EFFECT OF DIFFERENT PARAMETERS ON PROPERTIES OF FIBRE COMPOSITES

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Abstract: Composite materials have capabilities of replacing many materials in space and automobile applications due to their high strength to weight ratio. Fibre composites are having dominant properties along the direction of the fibre, but across the fibre direction they show some poor properties. Properties of composite material depend on many parameters like fibre and matrix type, fibre length and content, curing process and time, etc. Aim of this paper is to review the effect of such parameters on the properties of the fibre composite materials. Different research articles are reviewed and how the properties of different composite materials affected by parameters is found out. Although composites are best suited for high strength and light weight application, property improvement of fibre composites still need some more investigation.

Keywords: Fibre composites, properties, parameters.

1. Introduction

In engineering terms, Composites can be defined as the combination of materials that are physically assembled together to form one single bulk, but the individual components do not dissolve or merge completely in the composite. The final composites have superior properties than that of the individual components have [1]. Two or more materials can be combined to take advantage of good characteristics of each of the material, which one of the major advantage to use composites [2].

Composite material mainly consists of two components, first is Filler Material and second is Matrix Material. Filler Material is primary load carrying component of the composite, hence it also termed as reinforcement. Matrix material holds the reinforcement together and transfer any applied load. Matrix material also determines the maximum service temperature of the Composite [2]. Matrix keep the fiber in their proper position and chosen orientation.

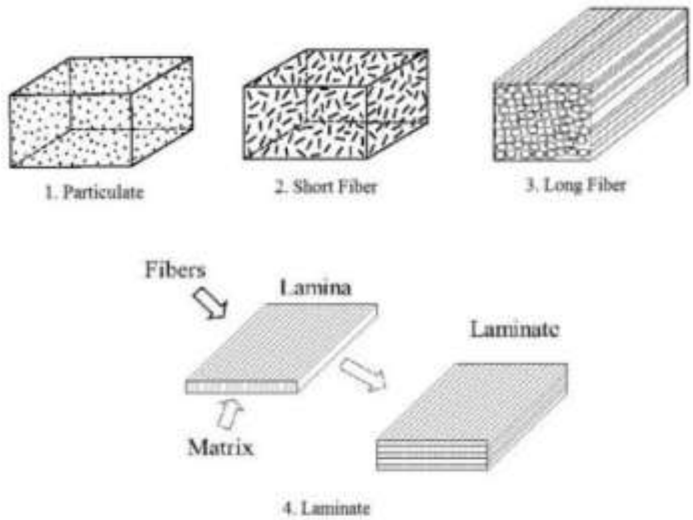

Figure 1.1 – Types of composite material [3]

According to shape and size of filler materials, composites can be classified as below:

1. Particulate Composite
2. Short Fiber Composite
3. Long Fiber Composite
4. Laminate Composite
5. Combination of some or all above type

Roughly round type fillers are there in particulate composite. For example, Unreinforced concrete is having cement as matrix and coarse aggregate as filler material. Long and Short fibers are having L/D value greater than 1mm. For short fibers (also termed as whiskers), L/D is less than 100 and L/D ~ ∞ for long fibers [2]. Filler material for laminate type composite is in form of ply or sheet. There are some multiphase composites are also in use which having more than one characteristic of the various classes, particulate, fibrous, or laminated composite [4]. For example, Reinforced cement is both particulate (due to gravel in cement-paste binder) and fibrous (due to steel reinforcement). Laminated composite with fibrous ply is obviously both laminated and fibrous type composite.

Different fibres in the forms of tows or yarns are used as the reinforcement materials which is the main load carrying component of composite material. Fibre ply are available in both dry as well as prepreg form. Prepreg is pre-impregnated with the resin material. Prepreg is available in either unidirectional tape form or bidirectional fabric form.

