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Cost-Effective Fabrication Of Carbon Fiber Reinforced Polyetheretherketone (CF/PEEK) Composite Materials

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A potential development in high-performance engineering applications is the reasonably affordable manufacturing of carbon fiber-reinforced polyetheretherketone (CF/PEEK) composite materials. Three-point bending and tension tests were used to physically analyze the composite material CF/PEEK, obtaining respectively the elastic modulus and the maximum tensile stress. Furthermore, produced in the composite material were threads; tension tests were used to assess their strength machined on the composite material. The elastic modules, peak tensile stresses and the strength of threads were evaluated between the composite material CF/PEEK and the composite material of carbon fiber and epoxy resin (CF/EP). These results imply that a viable material for uses needing increased shear resistance and durability in threaded joints is CF/PEEK composites.

Keywords: Carbon Fiber, Epoxy Resin, Mechanical Characterization, Thread, Composite Materials

I. Introduction

The mechanical qualities of composite materials are better to those of traditional materials like metals and ceramics, which has led to a revolution in engineering and production. A matrix phase and a reinforcing phase are two of the main components of these materials; they complement each other to provide remarkable strength, low weight, and long-term durability. Due to their remarkable mechanical performance, simplicity of manufacturing, and adaptability, polymer matrix composites (PMCs) have become prominent among diverse composite materials. Composites made of carbon fiber and polyetheretherketone (CF/PEEK) have recently become a leading material system in several high-performance industries, including aerospace, automotive, biomedicine, and industrial engineering.[1]

Composites that combine carbon fibers' exceptional mechanical qualities with PEEK's high thermal and chemical stability are a huge step forward in the field of materials research. In contrast to carbon fibers' superior heat stability, stiffness, and strength-to-weight ratio, PEEK is a semi-crystalline high-performance thermoplastic that offers remarkable resistance to chemicals, fatigue, and extreme temperatures. With their complementary properties, CF/PEEK composites surpass thermoset composites and conventional metals in a number of important uses.

When it comes to improving fuel efficiency and overall performance, the aerospace and automotive sectors are big fans of CF/PEEK composites due to its lightweight nature, which drastically decreases the weight of structural components. The biocompatibility and exceptional wear resistance of CF/PEEK composites make them a promising material for use in biomedical implant and prosthetic applications. For use in extreme conditions like space travel and deep sea research, its exceptional fatigue and corrosion resistance are major selling points.[2]

Fabrication Techniques for CF/PEEK Composites

To attain best mechanical characteristics and microstructural integrity from CF/PEEK composite materials, exact control of processing parameters is necessary during their manufacture. Each of many manufacturing methods established to produce CF/PEEK composites has benefits and drawbacks. Most often used techniques consist in:[3]

- **Compression Molding**

Particularly for big and complicated-shaped components, compression molding is a commonly utilized method for creating CF/PEEK composites. Pre-impregnated carbon fiber/PEEK sheets (prepregs) or a combination of carbon fiber and PEEK powder is inserted into a mold in this process, then exposed to high temperature and pressure. Heat softens the PEEK matrix so it may flow and solidify around the carbon fibers, producing a dense and void-free composite structure. A recommended technique for structural uses, compression molding guarantees uniform consolidation and great control over fiber orientation.[4]

- **Injection Molding**

Another manufacturing technique that lets mass manufacture of CF/PEEK composite components with intricate geometries possible is injection molding. Short carbon fiber-reinforced PEEK pellets are heated and then high pressure poured into a mold cavity. The stuff forms into the right form when cooled. Manufacturing tiny, complex items with great accuracy benefits from injection molding. Short carbon fibers used in this method might, however, have less mechanical strength than continuous fiber-reinforced composites.[5]

- **Filament Winding**

Tubular or cylindrical CF/PEEK composite construction are produced using frequently used filament winding. This method winds continuously carbon fiber tows impregnated with PEEK resin around a revolving mandrel in a regulated pattern. The assembly is next heated to unite the composite construction. Lightweight, high-strength constructions with ideal fiber orientation for particular stress situations are made possible via filament winding.[6]

