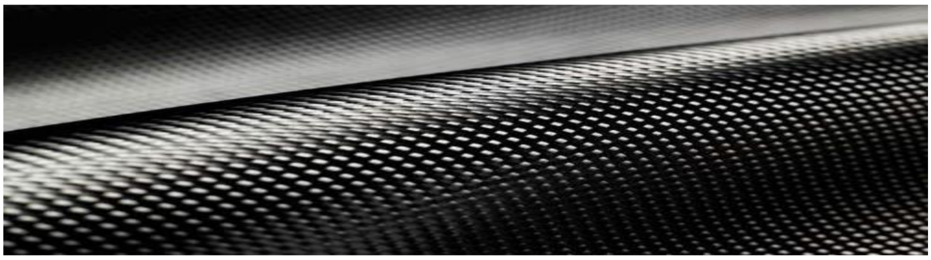

Figure 1.1. Carbon Fiber

Cryogenics is defined as the branches of physics and engineering that study very low temperatures. How to produce them and how materials behave at those temperatures. Rather than the familiar temperature scales of Fahrenheit and Celsius, cryogenicists use the Kelvin and Rankine scales [8].

Generally, the temperature referred is below 120 K (-153°C). The cryogenic treatment system developed by Ed Busch in the late 1960s and later improved by Peter Paulin with a temperature feedback control on cooling and heating rates allows to perform effective and crackles. CT until very low temperatures subsequently, the research about CT has been validated during the 1980s by the first request in machine tools. Since World War II era it is utilized on steel and other metals to improve the strength and wear resistance of the material. It is known that almost all steels at 193 K transform the austenite into martensite. The use of cold treatment has been initially developed on martensitic tool steels in order to remove retained austenite with benefits on hardness.

2. Experiment Details

2.1. Fabrication of composites

Three different laminates with different carbon epoxy proportions are fabricated using hand layup technique. Carbon fiber was selected as reinforcement and epoxy as matrix material.

Figure 2.1. Preparing Mould

Figure 2.2. Mould after curing

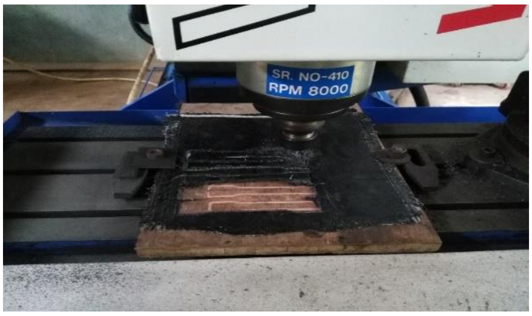

Figure 2.3. Specimen Cutting

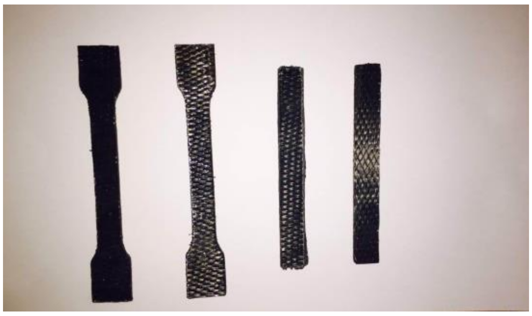

Figure 2.4. Specimens after cutting

2.2. Cryogenic Treatment (Liquid Nitrogen)

The composite specimens prepared of three different composition were immersed in liquid nitrogen tank. The specimens were inserted in liquid nitrogen tank for a duration of 24 hrs and 48 hrs.

Figure 2.5. Specimens immersed in liquid nitrogen tank for 24 hrs and 48 hrs

2.3. Testing of Specimens

2.3.1. Tensile Test

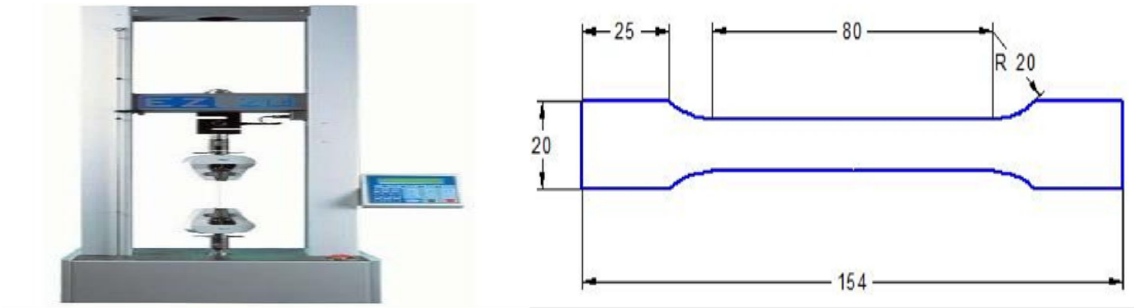

Figure 2.6. Computerized Universal testing machine and Dimensions of Tensile test specimen (mm)

