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REVIEW ARTICLE - MATERIAL SCIENCE (MISCELLANEOUS)

A Review on Woven Carbon Fiber-Reinforced Epoxy Composites: Processing Methods and Mechanical Enhancement

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Abstract

Recently, epoxy resin-based composite structures have been widely used in many engineering applications due to their superior mechanical properties, thermal insulation and acoustic damping. However, to further improve the mechanical performance, several studies indicate significant benefits can be achieved using woven carbon fibers and different core material reinforcements for sandwich composite materials. The present review includes a comprehensive review of the most important composite material manufacturing techniques such as hand layup, spray layup, compression moulding, extrusion compound, filament winding, moulding injection, pultrusion, resin transfer moulding, and vacuum infusion or vacuum-assisted resin transfer, and the advantages of each method. In addition to the mechanical performance of epoxy composites and the possibility of improving these properties by using different strategies to enhance interfacial bonding and mechanical performance. These strategies include the incorporation of nanoparticles, surface modifications, the use of advanced resin systems, and a review of the latest studies in this field. Each approach aims to interaction improvement between carbon fibers and the epoxy matrix, thus enhancing properties such as tensile strength, compression strength, impact resistance, and interlaminar shear strength. To establish a systematic understanding of design criteria, this work intends to summarize all studies in the open literature about this topic. It is concluded that enhancing the mechanical performance of sandwich structural composites depends on the selection of the appropriate manufacturing method, which is determined by material properties, cost considerations, processing requirements, and specific applications.

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Keywords: Composite Structure; Core Structure; Woven Carbon Fiber; Mechanical Performance.

1. Introduction

Epoxy composites are a fundamental part of modern materials technology, with applications covering various industries. Due to their exceptional properties, such as high strength, heat resistance, and chemical stability, epoxy composites are widely utilized in the aerospace and automotive industries, construction, energy production, and other sectors[1, 2]. These composites prove useful in the aerospace, automobile, marine, and construction industries since they are light yet strong, as provided by the structure of the composite. To improve fuel economy, performance, and sustainability in contemporary engineering projects, engineers are increasingly turning to sandwich composites, which enable substantial weight reduction without sacrificing structural integrity. In addition to reducing the total weight and material costs, using a core material in the face sheets reduces the number of woven layers required, making sandwich composites a cost-effective alternative for high-performance applications[3].

Common core materials for sandwich structures include honeycomb and foam, although new core structures have been developed to improve the mechanical properties of sandwich composites. Additionally, uniformly dispersed short fibers within epoxy composites can offer superior mechanical properties at lower cost.[4, 5]. To improve mechanical performance while reducing costs, an effective product option is to use composites with short fiber-reinforced foam as the core material and woven fibers used as the face sheets. Utilizing sandwich composites with short fiber-reinforced foam as the core material and woven fiber face sheets is an efficient use of this technology. Hence, an effective product solution is to apply short fiber-reinforced polymer as the core of sandwich composites and woven fibers as the face layers in composites as this can result in mechanical enhancement at lower costs[6].

Nomenclature & Symbols			
CFs	Carbon Fibers	FRP	Fiber Reinforced Polyester
VARTM	Vacuum-Assisted Resin Transfer Moulding	GFRP	Glass-Fiber Reinforced Polyester
RSVAM	Resin Spraying with Vacuum-Assisted Moulding	RTM	Resin Transfer Moulding
JFRP	Jute Woven Fabric Reinforced Unsaturated Polyester Layer	GO	Graphene Oxide
NGFRE	Neat Glass Fiber Reinforced Epoxy Composites	3DOWC	3D Orthogonal Woven Composite

One of the most appropriate uses of this fiber reinforcement technology is in sandwich composites that incorporate short fiber reinforced epoxy as the core structure with woven fiber face laminates. This layout effectively takes advantages of the lightweight and high strength characteristic of the core structure, and the woven fibers that are aligned over the core greatly enhance the core's strength [7]. This hybrid composite structure enables manufacturers to attain desired performance levels without the high prices of typical high-strength composites, offering a compelling alternative for sectors wanting to improve performance while limiting costs[6].

