International Journal of Research in Advent Technology, Vol.2, No.11, November2014
E-ISSN: 2321-9637

Optimal utilization of Carbon Fibre according to basis of factor of safety

Narayan Prasad Sahu[1], Dev Kumar Khande[2], Gesh Chandra Patel[3],
Prakash Kumar Sen[4], Shailendra Kumar Bohidar[5]
Student [1, 2, 3], Bachelor of engineering, Mechanical engineering,
Kirodimal Institute of Technology, Raigarh, Chhattisgarh, INDIA
Faculty[4, 5], Department of mechanical engineering,
Kirodimal Institute of Technology, Raigarh, Chhattisgarh, INDIA
Email: npsahu21993@gmail.com

Abstract- Carbon Fibres (CFs) are the best composite where need of light weight, high tensile strength, high load bearing are essential in any industry like automobile, aerospace, ship building etc. Present paper concentrate on CFs on the basis of factor of safety. Carbon Fiber has high corrosive resistance, light weight, high temperature tolerance comparison to other materials. Factor of safety is considered for designing of any part of body for safety purpose. Future Scope of Carbon Fibre is incredible rather than other material because of their special properties and low cost therefore it works properly and also energy intensity of CFs are good. Carbon Fibers (CFs) are widely used as reinforcement material in polymer composites.

Index Terms- Introduction of carbon fibre, Importance of CFs, Factor of safety.

1. INTRODUCTION OF CARBON FIBRE

Carbon Fibre is the component of Fiber Reinforced Plastic (FRP). "FRP has two main constituents, 1st is matrix and 2nd is fiber. The function of matrix is to provide the rigid base for holding the fibers in correct position. The function of fiber is the transmission of load which acts on the component. The bond between fibers and surrounding matrix is generally chemical" [1].

The Matrix protects the fiber from the surface damage and from the action of environment. There are mainly two types of fiber is used; viz. glass and carbon fiber. A carbon fiber reinforced plastic (CFRP) consists of 'carbon fibre' and 'polymers'. "Carbon fibre makes contribution to is tensile strength because CFRP has higher specific strength compare with metal material and chemical resistance and dimensional stability, it is suitable material for automobile aerospace and any case whenever higher strength to weight ratio is necessary" [2].

It means the reduction on mass by keeping stiffness and strength. It is eligible to bear higher load. "The term Polymer is derived from the two Greek word: poly, meaning 'many' and meros, meaning 'parts' or 'units'. The polymers are composed of a large no. of repeating units (small molecules) called monomers" [3].

Future scope of carbon fiber is better than other metal material because of their high mechanical properties and chemical properties. "Carbon fiber reinforced polymer is instead of aluminum, which is the most common material in light weight design, can reduce the mass of a product up to 40% by keeping mechanical properties" [4]. Therefore extra cost is saved and gets benefit in production.

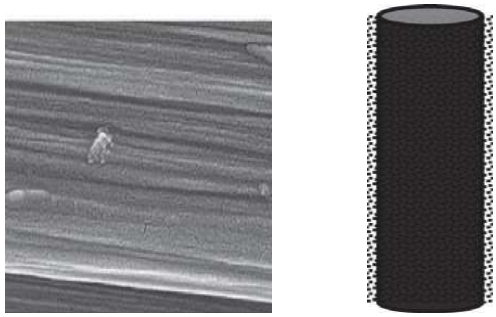

Fig.1. CARBON FIBRE

2. IMPORTANCE OF CARBON FIBRE

In bad to bad environment, the carbon fiber has great tolerance because of their excellent properties which is allowable.

Comparing with other material, it is mainly utilized like in automobile, aerospace, marine etc. parts (making carbon fiber composite) of anybody like aerospace, which bear high temperature, resist corrosion, and tear the air.

Table 1. Embodied energies of common constituent materials and 2 common metal [5]

Material	Embodied energy(MJ/KG)
Carbon fiber	183 to 286
Glass fiber	13 to 32
Polyester resin	63 to 78
Epoxy resin	76 to 80
Aluminum alloy	196 to 257
Stainless steel	110 to 210

From table 1, the carbon fiber is differentiated with other like glass fiber, polyester resin, epoxy resin, aluminum alloy and stainless steel. Embodied energy of the carbon fiber is more than other. The energy intensity of carbon fiber production is significantly higher than for glass. Embodied energy of resin is intermediate between carbon fiber and glass fiber. Higher energy included in carbon fiber.

Table 2. Thermo physical properties of CFRP [6, 7, 8]

	Resin	Carbon Fiber
Density [kg/m^3]	1250	1850
Thermal conductivity (w/mK)	0.2	50 (parallel) 5 (perpendicular)
Heat capacity	1200	710

3. FACTOR OF SAFETY

A mechanical component may fail, i.e., may be unable to perform its function satisfactory. Therefore we apply factor of safety for safety purpose. FOS is used for both ductile and brittle materials.

Formula of factor safety [9]

$$\textbf{Factor of safety} = \frac{\textbf{Failure stress}}{\textbf{Allowable stress}}$$

or

$$\textbf{Factor of safety} = \frac{\textbf{Failure load}}{\textbf{Working load}}$$

Factor of safety is defined as the 'ratio of failure stresses to allowable stresses. Factor of safety is dimensionless. For understanding, we can explain theoretically:-

Designer design a bike which can bear 200N load. This 200N is a failure load. After this load, bike fails. In other word, if bike carry more than 200N, then it fails. Therefore designer take a working load suppose 100N from which bike remain in safe condition and also safe for industry and customer.