- Specimen is cut according to ASTM D-638 dimensions shown in figure 2.6
- Specimen plate is enclosed between the grippers of universal testing machine shown.
- Load is applied by deforming the specimen and corresponding to deformation is noted down.
- Stress strain for corresponding load and corresponding deformation are calculated and repeated for different trials.

2.3.2. Flexure Test

- Specimen is cut according to ASTM D-790 dimensions shown in figure 2.7
- Specimen plate is placed as simply supported beam of flexural testing machine and a central load is applied as shown
- Load is slowly applied by deforming the specimen.

➢ Load at which maximum deformation is noted down and repeated for different trials.

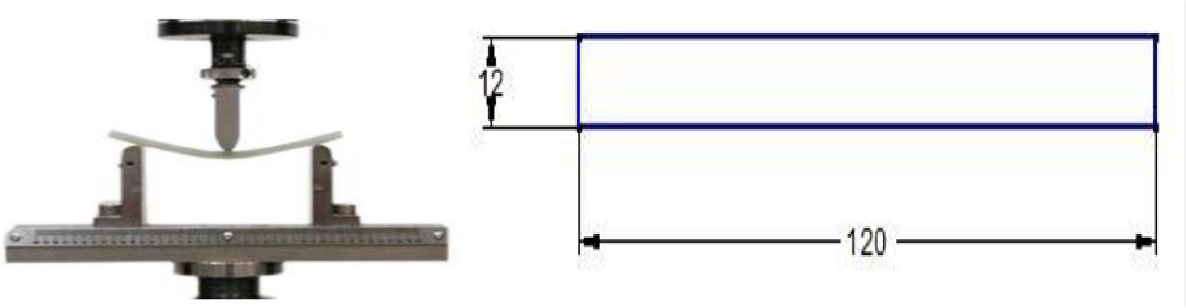

Figure 2.7. Flexure testing machine and Flexure testing specimen (mm)

3. Results and Discussion

The results and discussion consists of studying and analyzing results of tensile strength and flexure strength of three different composition of specimens at normal condition. It also consists of studying and analyzing results of tensile strength and flexure strength of three different composition of specimens when they are cryogenically treated for 24hrs and 48hrs respectively.

3.1. Tensile Strength

The tensile strength obtained for all the different conditions and different compositions discussed previously are as shown in table 3.1

Table 3.1: Results of tensile strength

Sl No	Specimen No / Composition	Tensile Strength (Mpa)		
		Normal	24 Hrs Treated	48 Hrs Treated
1	S1 / (70:30)	168	303	286
2	S2 / (60:40)	82.7	84.9	74.5
3	S3 / (50:50)	80	82.4	78.2

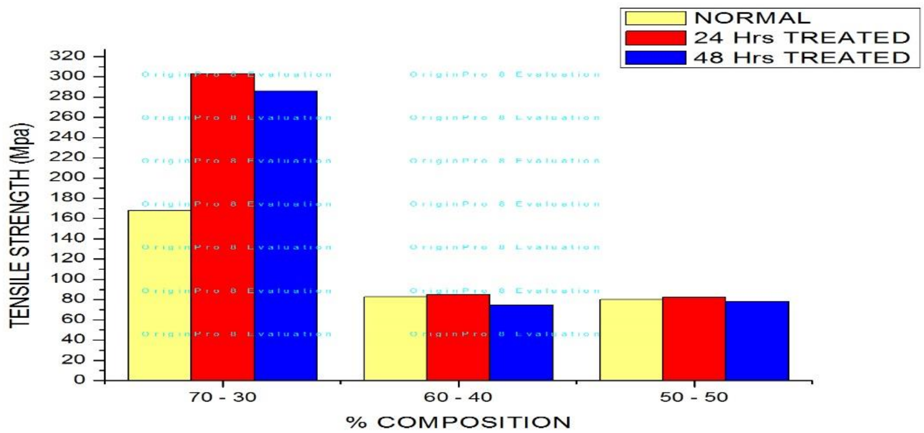

Figure 3.1. Results of tensile strength

From the table 3.1 and figure 3.1 it is observed that the 70:30 specimen which was 24 hrs treated had more tensile strength when compared to other specimens. It was also observed that the tensile strength had increased for 24 hrs and then reduced for 48 hrs cryogenic treated specimens. For 60:40 and 50:50 specimens the values reduced for 48 hrs treated specimens than the normal values.