A woven structure represents a type of multilayer composite that consists of interwoven yarns between the straight fibers of each layer. The interwoven yarns, also known as binder yarns, successfully inhibit the delamination of the composite plastics [8]. Woven composites are commonly used in engineering, particularly in aircraft and marine sectors, owing to their lightweight nature, superior strength, and high specific modulus[9]. Commercially available composites can be reinforced using woven carbon fibers (CFs), known for their high strength (530 ksi) and stiffness CFs yield enhanced strength for high-stress activities. Carbon fibers (CFs) exhibit excellent multifunction characteristics, including superior strength, stiffness, high-temperature resistance, corrosion immunity, and excellent electrical and thermal conductivity[10, 11].

By improving the mechanical characteristics and structural integrity of sandwich epoxy composites, which use woven carbon fibers as a face sheet and 3D network short fibers reinforced epoxy composites as a core, several performance-related issues with composite materials are efficiently addressed. Composite polymers made with this hybrid design have several benefits over those made with either woven carbon felt or carbon felt based on 3D networks of short fibers. Woven fiber face sheets increase composite structure rigidity and stiffness, making them ideal for aerospace and automotive applications[12, 13]. 3D network foam epoxy composites are noted for their isotropic properties, low cost, multidirectional strength, and energy absorption [14-16]. This combination takes advantage of the strengths of both materials, with the woven layer adding strength and integrity to the surface and the 3D network improving properties in multiple directions and interlaminar bonding[17].

Epoxies with carbon fiber reinforced polymers that incorporate nanoparticles can be significantly enhanced in performance by casting epoxy with woven carbon fibers. The composite benefits from the addition of various nanomaterials, such as carbon nanotubes(CNT)[18], graphene[19, 20], nano-silica[21], nano-clays[22], polysulfone[23]. One main way these nanomaterials boost mechanical performance is by making the matrix more efficient in transferring loads and distributing stresses. The woven carbon fibers act as the primary structural reinforcement, while the nanomaterial-infused epoxy matrix works at the nano scale to optimize the composite's mechanical properties. Together, produce a high-performance composite material that is well-suited for applications requiring superior mechanical strength, durability, and reliability[24].

Sandwich structures are a form of laminated composite material. The structure consists of two durable ,thinner face sheets adhered together with a substantial, lightweight core sandwich composites provide an achievable option to reduce the cost of high-performance composite materials, while simultaneously enhancing ultimate mechanical properties[2].

Sandwich-structure composites offer significant advantages and have a wide range of potential uses, making them more attractive than conventionally manufactured composites. These composites are suitable for different industries and applications, such as aircraft, rail, and road vehicles, civil engineering (bridge decks), shipbuilding, and the energy sector (wind turbine blades). They are cost-effective, thin and strong, easily designed, and manufactured efficiently[11]. Sandwich epoxy composites are sandwich structural composites. Low-strength core elements like balsa wood, cork, honeycombs, or foams are bonded to high-strength skin materials like epoxy, glass fiber, or carbon fiber-reinforced polymers to make these composites. Core components give the composite great bending stiffness, while skin materials give it strength. 3D integrally woven glass fiber, natural fibers, foams, and carbon or glass fiber face sheets have been used to make epoxy-based sandwich composite[14].

This review is useful in promoting scientific research and developing technological capabilities by identifying the optimal method for manufacturing sandwich composite materials based primarily on woven carbon fibers, given the importance of this type of composite as an alternative in structural industries due to its qualitative properties. The review also addresses the most important factors affecting the mechanical properties of manufactured composite materials.

2. Manufacturing Process of FRP Composites

Fibers are woven, braided, knitted, or stitched into long sheets or matt structures to produce a fiber preform, which is then reinforced with a polymer matrix during the production of FRP composites. Occasionally, we utilize prepregs to produce composites. A thermoplastic or thermoset polymer matrix has already impregnated these fiber materials. The manufacturing methods are classified as open or closed moulding based on the curing conditions type. Open moulding involves exposing the reinforcing components and resins to air for curing or hardening. Open moulding techniques, including hand lay-up [25], spray-up [26], and filament winding, are frequently used to create FRP composites. During closed moulding, the reinforcement materials and resins cure inside a vacuum bag or a two-sided mould. High-capacity factories with the necessary machinery typically employ the closed moulding method. A variety of closed moulding methods, including compression moulding [27], extrusion compounding [28], injection moulding [29], pultrusion[30], resin transfer moulding (RTM) [31], and vacuum-assisted resin transfer moulding (VARTM) [32], can make FRP composites.

