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Critical Length for Short Fiber Composites Derived using Coir Fiber and Epoxy Resin

Rahul G.Karmankar

Mechanical Engineering department
Usharama college of Engineering and Technology-Vijayawada-AP-India

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Abstract - *This paper views the beauty of short fiber composites specially fabricated using coir fiber and epoxy resin. As per the current scenario of Industrial growth and resource utilization for manufacturing Industries are either manmade or naturally available. Manmade resources are costly as compared to available natural resource so people are more interested in naturally available resource which would give us eco-friendly products at minimum cost. There are huge number of value added products can be manufactured using naturally available resource as coconut coir because of its specific physical properties and availability. Length of coir fiber is also play in important role for finally manufactured products and can be varied its mechanical properties. Generally available length of coir fiber is 20 to 150 mm. And as per various experiments and research results mechanical properties can be varied by changing its length. So to get optimum value of mechanical properties we have to select exact length for fiber and this can be achieved by selecting critical and minimum length of the fiber. So this paper showing some view on mechanical properties at the point of critical length. Length of short fiber should be greater than critical length of fiber or load transfer length of fiber to get optimum strength value.*

Key words: *Short fiber, critical length, minimum length, coir fiber*

1. INTRODUCTION

Having distinguish features of short fiber composites as compared to continuous fiber composites they are used to manufactured various types of industrial products as cylinder, circular section etc. Why we want to use short fiber composites? Generally composites are manufactured using continuous fiber of unidirectional, bidirectional, multidirectional fiber etc.But their mechanical properties are more superior in longitudinal directional as compared to transverse direction. In longitudinal direction as per so many result and experimental analysis their strength are more than transverse direction especially for unidirectional composites. To overcome this difficulty researcher tried bidirectional, multidirectional fiber but till then also transverse direction properties shown the less strength as compared to longitudinal direction. There are number of Industrial products which need isotropic strength in all direction and this concept emerges with the specialty of short fiber composites.

In application where protection need from corrosion environment, storage tank, cylinder, boat manufactured products using laminated composites, unidirectional fiber base composites need not fulfill the expectation of required strength and properties but short fiber composites give the best result by providing isotropic strength in all direction. This is the special beauty of short fiber composites.

To enhance the beauty of short fiber composites here I am using the naturally available resource as coconut coir through which we can be manufactured huge number of Industrial products. Also it's availability at low cost and renewable resource more people are inclining to provide value added products using coconut coir.

Mechanical properties of coir fiber are

Mechanical Properties	Coir fiber
Density (g/cm^3)	1.2 to 1.5
Length (mm)	20 to 150
Diameter (μm)	100 to 450
Tensile strength(Mpa)	140 to 600
Young's modulus (Gpa)	3 to 6
Elongation at break	15% to 35%

Table-1

Mechanical analysis of unidirectional composites is somewhat different than short fiber composites because here for the analysis of short fiber we have to consider end effect of the fiber also unlike continuous fiber. In composites load are transferred through the matrix to the fiber so length of the fiber is very important. When the length of the fiber is more than the length over which stress are more effective then we can ignore length and consider as a continuous fiber but if not then length of fiber and it's end effect play a major role for the strength of the composites as short fiber composites. So for the manufacturing of short fiber base composites we should know effective length of the fiber or we can called it is as critical length of the fiber.Effective length or critical length of the fiber is that length which can give us optimum value of mechanical strength. After having some research work and experimental result some infer shows that if we increase the length of the fiber then mechanical properties also going to change but up to some limit after that we cannot increase it. And we can't use high length for short fiber composites and less length than required so it is always better to select the critical length for

the short fiber composites for optimum value of mechanical strength and isotropic properties.

MATHEMATICAL CALCULATION FOR CRITICAL LENGTH

As per research and experimental data it is cleared that length of the short fiber should be greater than critical length of short fiber to improve the beauty of the short fiber composites. Critical length of short fiber can also be called load transfer length of fiber.

