COMPOSITE ENVISIONS KNOWLEDGE HUB
PRACTICAL AND INSIGHTFUL COMPOSITES INFORMATION

COMPOSITE FIBER CHARACTERISTICS

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INTRODUCTION

There are three main types of fibers used in composites today; Carbon Fibers, Fiberglass, and Kevlar (Aramid). When used in composites, fibers define the performance criteria and are held responsible for carrying the load in a designed structure. (Resins are responsible for transferring the loads onto the fibers.) In short, fiber selection is an integral part of the design process.

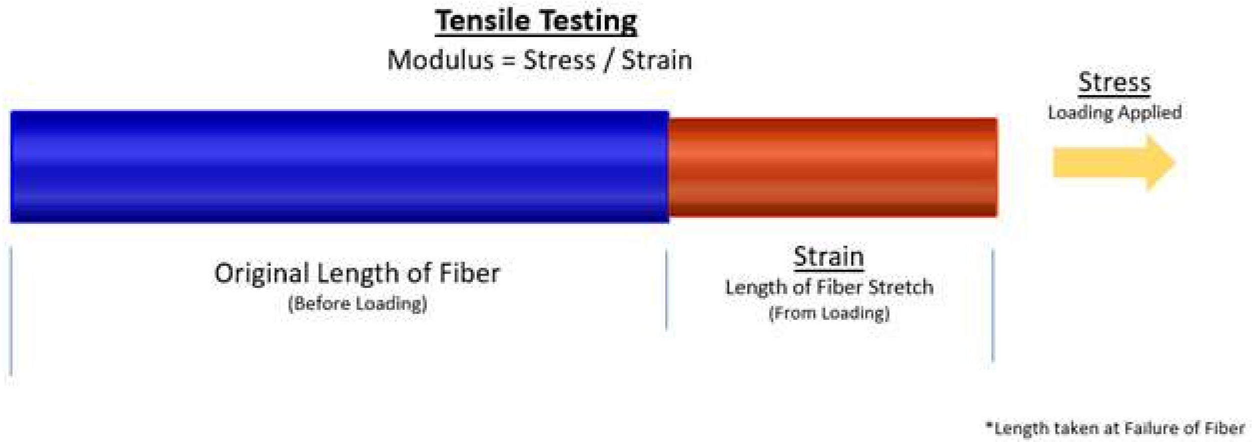
Composite Fiber Characteristics

- Modulus
- Tensile Strength
- Compressive Strength
- Toughness
- Rigidity / Hardness / Stiffness.

Often, composite structures utilize more than one of these fibers to achieve needed design specifications for final use. Although there are endless fiber properties that can further define a components final use, the following high-level characteristics provide a high level for defining purposes for design: Modulus, Tensile Strength, Compressive Strength, Toughness and Rigidity / Hardness / Stiffness.

MODULUS

Modulus is known as the change in length a fiber goes through as increased loading is applied upon it. This loading can be compressive or tensile. It is calculated as Stress divided by Strain. The modulus most often characterizes the material's stiffness or rigidity. On a given stress / strain curve, it is referred to as the slope of the line. Most fibers are categorized by modulus as it helps determine the rigidity or stiffness of a composite material. Generally, composites using Carbon Fiber, Fiberglass, and Kevlar are all categorized as brittle and fail with little stretch in comparison to more plastic or non-brittle materials. exposed to UV radiation and sunlight.



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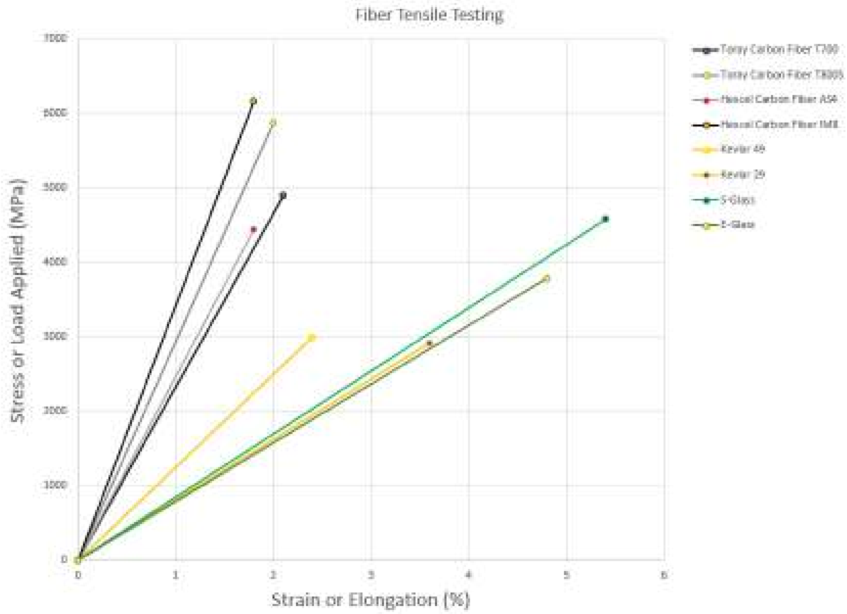
TENSILE STRENGTH

Tensile Strength is a material's resistance to withstand loading while being stretched. It is the maximum force or loading that is applied before permanent deformation of the fiber occurs



As shown, carbon fibers are overall superior in strength and weight. However, a significant difference is shown between S-Glass and E-Glass. Kevlar is the lightest of the materials in terms of density. While exhibiting the lowest ultimate strengths, Kevlar, in terms of strength to weight, exceeds fiberglass and is comparable to that of carbon fiber. Economically speaking, if ultimate strength is the only design criteria, E-Glass is the top choice.