2.1. Hand lay-up method

Hand layup is the main method for producing open-mold composites. It entails the hand placement of individual layers of reinforcing materials, followed by the application of liquid resin over them. Often, a roller compresses the resin, consolidating the laminate, thoroughly soaking the reinforcing layers, and eliminating trapped air Fig. 1(a). The inexpensive start-up cost enables the production of an extensive variety of products, including various geometries, novel components, and designs. However, this method has some problems, such as a slower production rate and a lower reinforcement volume fraction. Also, because the materials and reinforcements are handled by hand, they are not evenly distributed, which means that the process is not good for making a lot of high-quality composites[33]. Al Mahmood [34] used the hand lay-up method in manufacturing six compositions of glass fiber-reinforced epoxy composites and TiO_2 as the filler material. the results show that the mechanical performance of composites without filler material had lower mechanical properties. The highest values were obtained for different filler material additions. Sadashiva [35] fabricated eco-friendly hybrid biocomposites using drumstick fibers, glass fiber, and polyester resin by hand layup method. Bending tests show that longitudinal fiber orientation hybrid composites have better-bending properties than transversals.

2.2. Spray lay-up method

Spray layup, an open moulding technique, involves spraying resin onto the laid-up fibers using a pistol, as opposed to pouring it over them. The roller using may simultaneously combine the fibers with the matrix material, facilitating the elimination of the bubbles and voids before curing Fig. 1(b). The operator maintains control over thickness and uniformity, thereby increasing the technique's reliance on them rather than the hand lay-up itself. The fibers orientation and limitations affect the mechanical qualities of the final product [36, 37].Germano [38] compared using two methods for producing glass-fiber reinforced polyester (GFRP), the traditional spray-up and resin spraying with vacuum-assisted moulding (RSVAM), then tested tensile, flexural, and Izod impact strength on GFRP samples containing 30% fiberglass. Results have shown that RSVAM samples have 168% higher Izod impact resistance, while the spray-up samples show no significant difference. Reliability curves predict failure probabilities, with Weibull distribution favouring flexural tests. Bing Xiao [39] laminated bathtub products using acrylic resin and glass-reinforced unsaturated polyester layers by spray layup method. The bending properties and acoustic emission were investigated. GFRP contributed to high bending modulus and high bonding properties. Also considered using jute woven fabric reinforced unsaturated polyester layer (JFRP) instead of GFRP for bending properties.

2.3. Filament winding method

Another open moulding technique is suitable for producing axisymmetric components, including pipes, tanks, tubes, vessels, drive shafts, missiles, and pressure vessels. This process has particular advantages over other manufacturing techniques, including the production of components with increased fiber volume fractions of 60–80% and superior specific strengths [40]. This process includes winding resin-impregnated continuous fiber onto a spinning mandrel at a certain winding angle, controlled by the speeds of both the mandrel and the carriage guide. After the winding process, thermosetting resins consolidate the resin by curing and then remove the mould [41], Fig. 1(c).

2.4. Compression moulding method

Compression moulding is a closed moulding technique widely used in manufacturing composite components, due to its ability to produce high-quality composite components rapidly and with accuracy at elevated volume[37]. In this process, preparations are placed into an open heated mould cavity, afterwards closed with a top plug, and squeezed using a hydraulic press to ensure the homogenous distribution of materials through the mould [40] Fig. 1(d). The integration of two production processes has been recorded, namely, the use of the hand lay-up method succeeded by a compression moulding method [41].