3.2. Flexure Strength

The flexure strength obtained for all the different conditions and different compositions discussed previously are as shown in table 3.2

Table 3.2: Results of flexure strength

Sl No	Specimen No / Composition	Flexure Strength (Mpa)		
		Normal	24 Hrs Treated	48 Hrs Treated
1	S1 / (70:30)	568	573	589
2	S2 / (60:40)	146	334	375
3	S3 / (50:50)	125	135	148

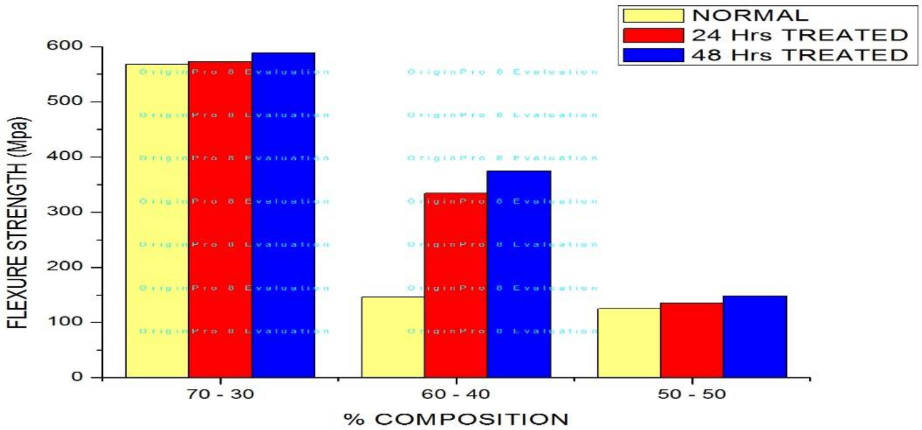

Figure 3.2. Results of flexure strength

From the table 3.2 and figure 3.2 it is observed that the 70:30 specimen which was 48 hrs treated had more flexure strength when compared to other specimens. It was also observed that the flexure strength had increased for 24 hrs and for 48 hrs cryogenic treated specimens. The flexure strength gradually increased for 24 hrs and 48 hrs treated specimens.

3.3. SEM Analysis

3.3.1. Normal Specimens

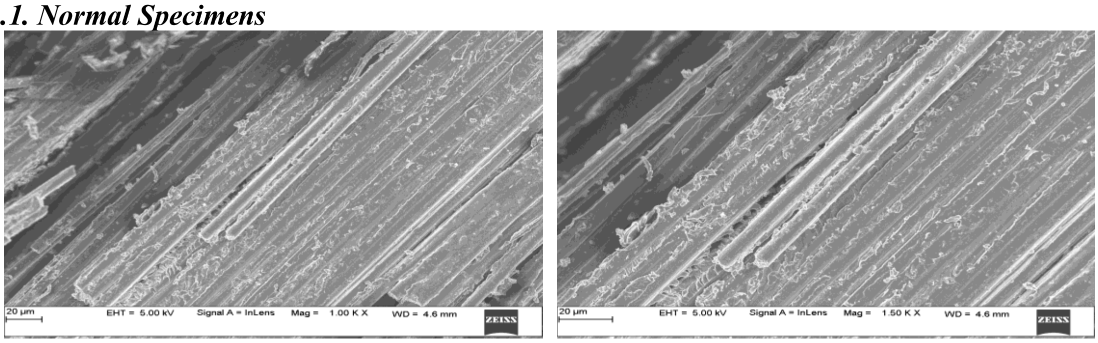

Figure 3.3. SEM images of 70:30 composition – Normal specimens

Figure 3.3 shows the SEM analysis of normal specimens of 70:30 composition. From the figures we can see that the fiber layers are bonded correctly and the fracture is of brittle fracture nature.