Fig.1

Assume Fiber as cylindrical shape
L= Length of the fiber
L_t= Load transfer length of the fiber
d=Diameter of fiber

From the geometry of the fiber we can prove through the mathematical calculation, how the critical length and length of the fiber play a major role to improve the strength of the composites. Generally short fiber composites and unidirectional composites have distinguished features like end effects of the fiber. In continuous fiber there is less effect of this factor while designing the composites but for short fiber composites we should not ignore the end effects. When we apply the load on composites specially fabricated from short fiber tip of the fiber play a major role as load is transfer through tip to other part of the fiber. This is also known as load transfer length of the fiber.Initialy matrix take the load and it transfer to the fiber during actual loading condition of the composites. Actually what happen because of interface of fiber and matrix shear stress are generated at the tip or end of the fiber means initial part of length of the fiber bear some shear stress and it goes on decreasing towards central part of the fiber and at the central part fiber bear tensile stress so fiber break lastly through tensile stress. High shear stress are generated at the end of the fiber means at the tip of the fiber at where the parts are hold during loading so this part can also be called as load transfer load is nothing but critical length of the fiber or load transfer length of the fiber.

Shear stress are developed at the tip then it decrease towards the central part of the of the fiber and become very less and due to loading action tensile stress are generated from same point and finally fiber will going to fail. Thereby through mathematical calculation also we can find the critical length of the fiber means it is that length length which carries maximum stress. Apart from this critical length effect other factors are also important to enhance the strength of short fiber composites as aspect ratio and good adhesion between fiber and matrix. Aspect ratio l/d should be large for good adhesion. Mathematically we can find the value of force and load transfer length. The force due to shear at the interface of matrix and fiber is given by this equation

$$F_{interface} = \tau_y \left(\frac{l_t}{2}\right) \pi d$$

Now force supported by the fiber = $\sigma_f \left(\frac{\pi d^4}{4}\right)$ Now equating these two equation $l_c = \left(\frac{\sigma_f}{2\tau_y}\right)_{max} d$

τ_y Shear stress of the fiber matrix interface

The highest value of the σ_f may be equal to tensile strength of the fiber σ_{fu} the fiber length corresponding to the above

condition is known as critical fiber length l_c which is given by $l_c = \left(\frac{\sigma_{fu}}{2\tau_y}\right)$

This is one of the way through which we can find the critical length or load transfer length of the fiber and our design length should be greater than critical length of the fiber. From this point if we increase further the length of the fiber then on small incremental length (dx) of the fiber there is an incremental increase in the stress in the fiber and can be found using this equation

$$\sigma_f = \frac{4\tau_y \left(\frac{1}{2}l - X\right)}{d}$$

We can also easily find the value of stress in fiber and in composites when its value compare with length of the fiber.

Case 1) Fiber length less than l_c

Average Stress in the fiber $\sigma_f = \frac{\tau_y \, l}{d}$

Stress in composites $\sigma_c = \left(\frac{\tau_y \, l}{d}\right) V_f + \sigma_m (1\text{-}V_f)$

Case 2) Fiber length equal to l_c

Stress in fiber $\sigma_f = \frac{2\tau_y \, lc}{d}$

Average stress in fiber $\sigma_f = \frac{\tau_y \, lc}{d}$

Stress in composites $\sigma_c = \left(\frac{\tau_y \, l_c}{d}\right) V_f + \sigma_m (1\text{-}V_f)$

Case3) Fiber length greater l_c

$$\sigma_f = \frac{2\tau_y \ lc}{d}$$

and average fiber stress is given by

$$\sigma_f = \sigma_f \text{ (max) } (1 - \frac{l_c}{2l})$$

Stress in composites - $\sigma_c = V_f \ \sigma_{f(\max.)} \ (1 - \frac{l_t}{2l}) + \sigma_m (1 - V_f)$

This equation shows that for the fiber stress to be closed to the maximum fiber stress and l should be greater than l_c

EXPERIMENTAL DETAILS

I have taken Epoxy resins of low molecular weight. Epoxy has a wide range of applications, including metal coatings, use in electronics / electrical components, high tension electrical insulators, fiber-reinforced plastic materials and structural adhesives. Hardener HY 917 is used as a curing agent, it solidify the mixture of resin and fiber. Selections of epoxy resin also play an important role on the properties of the material. Second I have purchased reinforcement material as coir fiber and cut it in different length as per experimental requirements and prepared the sample using hand-lay and compression molding technology. Before using the coir which is collected naturally should be decorticating, dewaxing and bleaching by using suitable reagent and heat treatment process so that it become free from foreign materials and made for good adhesion

Figure 1-Coir and Epoxy resin composites

Here are some samples which are fabricated to test its mechanical properties with respect to various length of the fiber as 1 cm, 1.5cm, 2cm.2.5cm.3cm.3.5cm etc. Composites are fabricated using load 50 to 80kg and curing temperature 50 to 85^{0}c.I have tested the sample for tensile strength, impact strength and flexural strength The tensile strength was carried out at room temperature by INSTRON 1195 testing machine with gage length of 32mm, applied load of 50kg with speed of 12.5 mm/min. Measurements dimensions of tensile bar were: length 32mm; width 7.8mm and thickness 3.2 mm according to ASTM-D638. This test was carried out with a Leybold-Heraeus 36110 hydraulic press. The measurement dimensions of flexural specimen were 15cm in length and 3cm in width based on ASTM-D790. The charpy impact test on unnotched specimens was determined using 5J pendulum impact testing machine. The measurements dimensions of impact specimen were 55mm in length and 10mm in width according to ISO-179.