2.5. Extrusion compounding method

Extrusion compounding, also known as closed moulding is a way to make composite components with uniform cross-sections, like rods, pipes, sheets and films. It works by forcing polymer through a two-dimensional die hole. A hopper introduces fiber and polymer matrix composites into the extruder, a feeding screw pushes them, and a die extrudes them, transforming them into a fiber-reinforced polymer product Fig. 1(e). The heating instrument positioned above the barrel softens and liquefies the polymer. You can mould both rigid and flexible materials into any arrangement, ensuring a polished surface finish. In injection moulding, following a similar concept, The screw injects the specified amount of material into the mould through a nozzle, where it cools and takes its final shape[42].

2.6. Injection moulding method

Injection moulding can produce complex 2D composite components of various shapes and dimensions with exceptional accuracy and minimal cycle time Fig. 1(f) [43].

2.7. Pultrusion method

Pultrusion is a continuous production technique for fiber-reinforced polymer (FRP) composites with uniform cross-sections. "Pultrusion" phrase combination of the term "extrusion" and "pull". In contrast to the extrusion process, where the composite material is produced by pushing components through a die, the material is instead pulled. Fibrous material layers are saturated with resin and then pushed through a stationary, temperature-regulated die that polymerizes the resin. A continuous profile is extracted from the manufacturing line using a pull-off mechanism Fig. 1(g), and severed at the specified length [44]. Pultrusion facilitates the production of very lightweight, high-strength composites characterized by remarkable homogeneity and few manufacturing errors[45].

2.8. Resin transfer moulding RTM method

RTM is another closed-mould technique producing high-performance composite components in medium quantities, ranging from 1000 to 10,000 parts. Dry reinforcement materials are put into a mould cavity that has been sealed off. The mould is then set to a certain cavity height, and a low-viscosity resin of about 0.1 to 1 Pas^{-1} is injected through a channel to the placed reinforcement materials while a moderate pressure of 3.5–7 bar is applied Fig. 1(h). The high pressure is used to reduce the possibility of the reinforcing material being displaced and confused inside the mould cavity[46, 47].

2.9. Vacuum-assisted resin transfer moulding (VARTM) method

Vacuum infusion, or VARTM, is an advanced version of the resin transfer moulding RTM process. The primary reinforcement materials are encapsulated in a vacuum bag, with a perforated tube positioned between the vacuum bag and the resin container. The vacuum force draws the resin through the perforated tubes onto the reinforcing components, eliminating excess air and thus creating the laminate structure Fig. 1(i). The superior results achieved via the elimination of void content make the VARTM process favored for big items[48, 49].