Resin is generic term used for the polymer matrix material which is mainly used in FRP (Fiber Reinforced Polymer) products. Type of resin and its chemical properties affect the processing, fabrication and ultimate properties of the laminate. Resin can be mainly classified in two types, thermosetting resin and thermoplastic resin. Thermosetting resin can be easily poured or formed into any shape. They are compatible with most other materials. Upon curing of thermosetting resin, liquid resin is converted into a hard rigid solid by chemical cross-linking [5]. Some examples of thermosetting resins are polyester resin, vinyl ester resin, phenolic resin, polyimides, epoxy, Polybenzimidazoles (PBI) and Bismaleimides (BMI). Thermoplastic resin can be softened repeatedly by an increase of temperature and hardened by decrease in temperature. Processing speed if the primary advantage of thermoplastic resin. Semi crystalline Thermoplastics, Amorphous Thermoplastics and Polyether Ether Ketone (PEEK) are some examples of thermoplastic resin. Other than polymer matrix, metal and ceramic matrix can also be used. The development of metal matrix composites has been concentrated on three metals, aluminum, magnesium and titanium. Some hardener and curing agent may be added to the resin for having desired properties of laminate and also for fast curing.

2. Literature Review

Carbon fibre may be continuous or of small length. Small length fibres are also called chopped fibres. Length of carbon fibre highly affects the properties of carbon fibre composites. **P. Amuthakkannan et. al.** [6] had investigated the effect of fibre length and fibre content of basalt fibre on mechanical properties of fabricated material. Specimen were prepared with short basalt fibre as reinforcing materials and polyester resin as a matrix in polymer composite. Four different length, 4mm, 10mm, 21mm and 40 mm of basalt fibre were used for specimen preparation. Different fibre volume fraction ranging from 10% to 90% were used. Table 2.1 shows the relation between volume fraction and fibre content by weight for basalt fibres.

Table2.1 - Volume Fraction of basalt fibres in composites [6]

No.	Adding of Fibre in composite (Volume Fraction)	Fibre Content (wt%)
1	10	21
2	20	32
3	30	43
4	40	55
5	50	64
6	60	66
7	70	67
8	80	68
9	90	71

Tensile test, flexural strength and impact strength were tested for different specimens and results were compared. Figure 2.1 shows the graphs for results of these 3 tests. 21 mm and 50 mm length showed the maximum tensile strength of about 120-130 MPa at fiber volume content of 68% and tensile modulus of 50 mm fiber at same fiber volume content was about 0.7 GPa. 21 mm fiber composite had highest flexural strength at 68% fiber volume content but its flexural modulus was quite low compared to 10 mm fiber composite. Impact strength of 50 mm fiber is maximum among all. Short fiber composites are having more fiber ends hence chances of matrix cracking due to stress concentration at fiber end is high.

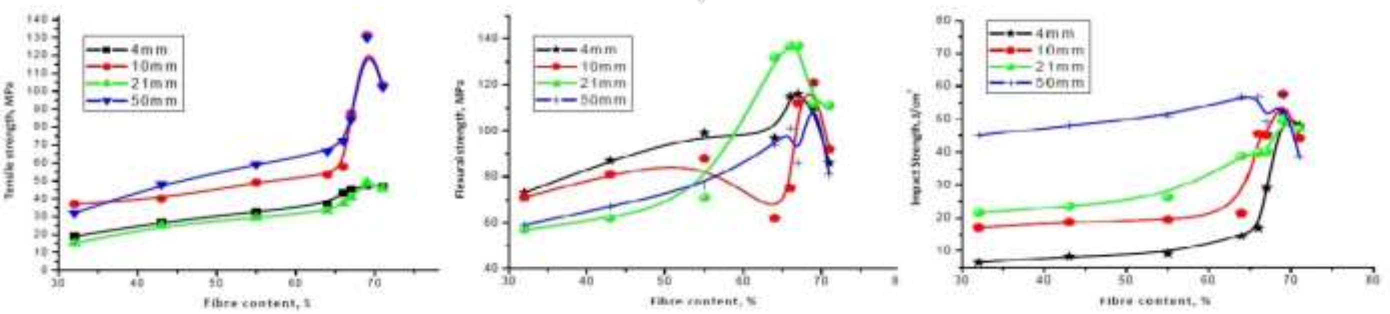

Figure 2.1 - Tensile, Flexural and Impact strength of basalt short fibre composites [6]

Lamination method of composite also affects the properties of laminate composite. **Min sang lee et. al.** [7] had studied the effect of different lamination methods on the interlaminar shear strength of composite. Ply lamination method is the most common method used for laminate manufacturing. Researchers proposed three more lamination methods: (i) Roll lamination, (ii) Half lamination and (iii) Zigzag lamination. They had used WSK-3K composite material which is a kind of woven fabric carbon fibre prepreg. In roll lamination method, the prepreg was rolled up to form laminate. In half method, sheet of prepreg is folded in half and in zigzag lamination method, sheet of prepreg is laminated in zigzag form. Figure 2.2 shows the newly proposed methods of lamination.