Figure 2-Coir fiber and epoxy resin composites

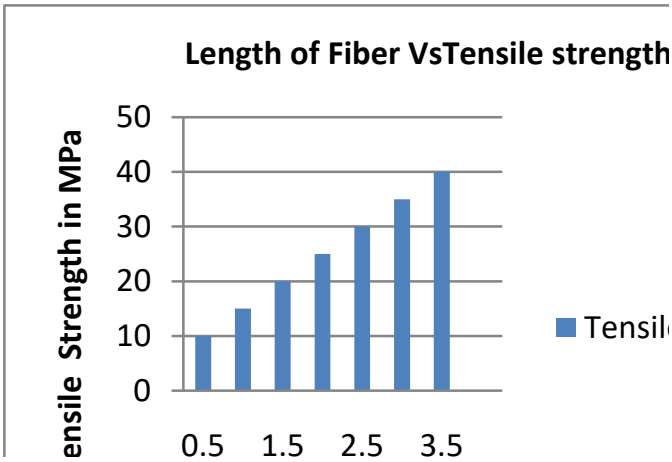

Figure 3-Graph-1

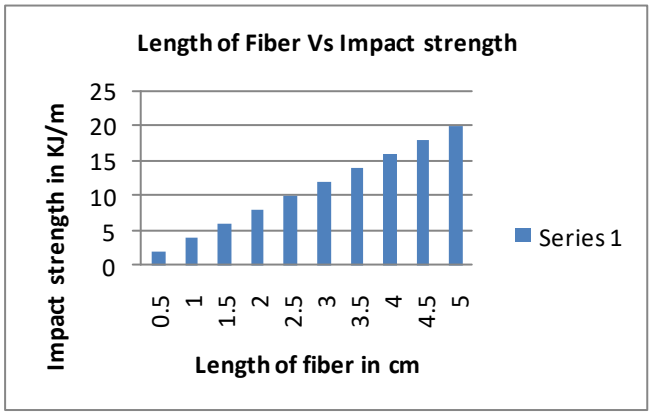

Figure 4 Graph-2

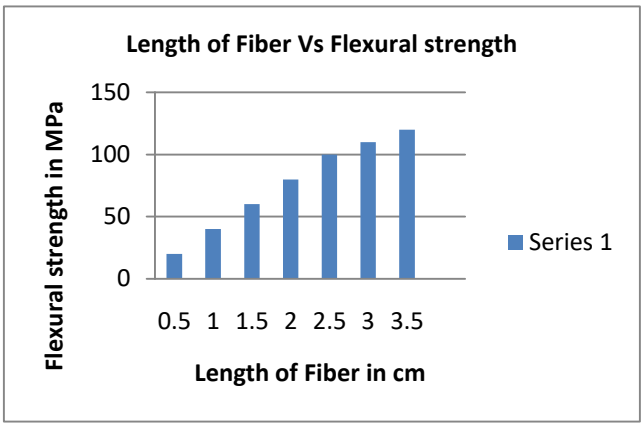

Figure 5-Graph-3

Result and discussion

Having determined and formulated view regarding critical length of the fiber it is clear that to improve the beauty of the short fiber composites we should pay attention towards the critical length of the fiber as per the design and requirement of the composites dimension. After having formulated mathematical calculation and experimental result as we increase the length of the fiber mechanical strength of the short fiber composites and fiber also going to increase but it is up to some extent because if we extend beyond its limit then it come under the category of continuous fiber means we would lose the specialty of short fiber campsites.Throughly graphically also I have tried to show the importance of length of the fiber in short fiber composites.

Conclusion

Having determined view regarding length of the short fiber it is infer that as we increase the length of the fiber mechanical strength and other strength also going to increase but after critical length of the fiber stress on the fiber means on the composites going to increase. So to avoid such type of high stress on the composites critical length of the fiber play a major role and we can improve the strength and beauty of the short fiber composites materials.

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