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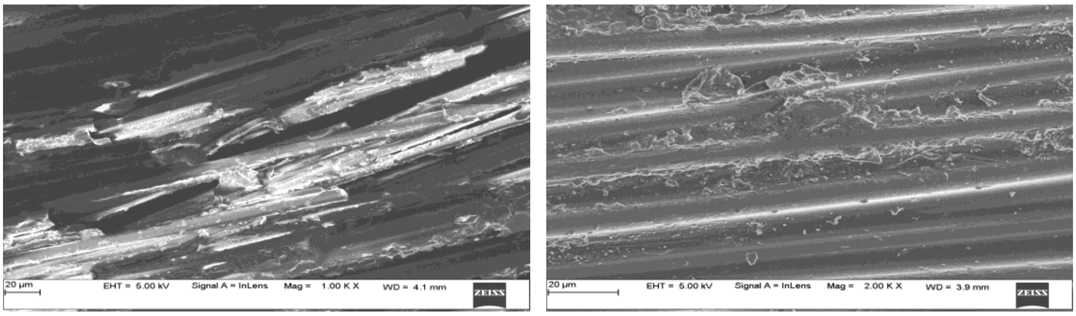

Figure 3.4. SEM images of 60:40 composition – Normal specimens

Figure 3.4 shows the SEM analysis of normal specimens of 60:40 composition. From the figures we can see that the fiber and epoxy bonding is not as strong as the 70:30 composition and the fracture is of brittle fracture nature.

3.3.2. Cryogenic Treated – 24 Hours

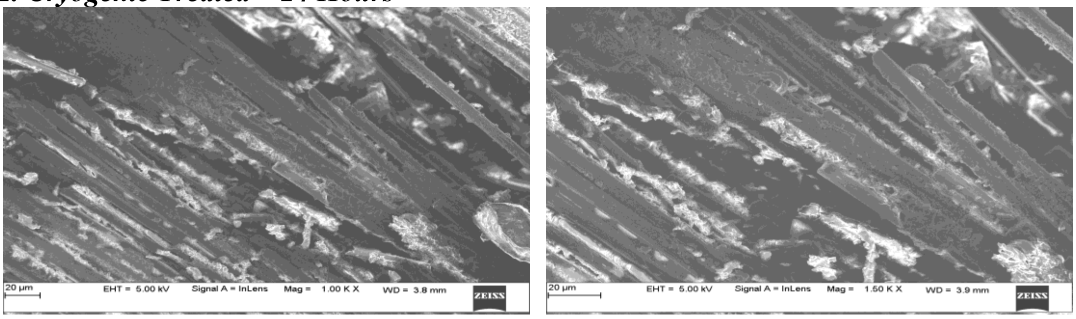

Figure 3.5. SEM images of 70:30 composition – Cryogenic treated 24 hrs

Figure 3.5 shows the SEM analysis of 24 hrs treated specimens of 70:30 composition. From the figures we can see the adhesion between fiber and matrix due to liquid nitrogen penetration and the fracture is of brittle fracture nature.

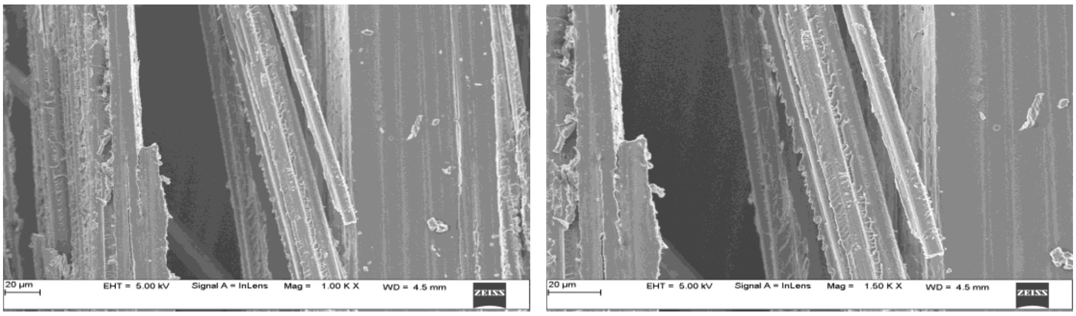

Figure 3.6. SEM images of 60:40 composition – Cryogenic treated 24 hrs

Figure 3.6 shows the SEM analysis of 24 hrs treated specimens of 60:40 composition. From the figures we can see the bonding between fiber and matrix due to liquid nitrogen penetration and the fracture is of brittle fracture nature. The bonding is less when compared to 70:30 composition

3.3.3. Cryogenic Treated – 48 Hours

Figure 3.7 shows the SEM analysis of 48 hrs treated specimens of 70:30 composition. From the figures we can see the bonding between fiber and matrix due to liquid nitrogen penetration. The bonding or adhesion is more when compared to 70:30 composition treated for 24 hrs.