- **Additive Manufacturing (3D Printing)**

With additive manufacturing, creating CF/PEEK composites now presents fresh opportunities. Investigated for manufacturing CF/PEEK components with complex geometries and tailored qualities are 3D printing methods like fused filament fabrication (FFF) and selective laser sintering (SLS). Whereas SLS employs a high-powered laser to selectively sinter PEEK powder reinforced with carbon fibers, FFF entails the extrusion of CF/PEEK filaments layer by layer to produce a component. Achieving high-performance CF/PEEK components requires addressing issues such void formation, fiber alignment, and interlayer adhesion even if additive manufacturing offers design freedom and fast prototype capabilities.[7]

- **Automated Fiber Placement (AFP) and Automated Tape Laying (ATL)**

High accuracy and efficiency are achieved by constructing large-scale CF/PEEK composite structures using advanced manufacturing processes like AFP and ATL. These methods automate the pre-impregnated CF/PEEK tape or fiber deposition onto a mold surface, then heat and pressure consolidation. Excellent control over fiber placement provided by AFP and ATL helps to lower material waste and increase structural integrity.[8]

Although CF/PEEK composites have many benefits, their manufacturing presents various issues that must be resolved if they are to be adopted generally in industry. The high processing temperature needed for PEEK is one of the main difficulties; thus, specific equipment and exact temperature control are necessary to guarantee consistent melting and consolidation. Furthermore influencing the final mechanical characteristics of the composite is the high viscosity of molten PEEK, which might cause problems in fiber impregnation and void development.[9]

The bonding between carbon fibers and the PEEK matrix presents even another difficulty. Effective load transmission and improved mechanical performance depend on strong interfacial bonding being achieved. Often used to increase fiber-matrix adhesion are surface treatments like chemical etching, sizing agents, and plasma treatment. Moreover, compared to traditional materials, the cost of CF/PEEK composites is still somewhat costly, which limits their general application in sectors with limited budgets. To get beyond these financial restrictions, constant research concentrates on refining manufacturing procedures, creating reasonably priced processing methods, and investigating hybrid composites.[10]

II. Review of Literature

Zhou, Zhe et al., (2022)[11] Various forms of carbon fiber reinforced polyetheretherketone were created and studied in an effort to identify non-metallic alternatives to traditional dental implant materials for use in clinical settings. Woven into the cloth were carbon fibers that were strengthened with polyetheretherketone fibers. By adjusting the experimental settings for injection or hot press molding, several types of carbon fiber reinforced polyetheretherketone were produced. The mechanical characteristics of carbon fiber reinforced polyetheretherketone, pure polyetheretherketone, and pure titanium were determined by a battery of experiments. After carbon fiber was added to polyetheretherketone composites, the mechanical and thermal characteristics were remarkable. Short carbon fiber reinforced polyetheretherketone had tensile and bending strengths comparable to those of human bone, whereas continuous carbon fiber reinforced polyetheretherketone achieved a bending strength of 644 MPa, surpassing even that of pure titanium. Polyetheretherketone composites may hinder the stress shielding phenomena and have mechanical qualities more akin to bone tissue than titanium. They show promise as potential bone tissue engineering materials and as titanium substitutes.

Hu, Jiqiang et al., (2021)[12] to ensure the long-term viability of the industrial sector, sandwich structures made of lightweight, high-strength materials are a must. The three-dimensional sandwich structure with lattice cores made of continuous carbon fiber reinforced thermoplastic polyether ether ketone (CCF/PEEK) is the subject of this paper's investigation into its compression characteristics and related manufacturing technologies. By capitalizing on the one-of-a-kind property of continuous carbon fiber reinforced thermoplastic polyether ether ketone, a new method of fabricating lattice cores out of these materials is suggested. The lattice cores made of thermoplastic polyether ether ketone and continuous carbon fiber were cast in a specially constructed mold. To join the face sheets and lattice cores, the conventional glue method is used. Through the use of both experimental and computational methods, the out-of-plane compression behaviors of lattice-core thermoplastic polyether ether ketone sandwich constructions reinforced with continuous carbon fiber were examined. By comparing the simulation model with the experimental data, we were able to confirm its accuracy and dependability. The simulation model was used to examine how the stacking sequence of the lattice cores affected the structural compression characteristics, and the results showed that the ±45° stacking sequence was correct. At a variety of densities, the thermoplastic sandwich structures that are latticed with continuous carbon fiber reinforcements show compression strength that is comparable with other thermoplastic sandwich structures and even exceeds that of some metal foam.