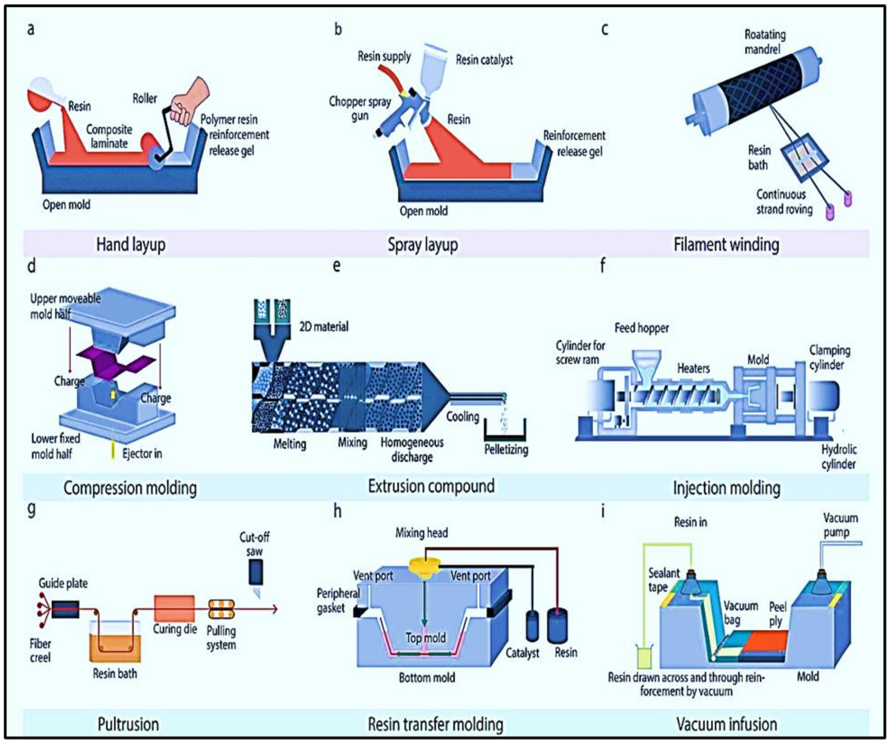

Fig. 1. Schematics illustrating common methods of manufacturing composites; (a) Hand lay-up, (b) spray lay-up, (c) filament winding, (d) compression moulding, (e) extrusion compound, (f) injection moulding, (g) pultrusion, (h) RTM, and (i) VARTM [50]

3. The Mechanical Characteristics of FRP Composites

The enhancement in epoxy composites' mechanical performance using woven fibers includes various strategies, like fiber treatment, incorporation with nanomaterials, and optimization of fiber content Fig. 2. These strategies aim to improve the interfacial bonding between fibers and the epoxy matrix, thereby enhancing mechanical properties such as tensile strength, compressive strength, flexural strength, and impact resistance. The integration of natural fibers like hemp, coir, and cotton, as well as synthetic fibers like glass and are:

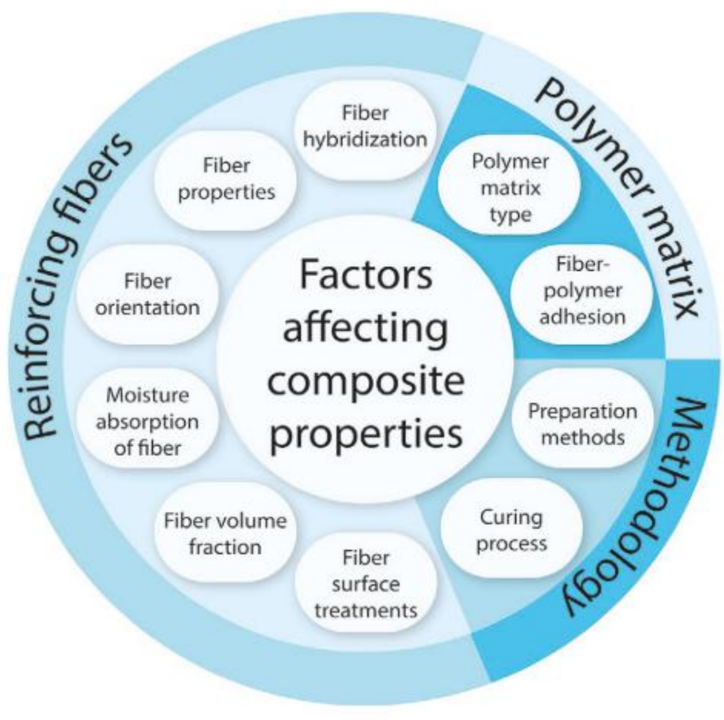

Fig. 2. Factors affecting the mechanical properties of FRP composites [50]

3.1. Fiber treatment and surface modification

Fiber treatment and surface modification are critical to improving the mechanical performance and Possibility of using different fibers in industrial applications. These modifications aim to improve properties such as hydrophilicity, adhesion, and resistance to fouling, which are essential for fibers used in composites, filtration, and other applications. Kim [51] studied the impact of surface treatment on dopamine concentration in super fabrics. Carbon and aramid fibers composites were manufactured using VARTM. The produced composites exhibited the highest tensile strength and hardness at dopamine and tri(hydroxymethyl)aminomethane concentrations. The produced composites showed the highest tensile strength and stiffness at dopamine and tris(hydroxymethyl) aminomethane concentrations, with the best bending strength improvement of over 11%. Tokonami [52] applied a two-step process for effective surface modification of carbon fibers (CFs) using multi-walled carbon nanotubes (MWCNTs). The first step involves (poly-2-isopropenyl-2-oxazoline) coating CFs with a highly reactive polymer (Pipozo), which is highly reactive with COOH of CFs and MWCNTs. The second step involves coating MWCNTs with a suitable solvent, resulting in a substantial quantity of MWCNTs strongly bonded to CF even after the washing process. resulted in a 20% improvement in tensile strength and modulus. Li [53] studied the influences of using plasma and strong acid treatment on surface morphology, surface-free energy, chemical composition, and 3D braided carbon fiber reinforced composites. The results show that synergetic treatment significantly enhances resin/fiber interfacial bonding, leading to a 64.6% higher interfacial shear strength (IFSS) compared to untreated composites.