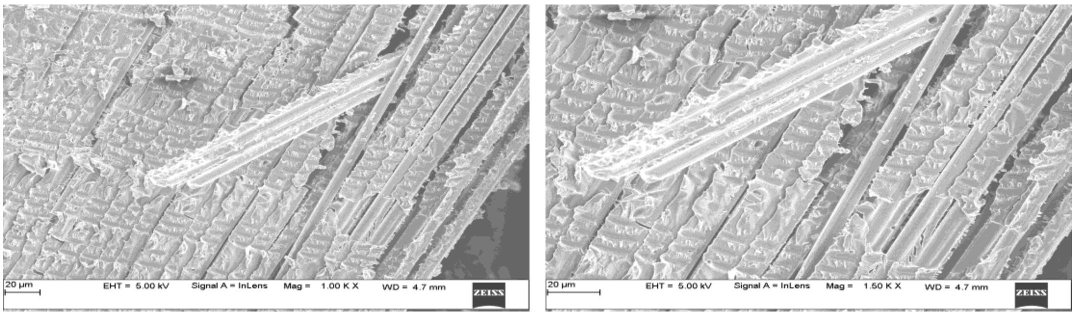

Figure 3.7. SEM images of 70:30 composition – Cryogenic treated 48 hrs

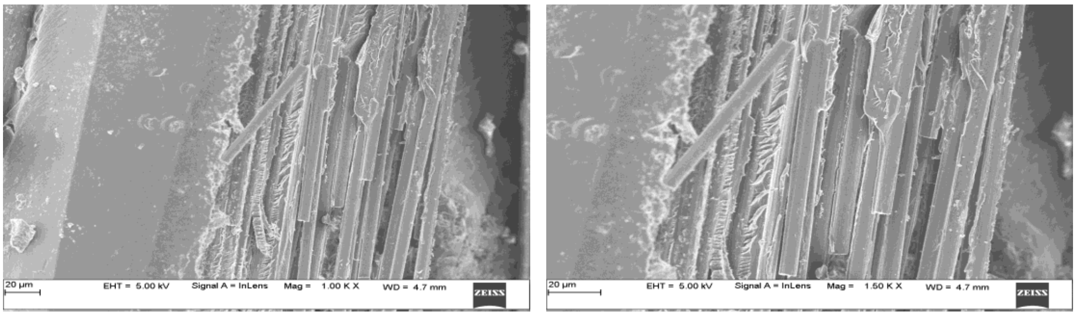

Figure 3.8. SEM images of 60:40 composition – Cryogenic treated 48 hrs

Figure 3.8 shows the SEM analysis of 48 hrs treated specimens of 60:40 composition. From the figures we can see the bonding or adhesion between fiber and matrix. The bonding is more when compared other specimens which were treated for 24 hrs and 48 hrs. This is due to more liquid nitrogen penetration and the fiber content is less in this composition.

4. Conclusions

From the results, discussion and analysis the following conclusions are drawn.

- Due to cryogenic treatment there was changes in the physical properties of the specimens. The specimens had deformed in their shape. The more deformation was seen in 60:40 specimen which was treated for 48 hrs.
- The tensile strength of the composites at cryogenic temperature has higher values than that normal temperature for 70:30 specimen which was treated for 24hrs.The tensile strength for 60:40 and 50:50 specimens which were treateated for 48 hrs had lesser values than the normal specimens. This may be due to the deformation which had occurred.
- The flexure strength of the composites at cryogenic temperature had higher values than the normal temperature for all the specimens. The flexure strength is more for 70:30 specimen which was treated for 48hrs.
- The improvement in the strength value after cryogenic conditioning is probably due to differential thermal contraction of the matrix during sudden cooling which leads to the development of greater cryogenic compressive stresses.
- This may increase the resistance to debonding and better adhesion by mechanical keying factor at the interface between fiber and the matrix.
- The SEM analysis showed that the liquid nitrogen penetration along the fiber/matrix interfaces caused resistance to debonding and better adhesion.

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