Fiber	Fiber Tensile Strength (MPa)	Density (g/cm^3)	Strength to Weight Ratio
Toray Carbon Fiber T700	4900	1.8	2722
Toray Carbon Fiber T800S	5880	1.8	3266
Hexcel Carbon Fiber AS4	4447	1.79	2484
Hexcel Carbon Fiber IM8	6170	1.79	3446
Kevlar 49	3000	1.44	2083
Kevlar 29	2920	1.44	2027
S-Glass	4585	2.48	1848
E-Glass	3790	2.4	1579

COMPRESSIVE STRENGTH

Compressive Strength is a material's resistance to withstand loading while a force pushes it together in compression. Ultimate strength is determined by the maximum loading applied as the fibers break or are permanently deformed. Compressive strength is taken generally with an epoxy matrix in laminate form.

Fiber	Compressive Strength (MPa)
Carbon Fiber	570
Kevlar 49	190
Kevlar 29	230
E-Glass	425

In compression, Kevlar is much weaker than Carbon Fiber or Fiberglass. The importance being Kevlar is more prone to crack when hit with a sideways blow, causing compression strains in the fiber. This is not to say that Kevlar should not be used, rather designed with a ply architecture that sufficiently covers the needs in which the structure may see.

TOUGHNESS

Toughness is a material's ability to resist cracking under stress or absorb energy. Although strength and toughness are often related, strength measurement is the highest stress a fiber can handle while toughness is measured on how much the material can give before deforming. It is also the area under a stress strain curve from the testing start measured to the point of failure. It is common to have a weaker strength fiber that will still exhibit "tougher" characteristics. Toughness can characterize a material's tendency to be resistant to fatigue and for abrasion resistance.

Fiber	Toughness (MPa*m^1/2)
Hexcel Carbon Fiber AS4	2.12±0.4
Kevlar KM2	6.63±0.61
Fiber Glass	1.08±0.14

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Kevlar, being the lightest fabric widely used in composites, also exceeds Fiberglass and Carbon Fiber in toughness. For this reason, Kevlar fibers are used heavily in vibration dampening applications and to offers better impact resistance than CF or FG. This toughness also helps Kevlar in the fact that it is more resistant to fatigue when loaded repeatedly.

RIGIDITY / HARDNESS / STIFFNESS

Rigidity / Hardness / Stiffness are all characterized by the material's ability to not deform under loading. It determines whether certain parts will stretch or move while under a load, which if in design critical areas, tight tolerances may be an issue on load bearing structures.

Fiber	Carbon Fiber	Kevlar 49	Kevlar 29	S-Glass	E-Glass
Strain %	2.00%	2.40%	3.60%	5.40%	4.80%

If a part is needed for keeping strict dimensional tolerancing under load, Carbon Fiber is the answer. While Carbon Fibers have the highest modulus among the three types of fibers, Carbon Fiber composites will keep tighter dimensional tolerances even when it is loaded near their ultimate strengths. Although each of the fibers are categorized as high-modulus materials, each behave differently when loaded near their ultimate strengths and along the entire loading cycle. While CF will only give ~2%, Kevlar 29 and Fiberglass will stretch to loads in the figure of nearly double than Carbon Fiber. The consequence of being stiff is that Carbon Fiber will fail suddenly without showing signs of failure.

THERMAL PROPERTIES

Thermal Conductivity is simply the material's ability to transfer or carry heat. It is measured by the transfer rate of which heat will flow through the given source (material). Higher thermal conductivity means that the heat transfer will occur at higher rates. Thermal conductivity in composites is anisotropic, meaning that the heat will be transferred through faster in the fiber direction. Overall thermal conductivity relies heavily on volume fraction of resin to fiber and the compactness of the fibers as the fibers carry out the heat transfer. It is important to note that the overall design of the composite structure plays a more important part in the thermal conductivity in a composite than the fiber itself.

Flammability Properties of these fibers conclude that they are all resistant to high temperatures. Carbon Fibers and Kevlar as fabrics are used commonly together for firefighting and protective clothing. Matted Glass fibers are commonly used in buildings to improve fire resistance. However, when used in a composite matrix, temperatures of the composite are limited to that of the resin's heat capability.

Electrical Properties of material's are defined by a fiber's ability to conduct electric current, it's resistance to current and any shielding effects in the electromagnetic spectrum. These properties are mainly only of concern regarding carbon fibers. Because Carbon Fiber is conductive, it is subject to causing Galvanic Corrosion on metallic parts. In response, industrial applicators have insulated metal parts bonded to carbon fiber or added layers of fiberglass in areas of contact in prevent this occurrence. Carbon Fibers have challenged aerospace designers and industry alike as its electrical properties must be designed around and are still being researched.

Fiberglass and Kevlar composites are virtually transparent to radio waves and do not conduct electricity. It is for this reason that Kevlar is commonly used in electrical transmission towers. (With the Kevlar being coated to prevent water absorption)

Chemical Resistivity is a material's ability to withstand exposures to differing chemical

agents along the pH scale and how a fiber reacts within a given time frame. These are widely tested in exposing fibers to such conditions as Water (Fresh & Sea), Organic Solvents, Strong Acid, Strong Alkalis, Weak Acid, and Weak Alkalis.

Carbon fibers are very strong in terms of chemical resistance and do not have great sensitives to any of the above with the expectation to strong oxidizing agents. Fiberglass is comparable to that of Carbon Fiber with a weak reaction to Strong Alkalis.

Kevlar is not suspectable to organic solvents or oils but has shown to degrade in the presence of strong acids, bases, and some oxidizing compounds. Chemicals such as bleach should not be used with Kevlar fibers. Kevlar is also degraded by UV radiation and sunlight.

Overall chemical resistivity of composites relies heavily on the resins used in the composite structure.

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