Putting this value in formula

$$\text{Factor of safety} = \frac{200}{100}$$

$$= 2$$

Factor of safety is 2. This 2 is safety point which is given to the material for safety purpose.

In other words, every material has breaking point. After breaking point, product breaks and fails. Factor of safety is the most important factor for every component for design consideration and safety purpose. If load is predictable, then factor of safety is less. In the contrast, load is unpredictable, and then factor of safety is high. Every design of product has safety load limit which is their maximum bearing load but in actually company give some factor of safety to the product for safety purpose of the consumer.

For carbon fiber, factor of safety depends upon the following factors:-

3.1 Carbon fiber material:

Carbon fiber is a non homogeneous structure and a higher factor safety based on ultimate tensile strength is taken. It has many mechanical properties and physical properties.

3.2 Force Analysis in product:

When force is predictable, then taking less factor of safety. On contrary, magnitude or direction of force is uncertain, then taking high factor of safety.

3.3 Failure's effect:

Failure of carbon fiber made product involves only a little inconvenience or loss of time and as well as financial loss or danger to human, e.g. failure on parts of aerospace.

3.4 Type of load:

When machine element is subjected to impact load, then higher factor of safety is high because impact load is suddenly applied to machine element at high velocities. On other hand, when load is static and then factor of safety is low.

3.5 Cost:

Carbon fiber has high tensile strength, stiffness. As the factor of safety enhances, dimension of component, material requirement and

cost increases. Factor of safety is low for cheap machine parts.

3.6 Testing of carbon fiber components:

Factor of safety can be chosen when the parts of carbon fiber can be tested under actual conditions of service and operation. If it is not tested, then higher factor of safety is necessary because parts deviate between test condition and actual service condition.

3.7 Operation condition:

Carbon fiber has high corrosive resistance therefore its parts work properly and less factor of safety is necessary. When the machine element is likely to operate in corrosive atmosphere or high temperature environment, a higher factor of safety is needed.

3.8 Manufacturing quality:

When manufacturing quality of carbon fiber parts are high, variations in dimension are less and low factor of safety is selected.

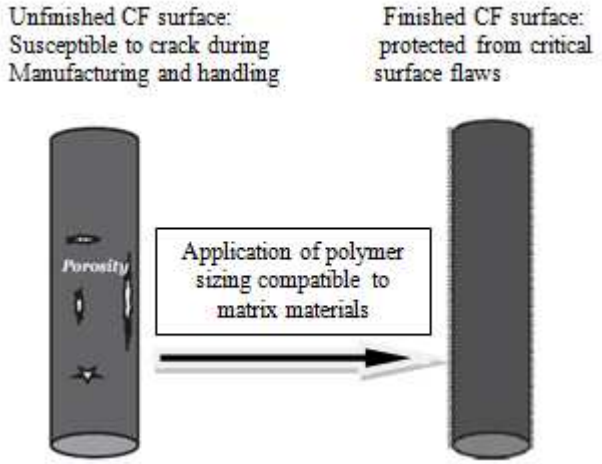

Fig.2. Schematic for the role of CF sizing to protect fiber from critical surface flaws [10].

. From figure, we can see unfinished carbon fiber surface and finished carbon fiber surface. During manufacturing and handling, unfinished CF surface is susceptible to crack. It rapidly fails rather than finished CF surface. Therefore unfinished CF surface has high factor of safety because their weak properties like less bearing power, less strength etc. in other hand, unfinished CF surface is better than unfinished CF because of their well properties. Unfinished CF is converted into finished CF. Therefore finished CF has less factor of safety because it is predictable.

4. BENEFITS OF CARBON FIBRE

I. Carbon fibre has less factor of safety.
II. CF has maximum high strength compared with all other fibre material.
III. Carbon fibre secure its strength at elevated ambient temperature
IV. Moisture, acid and solvent at ambient temperature don't affect carbon fibre.
V. Carbon fibre is cheap.
VI. Light weight at low cost.

5. LIMITATION OF CRBON FIBRE

I. Manufacturing techniques required to produce carbon fiber are relatively complicated.
II. Design of component made of fiber reinforced plastics is complex. It is necessary to know the direction of principal stresses in such components. The fibers are aligned along the direction of principal stresses.
III. The manufacturing and testing of fibre reinforced component is highly specialized.

6. APPLICATIONS OF CARBON FIB RE

Typical Application of Carbon fibers are as follows:

I. Aerospace engineering:
CF is used because of their high tensile strength, high bearing at elevated temperature.

II. Automotive engineering:
Carbon fibre is used extensively in high-end automobile racing. Ex. BMW i3.

III. Sports:
Before some years, thin layer of carbon fiber is used in bat therefore it has good strength.

IV. Civil engineering:
Carbon fibre is mostly used in civil engineering fields because of their high tensile strength.

Future scope of carbon fibre is following as:-

I. Alternate energy- wind turbine, compressed natural gas turbine and transportation, fuel cell.

II. Automobile fuel effect

III. Construction and infrastructure: - light weight pre cast concrete, earth quake protection.

6. CONCLUSION

It has bright future scope because of their low cost, light weight, good mechanical and physical properties like stiffness, high tensile strength etc. from this paper, factor of safety is essential for every component. It depends upon factor i.e. predictable or unpredictable. If predictable, than factor of safety is less and if unpredictable, than factor of safety is high. Carbon fibre is better than all other fibres.

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