3.2. Incorporation with nanomaterials

Incorporating nanomaterials into woven fiber composites significantly enhances their mechanical performance by improving interfacial bonding, increasing tensile strength, and providing additional functional properties. The integration of nanomaterials such as carbon nanotubes (CNTs), graphene oxide (GO), and nano clays into fiber-reinforced composites have been shown to improve various mechanical properties, including interlaminar shear strength, tensile strength, and modulus of elasticity. These enhancements are primarily due to the improved interfacial interactions between the fibers and the matrix, as well as the unique properties of the nanomaterials themselves. Megahed [54] studied the effect of adding nanofillers of silica and carbon particulate on epoxy reinforced with tissue glass fiber. the results show improvements in tensile properties, impact strength, and fatigue life with nanoparticle additions. The hybrid composites filled with 0.5 wt.% carbon black showed the highest tensile strength and fatigue performance, with an increase of 19% and 60% compared to the neat glass fiber reinforced epoxy composites (NGFRE). Additionally, adding 0.25wt.% SiO_2 and 0.25wt.% carbon black improved mechanical properties. S. Li [55] studied the mechanical properties of the epoxy matrix and carbon fiber-reinforced epoxy sheets were studied to be enhanced in both room temperature and cryogenic environments. The results indicated that the tensile strength of carbon fiber reinforced epoxy sheets is 16.64% and 25.01% higher than that of pure epoxy sheets.

3.3. Fiber type and configuration

The mechanical performance of epoxy composites can be significantly improved by the type and configuration of woven fibers utilized as reinforcement. Different fiber types and configurations influence the tensile, compression, flexural and impact properties of the composites. The choice of fiber types, such as natural or synthetic, and the configuration, including fiber orientation and layering, play crucial roles in determining the overall mechanical performance of the composite material. Hu [56] studied the tensile, compressive, and flexural properties in three directions of three types of 3D woven composites. the results show that 3D orthogonal woven composite (3DOWC) has exceptional overall mechanical properties in the warp direction, while its tensile and flexural strength are similar to 3DSBW, but compressive strength depends on the number of weft yarns. Kirmasha [57]studied the mechanical performance of unstitched and silk fiber-stitched woven kenaf-reinforced epoxy composites. The study found that stitched specimens had comparable in-plane mechanical properties to unstitched ones. The result showed 17.1% higher tensile strength and a 9% decrease in flexural strength. However, the Izod impact test showed an improvement of 33% in the stitched specimens, concluding that stitching successfully enhanced out-of-plane mechanical properties. The reduction in flexural strength is insignificant, contrasting with the significant enhancement in impact strength.