Sun, Qili et al., (2021)[13] A potential method for the small-batch production of highly personalized items is fused deposition modeling (FDM). The necessary performance of FDM is far higher than that of traditional production techniques. Nevertheless, FDM's temperature gradient produces internal stress, which in turn induces warp deformation and impacts the quality of the created sample. Therefore, the secret to better FDM sample forming quality is to determine what causes cause warp deformation. The FDM technology was used to manufacture PEEK/short carbon fiber (CF) composites, and the warp deformation mechanism and formula were developed in this study. The impacts of material linear expansion coefficient, forming chamber temperature, and forming size on warp deformation were found to be substantial, according to the results. Additionally, due to their low Poisson's ratio and strong heat conductivity, CF has the potential to enhance the warp deformation of PEEK/CF composites. Composites' residual stress and warp deformation might both be improved with the inclusion of CF. Furthermore, the PEEK/CF composites' tensile and bending mechanical characteristics might be enhanced via annealing. The tensile mechanical characteristics of the composites increased to 10.7% and the bending mechanical properties to 11.6% after three hours of heat treatment at 190 °C. An examination of the PEEK/CF composites' crystallinity showed that it was very important to their mechanical characteristics. A decrease in crystallinity, tensile strength, and elastic modulus was linked to rapid cooling. Since the PEEK/CF composites had a higher glass transition temperature than the pure PEEK resin, DMA testing confirmed that the inclusion of CF might increase the composites' high-temperature resilience. Results from a porosity study demonstrated that the amount of CF allowed for control over pore size and distribution. The presented research may be used as a guide to enhance the mechanical characteristics and forming quality of FDM-fabricated PEEK/CF composites.

Yang, Yanchao et al., (2020)[14] A soluble precursor called PEEK-1,3-dioxolane is used to introduce crystalline poly(ether ether ketone) (PEEK) to the interfacial phases of carbon fiber (CF) reinforced PEEK composites, thereby improving the poor solvent resistance and poor temperature resistance caused by standard sizing agents. You may adjust the quantity of PEEK coated on the CF fiber surface and achieve variable interfacial qualities of the PEEK composites by varying the soluble precursor molecular weight and concentration in the sizing solution. The findings demonstrate that this approach is capable of coating the CF surface with crystalline PEEK, and that the PEEK composites' interfacial shear strength rises from 43.42 to 83.13 MPa. Because PEEK composites do not include any soluble chemicals, their interfacial shear strength (IFSS) remains above 85.4% in organic solvents and 90.44% in hygrothermal conditions, respectively. This ensures that the interfacial layer remains intact. Improved wetting of crystalline PEEK on the surface of the fibers is the mechanism that improves the interface, as shown by scanning electron microscopy. Because no harmful reagents, such 2,4,5-trichloro-1-hydroxybenzene or concentrated sulfuric acid, are needed for size, the sizing method of this investigation has the potential to be commercially valuable.

Han, Xingting et al., (2019)[15] one promising new 3D printing method with enormous medical applications is fused deposition modeling (FDM). A biocompatible high-performance polymer, polyether-ether-ketone (PEEK) is an excellent choice for use in dental and orthopedic implant systems. It is currently unclear, however, whether FDM-printed PEEK and its composites are biocompatible and have satisfactory mechanical qualities. The research successfully used FDM to manufacture CFR-PEEK composites and FDM-printed pure PEEK, and then used mechanical testing to characterize the composites. The impact of surface topography and roughness on overall biocompatibility (cytotoxicity) and cell adhesion was further investigated by polishing and sandblasting the sample surfaces. While there was no statistical difference in compressive strength, the findings showed that the printed CFR-PEEK samples had much greater general mechanical strengths compared to the printed pure PEEK. The biocompatibility of PEEK and CFR-PEEK materials was found to be satisfactory both after and before surface modification. In comparison to their polished and sandblasted counterparts, the cell densities on the CFR-PEEK and "as-printed" PEEK surfaces were noticeably greater. Because of its suitable mechanical properties, the FDM-printed CFR-PEEK composite shows promise as a biomaterial for use in tissue engineering and bone grafting.