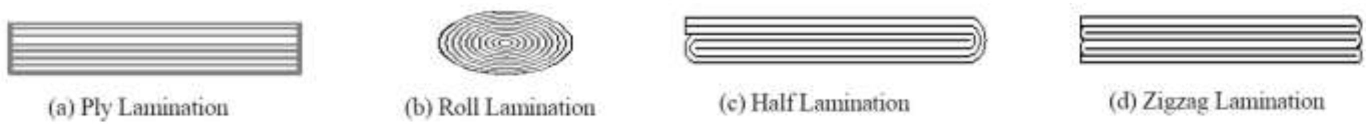

Figure 2.2 – Several types of lamination method [7]

Five samples are prepared for all proposed lamination methods. Interlaminar shear strength (ILSS) test were performed on each specimen. Figure 2.3 shows the average results of ILSS tests for each specimen. The results presented that the interlaminar shear strength of the newly proposed lamination methods were have more strength compared to conventional ply lamination method. The interlaminar shear strength in the roll method with relatively dense fiber distribution was approximately 1.75% higher than that in the existing ply lamination method. Table 2.2 shows the maximum ILSS for each lamination method and strain at maximum ILSS.

Table 2.2 – Max ILSS and strain at max ILSS for different lamination method [7]

Lamination Method	Maximum ILSS (MPa)	Strain (mm/mm) at maximum ILSS
Roll	52.3	1.34
Half	51.8	0.96
Ply	51.4	0.81
Zigzag	50.3	0.79

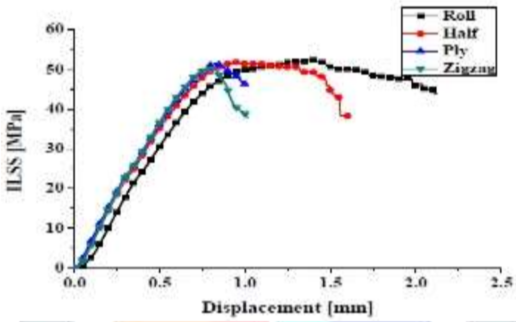

Figure 2.3 - Average graph from interlaminar shear strength test [7]

Nowadays Additive manufacturing processes are also used for metals and plastics component manufacturing. Additive manufacturing of fibre composite products is also possible. **Fuda Ning et al.** [8] had tested if the properties of CFRP composite part would be enhanced compared to pure plastic part made by FDM. For experiment, two parts were prepared, one is from pure plastic and another from CFRP. In FDM, part is build layer by layer depositing of build material and support material. For next layer, build platform slightly moves downward. Support material can be removed by water-based cleaning solution with no surface damage. The most commonly used thermoplastic material in FDM is ABS (acrylonitrile butadiene styrene). ABS plastic pellets were mixed with Carbon fiber powder (Panex 35) with different carbon fiber weight percentage including 3wt%, 5wt%, 7.5wt%, 10wt%, and 15wt%. The tensile test was performed according to ASTM D638-10 standard. Here average length of 150 µm carbon fibers were used to prepare five different samples. Effects of fiber content on mechanical properties like tensile strength, young modulus were analysed after test results.

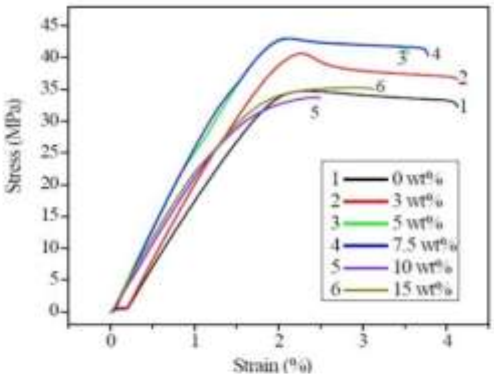

Figure 2.4 - The Strain-Stress Curve of The Specimens with different fiber content with additive manufacturing [8]

Test results showed that tensile strength firstly increased and then decreased at the settings of carbon fiber content from 5wt% to 10wt%. The largest tensile strength value (42 MPa) could be found at carbon fiber content of 5wt%. After an increase of Young's modulus with increasing of carbon fiber content from 0% to 7.5wt%, there was a decrease when fiber content increased from 7.5wt% to 10wt%. Highest value of Young's modulus (25 MPa) at 7.5wt%. The largest ductility of 4.14% is found at 0wt% i.e. pure plastic part. Then ductility goes on decreasing with increase in fiber content.