4. Composite Sandwich

Advanced materials that combine lightweight cores with durable face sheets, provide exceptional strength-to-weight ratios and multipurpose use. The core materials and face sheets may be designed to improve specific characteristics such as thermal stability, impact resistance and energy absorption. Dinesh [58] prepared structural sandwich composite panels using various core materials like Aluminum honeycomb, balsawood, high-density polyurethane foam, rohacell foam, or Nomex core. Carbon fiber is used as a reinforcement phase, and epoxy is used as a matrix. Three-point bending, tensile, and compressive tests validate the design. The results indicated the foam-based sandwich panels have better tensile and compressive load-bearing capacity than aluminum honeycomb panels, while aluminum honeycomb panels have better flexural properties due to their core line up. Wang [59] found that the bending properties and failure causes 3D hybrid spacer fabrics, which are made by weaving E-glass fibers as warp and pile yarns and carbon fibers as weft yarns. The results show a significant enhancement in modulus of bending and stiffness compared to glass fiber-based spacer composites. However, there is no clear improvement in flexural strength. The brittle nature of carbon fibers leads to significant face sheet breaking, but only modest improvements in bending strength. The normalized bending strengths, bending moduli, and bending stiffness of the composites increased by 10.5, 51.1, and 74.8%, respectively. Junaedi [60] studied sandwich composite structures with carbon fiber-reinforced (CFR) polymer as face sheets and glass-fiber-reinforced (GFR) rigid polyurethane foam as a core. Mechanical property tests showed an increase in tensile and shear stress with milled fiber loading. The largest increase occurred at 10% loading, and the compressive modulus and strength increased up to 20% loading. Ponnusamy [61] used an ultrasonic frequency to investigate the effects of nano silica SiO_2 inclusion on the tensile, flexural and affected properties of woven fiber-reinforced kenaf/carbon fiber/epoxy hybrid composites. Test samples were manufactured by the compression moulding method. The results showed that at nano silica concentration of 1.5wt%, the improvement in tensile strength was 31%, and the improvement in flexural strength was 42.36%. The interaction of nano-silica particles with epoxy and fiber improved mechanical and water retention capabilities. Taieh [2] used the cast-in-place method to make a sandwich composite of epoxy reinforced by 3D CF foam and woven basalt fibers (WBFs). Using woven basalt fibers (WBFs) as a face sheet and core material of 3D carbon felt foam (3D CFs) created bicontinuous epoxy-based sandwich composites with good mechanical performance and lightweight. The sandwich was infused with epoxy using the cast-in-place procedure, and a silane coupling agent was added to improve fiber-epoxy adhesion and composite durability. The epoxy/3D CFs/WBFs composite sandwich had 298.1% and 353.8% higher flexural and tensile strengths than pure epoxy, Fig. 3.

Table 1 shows a summary of the most important studies conducted to determine how WCFs enhance the mechanical performance of epoxy composites. It includes a comparison between manufacturing methods, the number of layers of carbon fiber woven, the type of filler used, and their effect on the mechanical properties of the manufactured sandwich structures, such as flexural, tensile, and compressive strength.

Table 1. Summary of studies conducted to determine how WCFs enhance epoxy composites' mechanical performance

Type of filler	Process	Flexural strength (MPa)	Flexural strain (MPa)	Tensile strength (MPa)	Tensile strain	Compressive strength (MPa)	Ref
WCFs (11 layers)	hand lay-up and compression	607.21	1.2	765.21	0.038	—	[62]
WCFs (6 layers)	hand lay-up	—	—	469.73	—	—	[63]
WCFs (12 layers)	H-VARTM	—	—	681	—	—	[64]
WCFs	manual lay-up	—	—	340	—	118	[65]
WCFs (8 layers)	hand lay-up	—	—	440	—	—	[66]
WCFs (8 layers)	Hand Layup	—	—	600	0.009	—	[67]
WCFs (8 layers)	Hand Layup	—	—	894.3	0.013	—	[68]
WCFs (8 layers)	VARTM	409	0.0291	—	—	—	[69]
WCFs (5 layers)	VARIM		—	690	0.019	—	[70]
WCFs (8 layers)	VARI	750	—	—	—	—	[71]
WCFs (10 layers)	hand lay-up	635	0.012	—	—	—	[72]
WCFs (10 layers)	VARIM	860.93	—		—	—	[73]
3DWCFs in 3D direction	VARI	1010	—	1100	—	700	[74]
WCFs (8 layers)	VB+VI	590	—		—	—	[75]
CFs-CNTs	Layer-by-layer	—	—	42.6	—	—	[76]
CFs-CNTs	(CVD) at ultra-low temperature	—	—	4410	—	—	[77]
CFs-MWCNTs-CNF-MLG	electrophoretic deposition	531	—	—	—	—	[78]
CFs-AL HDPU foam	Hand lay up	8300	—	—	—	—	[58]
NWCFs	(LRI)	—	—	—	—	6.40	[79]
CFs-PUF-GF	Hand lay-up	—	—	—	—	900	[60]
3DHW CFs-GF	Layer-by-layer	660	—	—	—		[59]
3DWGF foam-CFs-GF facing	wet hand lay-up co-lamination	363	—	—	—	216	[80]
3D CFs foam/WBFs	Cast-in-place	363.3	—	325.0	—	—	[2]
20 Wt.% of silica /10 Layers of CFs	VARIM	818	—	—	—	—	[81]
12 Wt.% of silica /6 Layers of CFs	VARTM	—	—	102	—	—	[55]
2 Wt.% of silica /8 Layers of CFs	—	—	—	208.2	—	—	[82]