Pan, Lei et al., (2015)[16] Thermoplastic polymer polyetheretherketone (PEEK) has a high melting point and a high processing temperature; this study aimed to increase its mechanical characteristics, including flexural strength and interlaminar shear strength (ILSS). The surface of carbon fiber (CF) was altered using either an oxidative or a non-oxidative process. In the oxidative chemical treatment, piranha and chromate solutions were used, whereas in the non-oxidative polymer coating, silicone-based polymers were utilized. Scanning electron microscopy (SEM) and Fourier transform infrared spectroscopy (FTIR) were used to describe the changes in the surface chemistry and structure, respectively. The FTIR analysis shows that the carbon element content reduces when coating fibers are added, but the oxygen and silicone content and functional groups on the surface are increased. Composites made of CF and PEEK were tested for flexural strength and ILSS characteristics using methods outlined in ASTM D-790 and ASTM D2344, respectively.

Kilroy, J.P. et al., (2008)[17] The European Space Agency is investigating several composite technologies for the production of massive composite components, such as the RLVs' liquid hydrogen tanks. The purpose of this research was to determine if the high performance thermoplastic composite of carbon fiber and polyetheretherketone (PETEK) was suitable for use in spacecraft. The mechanical qualities of a newly developed carbon fiber/PEEK pre-impregnated tape are anticipated to be on par with, if not better than, those of the currently available options. Using the most appropriate autoclave technique for large space structures as a benchmark, this study set out to thermo mechanically characterize a novel kind of carbon fiber/PEEK for use in space applications under pressure-formed autoclaved conditions. The most promising out-of-autoclave approach for fabricating large composite structures is thermoplastic in-situ automated tape placement (ATP). The treated carbon fiber/PEEK materials underwent extensive mechanical testing to compare their ATP mechanical characteristics to those of the baseline autoclave. The two production procedures were utilized to create laminates with the lay-ups often used in the aerospace sector, including 0°, 0°/90°, ±45°, and quasi-isotropic configurations. All of the following types of tests were performed on the materials: tensile, compression, flexure, in-plane shear, and interlaminar shear. The temperature differentials seen in space were replicated by conducting experiments at incremental temperatures ranging from -70°C to 250°C. The material was subjected to compression following impact testing in order to replicate the effects of collision with space debris. To determine the carbon fiber/PEEK's fracture toughness, G IC and GIIC tests were performed. The ability of these materials to absorb moisture, which may taint and destroy space constructions when exposed to space vacuum, was also examined. After the material was processed, it underwent qualitative testing, which included DSC analysis and fiber volume fraction. Bonding huge composite parts together for RLV tanks could be necessary in the end. A number of bonding techniques have been refined to make use of PEEK's exceptional properties as a hot melt adhesive. Among them, two stand out: amorphous interlayer bonding using PEI film and resistance welding with metal mesh. The best way to bind the laminates was determined by experimenting with several techniques and adjusting various parameters. After comparing the methods, we narrowed it down to the bonding approach that showed the greatest potential. Then, we tested it at full size under different temperatures.

III. Materials And Methods

For this research, we used carbon fiber 3K reference HexForce 282 fabric, which has a plain weave style and fibers that are oriented in the 0° and 90° directions, to make the composite material. The potential use of PEEK as a matrix at high service temperatures (up to 250°C) led to its selection.

Its yield stress is 100 MPa, elastic modulus is around 4 GPa, and fracture toughness is more than that of epoxy resin. As a matrix, 1.75 mm diameter PEEK filaments were utilized. Epoxy resin 744 was utilized for the thermosetting matrix composite.

Fabrication process

The chosen production technique is hot compression molding since, despite the necessary equipment, it is one of the most cost-effective options. First, you'll need to cut a rectangle out of the cloth. The process continued with the addition of PEEK filaments to the fabric, which were then covered with an additional layer of fabric. This continued until a total of eight layers of fabric and PEEK filaments were used.

The PEEK fabric and filament layers were compacted and piled within a mold constructed of AISI 1020 steel plates. The dimensions of the mold were 150 mm × 150 mm × 4 mm, and it had an electrical resistance operating at 110 V at its base. It took 90 minutes to make the composite material. Within this thermal cycle, the following values were utilized: temperature 380°C, pressure 0.47 MPa, and cooling rate 2.2°C/min.