In another paper by **Fuda Ning et al.** [9], same dimension parts as shown above were made from 5wt% carbon fiber content. Four Process parameters were analysed as listed below:

1) Raster angle - refers to the direction of raster pattern relative to the X axis of the print bed. There are two raster angles were used for the paper, [0, 90] and [-45, 45]. The angle [-45, 45] means that the raster deposition directions for different layers were -45 and 45.
2) Infill speed - the speed of the nozzle travelling relative to the print bed which could control the volume of the extruded filament and cross-sectional geometry of specimen.
3) Nozzle Temperature - working temperature of the nozzle, which could influence the fluidity and solidification characteristics of the extruded filament.
4) Layer thickness - vertical declination height of print bed after each layer.

It was concluded from test results data that raster angle [0, 90] had significantly larger strength, Young's modulus, and yield strength than [-45, 45]. Infill speed of 25mm/sec gave the largest mean values for all the tensile properties. All tensile properties were first increased and then decreased with inflation point of 220^{o} C. Tensile strength and Young's modulus had the largest mean values when the layer thickness is 1.5 mm.

D.D.L. Chung [10] discussed different methods of tailoring of damping property in structural composites. One of the methods is the selection of matrix and fiber. Usually thermosets such as epoxy is used as matrix for its good adhesive ability. However, the loss tangent of epoxy is only 0.04 at 1 Hz which represents the poor damping capacity. In the case of Neoprene rubber loss tangent is 1.1 at 1 Hz but the storage modulus (stiffness) is very low which makes it unsuitable for structural application. Polytetrafluoroethylene (PTFE) is a thermoplastic that exhibits high values of both loss tangent (0.22 at 1 Hz) and storage modulus (1.3 GPa at 1 Hz). Another thermoplastic polymethylmethacrylate (PMMA) has lower loss tangent (0.10 at 1 Hz) compared to PTFE, but high storage modulus (3.5 GPa at 1 Hz).

Hajime Kishi et. al. [11] studied the damping behaviour of CFRP with several viscoelastic interleaf films. Several types of thermoplastic-elastomer films were used as the interleaving materials. This method of incorporation of interleaf is also known as constrained layer damping technique. Four types of interleaf films were used to get the result data. For each sample viscoelastic property of polymer films were evaluated by dynamic mechanical analysis method in shear mode. Three different carbon fiber prepreg were used for making samples with different lay-up sequences. Both interleaved and non-interleaved samples were tested for same material and lay-up. Result concluded that the viscoelastic property of interleaf films was reflected in the damping enhancement of CFRP.

M. Srinivasan et. al. [12] discussed in their paper that out of plane thermal conductivity of CFRP can be increased by incorporation of the diamond powder in epoxy. Samples of standard modulus T300 carbon fiber with 44% and 55% fiber volume fraction and high modulus YS90A carbon fiber with 50% fiber volume fraction were fabricated. Their matrices comprised of neat epoxy and different loading of diamond powder within epoxy resin. The out of plane thermal conductivity of standard modulus composite was found to be increased by a factor of 2.3 with 14% diamond powder volume fraction. In High modulus composite, it was found to be increased by a factor of 2.8 with 12% volume fraction of diamond powder.

3. Conclusion

After studying these papers, it can be concluded that CFRP having capabilities to alternate the aluminum alloy 6061 in Electronic housing. CFRP have approximately more than 30% weight saving compared to metals and alloys. Only limitation of CFRP is its weak properties in out of plane and lateral direction. These properties can also be improved with further investigation, Also, Carbon Fiber draping and material direction also affects the laminate properties, hence proper fiber orientation is must for desired final properties. Fiber-matrix combination selection is also important as matrix properties defined the maximum service temperature of Laminate. Integration of conventional metal parts with CFRP laminate required further more investigation.

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