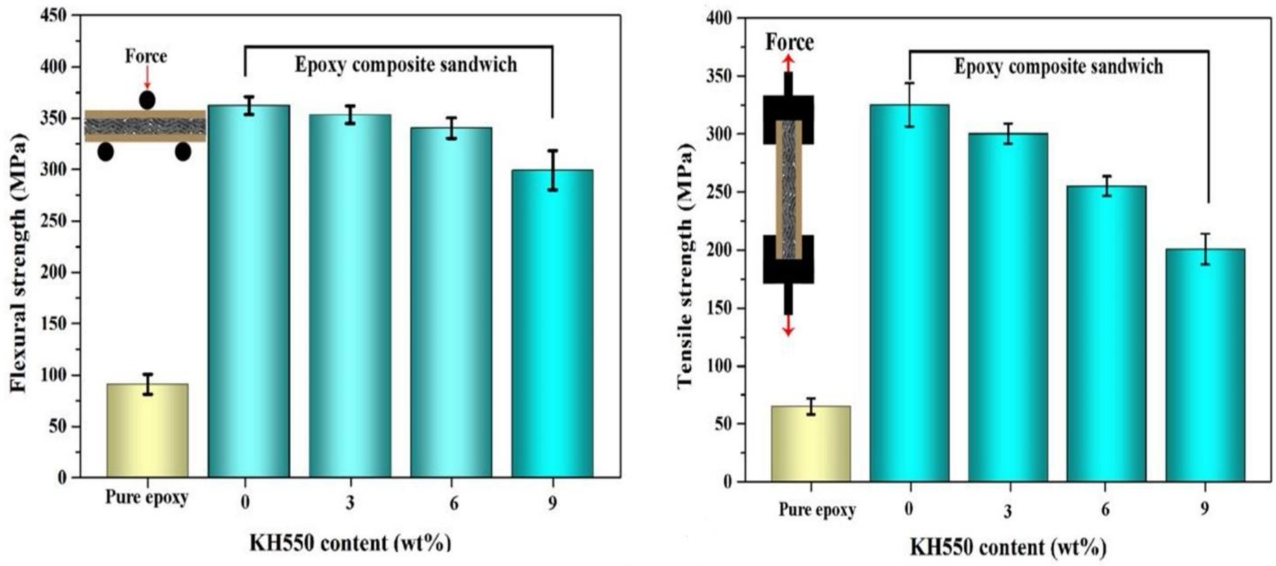

Fig. 3. Flexural and tensile strength of the 3D CFs felt/WBFs epoxy composite sandwich modified with 3-aminopropyl tri ethoxy silane[2]

5. Conclusion

This study reviewed the results of the investigation into the main technologies used in the manufacture of structural composite materials, in addition to the most important factors affecting the mechanical properties and the possibility of improving them to obtain exceptional properties of manufactured structures and investigating the use of woven carbon fibers and suitable core material for sandwich composite materials on the mechanical properties, and the following conclusions were drawn:

- Lightweight core sandwich composites provide a feasible option for reducing the cost of high-performance composite materials while enhancing their tensile, compressive, and bending properties.
- Woven carbon fibers have excellent multifunctional properties, including superior strength, stiffness, high-temperature resistance, corrosion resistance, and excellent electrical and thermal conductivity.
- To improve many mechanical properties of woven carbon fiber epoxy, reinforcing core elements such as HDPU foam, aluminum honeycomb, Rohacell, polyurethane foam, polysiloxane foam, carbon fiber foam, etc. can be added

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