A Hubbard-field mechanical vise capable of supporting 1,000 pounds was used to progressively apply pressure while heating the mold. The CF/PEEK that was extracted had a thickness ranging from 4 to 6 mm and exhibited a high level of surface polish. Specimens for bending tests measuring 15 mm × 150 mm and specimens for tensile testing measuring 25 mm × 150 mm were obtained from these sections using a band saw. The FC/EP was made using the hand lay-up method.

Fiber weight fraction

As a consequence of the compaction and heating procedure, the fiber weight fraction in the composite material was determined using (1).

$$W_f = (W_t / W_t + W_m) \cdot 100 \qquad (1)$$

Where wt and wm are the weights of the fabric used and matrix respectively.

The weights indicated above were determined for CF/PEEK using the following approach. To begin, the necessary carbon fiber cloth and PEEK filaments for the composite were measured and recorded. After the compaction and heating processes are complete, the mold is filtered to eliminate any remaining PEEK from the hot compression process. At last, the CF/PEEK composite manufacturing process's end product was weighed.

In contrast, for the CF/EP composite, we compared the ultimate weight of the piece impregnated with the cured resin to the weight of the fabric first injected into the mold to determine the fiber weight percentage.

The total fiber volume fraction is determined by applying the formula (2) as follows:

$$V_f = \frac{w_t/\rho_t}{w_t/\rho_t + w_m/\rho_m}$$

Here, ρt and ρm are the densities of the fabric used and matrix respectively.

Mechanical tests

The composite materials' ultimate strength and elastic modulus were determined by subjecting samples to tensile and three-point bending tests. Also, as mentioned later on, tensile tests were used to assess the strength of a thread that was machined into the composite material. Each type of test was applied to three specimens.

The strain range of 0.002, with a start point of 0.001 and an end point of 0.003, was suggested by the ASTM D7264 standard. As a result, only the elastic portion of the stress-strain curve that was valid was recorded. Figure 1 shows the results of the three-point bending tests that were performed on the specimens. Loading was done at the midway, with the two ends just supported. A testing machine referenced by Lloyd LF plus instruments was used for the experiments. To assess the material's linear elastic zone, a displacement of two millimeters was applied without damaging the specimens.

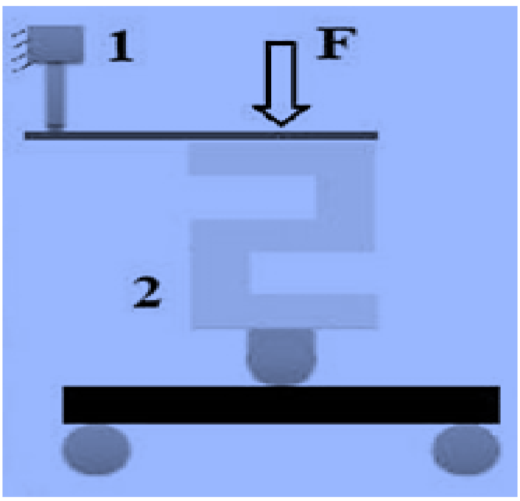

Figure 1: Three-point bending tests

A reference LVDT LD620-7.5 was used to measure displacement. A tension-compression load cell of the S NTEP type was used to measure the force. Two, a DC 204R data collecting system sampling at 100 Hz was used for data registration. As per ASTM D7264, the force is used to compute the stress (σ) in the specimen's center using equation (3).

$$\sigma = 3PL/2bh^2 \quad (3)$$

The distance between the supports (L), the specimen's breadth (b), and its thickness (h) are all variables that contribute to the applied force (P). Furthermore, the central strain (ε) was determined by applying equation (4):

$$\varepsilon = 6\delta h/L^2 \quad (4)$$

Where δ is the deflection at the midpoint.

The stress-strain curve's linear zone slope was used to calculate the elastic modulus. As per the specifications laid down by ASTM D3039, tensile tests were conducted. In order to determine the ultimate tensile stress of the material, the tests were conducted using a universal Tinius Olsen H50KS testing machine (Figure 2).

Figure 2: Tensile test

The ultimate tensile stress (Ftu) measured at the specimen's failure may be determined by applying the following formula, as per the ASTM D3039 standard:

$$F^{tu} = P_{max}/A \quad (5)$$

Where P_{max} is the maximum force reached just before the fracture and A is the cross-sectional area of the specimen.

Additionally, the composite material's ability to support a machined thread was tested. The thread was created by drilling a 13⁄64 in hole into the composite material and then inserting a 1/4 in tap with regular thread. A tensile test was conducted on the thread using the Tinius Olsen H50KS universal testing machine, which is based on ASTM F549-17, after a 1/4-inch bolt was placed into it.

An assembly was built for the testing (Figure 3). A permanent base (1) keeps the threaded region of the composite material (2) contained, and the test piece (3) is supported by bolts from the cover (3). Applying force is done via the screw (4).

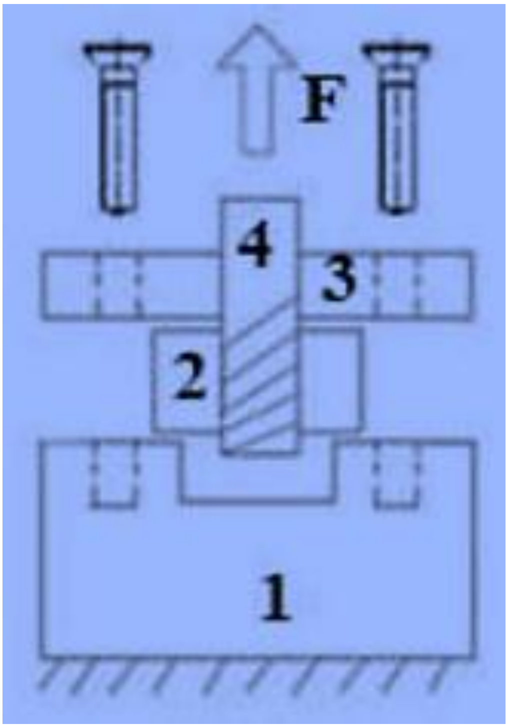

Figure 3: Tensile testing scheme in composite thread

<u>Statistical analyses</u>

Elastic modulus and ultimate tensile stress were subjected to 95% confidence interval statistical analyses of variance.

IV. Results And Discussion

For all analyses of variance, p-values larger than 0.1 were used to confirm the results using the Ryan-Joyner test, which is comparable to the Shapiro-Wilks test. Also, we analyzed the elastic modulus with a p-value of 0.264 and the tensile ultimate strength with a p-value of 0.386 using the Levene test. The independence was ensured by randomly arranging the tests in a certain order.

A fiber weight fraction of 44.29% was attained by the CF/PEEK composite, compared to 65.6% by the CF/EP. Figure 2 shows that under the test circumstances, both the CF/PEEK and CF/EP specimens exhibited elastic linear behavior, albeit only in the elastic area.

Within the range of the matrix and reinforcement's elastic moduli, the CF/PEEK material had an average elastic modulus of 8.38 GPa (standard deviation: 0.79), whereas the CF/EP material exhibited an average elastic modulus of 21.2 GPa (standard deviation: 8.57).

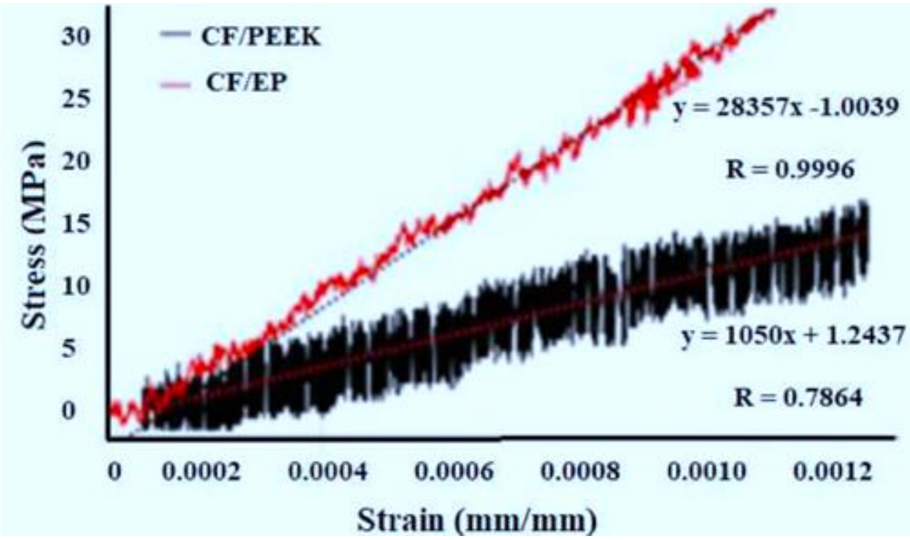

Figure 2. Typical stress vs. strain curve obtained in FC/PEEK and CF/EP specimens tests

Table 1 shows the results of an analysis of variance (Anova), which likely resulted from the small sample size (three for treatment and two for testing) because the difference between the two averages was not statistically significant (p-value >0.05).

Table 1: Anova elastic modulus

Source	**SS**	**Ms**	**F**	**p**
Composite Material	232.8	232.91	6.36	0.067
Error	147.2	36.87		
Total	380.5			

The CF/PEEK composite materials had an average ultimate tensile strength of 256.1 MPa and a standard deviation of 117.6 MPa. The high standard deviation could be explained by the bond between the PEEK layers and the carbon fiber cloth during composite material manufacture. On the other hand, the CF/EP composite materials had an average ultimate tensile strength of 365.2 MPa and a standard deviation of 20.9 MPa. A statistical analysis of variance (Table 2) revealed that there was no statistically significant difference between these average values (p-value = 0.312). The tensile tests were conducted solely to determine the material's tensile strength; consequently, the strain was not recorded during these tests and the corresponding stress-strain diagrams were not obtained.

Table 2: Anova ultimate tensile strength

Source	**SS**	**Ms**	**F**	**p**
Composite Material	14153	14153	1.50	0.312
Error	28260	9429		
Total	42413			

Tensile tests on threads manufactured of CF/PEEK composite material achieve a maximum force of 5.8 KN on average with a standard deviation of 0.72, whereas threads made of CF/EP reach an average maximum force of 2.4 KN with a standard deviation of 0.82. According to table 4, the CF/PEEK composite outperformed the CF/EP in this application with a p-value of 0.008.

Table 4: Anova tensile on the threads

Source	**SS**	**Ms**	**F**	**p**
Composite Material	11358544	11358544	20.42	0.008
Error	2225118	556279		
Total	13583662			

According to table 5, the CF/PEEK composite material had a lower ultimate tensile strength and modulus of elasticity than the CF/EP composite. This is likely because the CF/EP composite was able to reach a far higher fiber weight fraction than the CF/PEEK composite.

Perhaps because PEEK has a higher shear resistance than EP, the CF/PEEK material outperformed EP when it came to the greatest force that could be applied to the threads. Because of this, CF/PEEK shows great promise as a material for threaded joint production.

Table 5: Comparison of results CF/ PEEK AND CF/EP composites

Composite	% Fiber Weight Fraction	E (GPa)	σmax (MPa)	$Fsmax$ (kN) on the threads
CF/PEEK	44.29	8.38±0.79	256.1±117.6	5.8±0.72
CF/EP	65.6	21.2±8.57	365.2±20.9	2.4±0.82

In terms of fiber weight fraction, elastic modulus, tensile strength, and maximum force on threads, the table contrasts CF/PEEK and CF/EP composites. Because its fiber weight percentage is larger (65.6% vs. 44.29%), CF/EP has a higher tensile strength (365.2 MPa) and is stiffer (21.2 GPa vs. 8.38 GPa). In contrast, the maximum force on threads of CF/PEEK is 5.8 kN, indicating superior load-bearing capability in threaded applications compared to 2.4 kN.

V. Conclusion

Due to its increased fiber weight fraction, the CF/EP composite demonstrated exceptional stiffness and tensile strength, positioning it as an excellent choice for uses necessitating high structural rigidity. On the other hand, CF/PEEK's superior shear resistance and longevity allowed it to show off its remarkable load-bearing capabilities in threaded applications. The outstanding performance of CF/PEEK in threaded joints highlights its potential for high-performance structural applications, even if statistical analysis did not reveal a significant difference in elastic modulus and tensile strength. In situations that need for strong and dependable threaded connections, our results indicate that CF/PEEK composites are a good substitute for CF/EP.

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