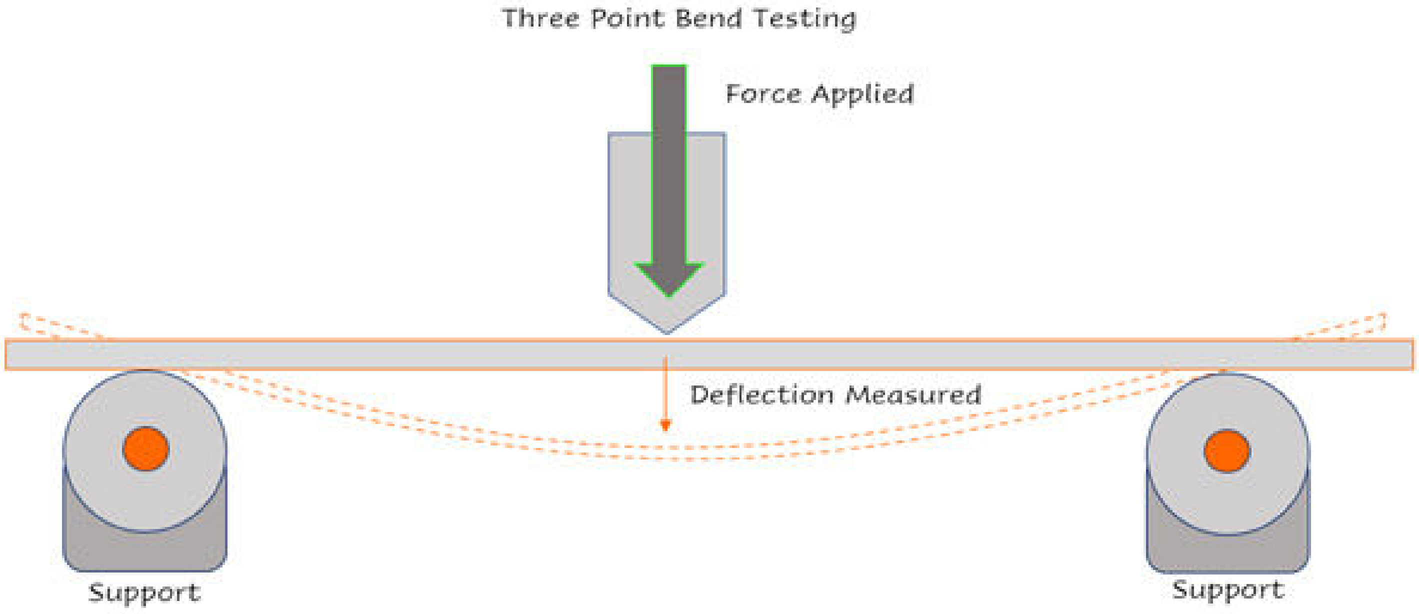
COMPOSITE ENVISIONS KNOWLEDGE CENTER
PRACTICAL AND INSIGHTFUL COMPOSITES INFORMATION



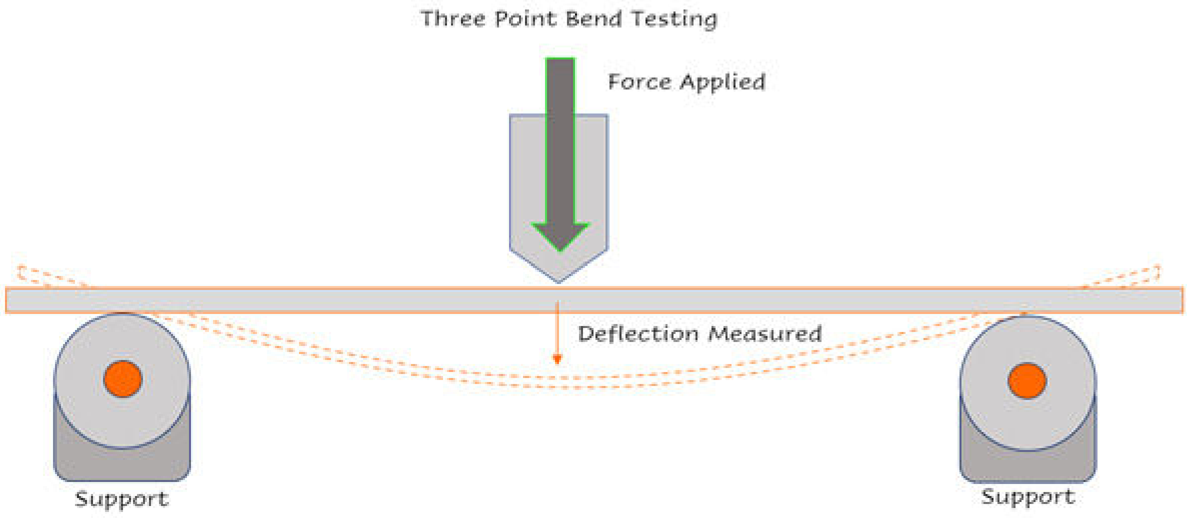
FLEXURAL MODULUS IN COMPOSITE PARTS

COMPOSITE ENVISIONS

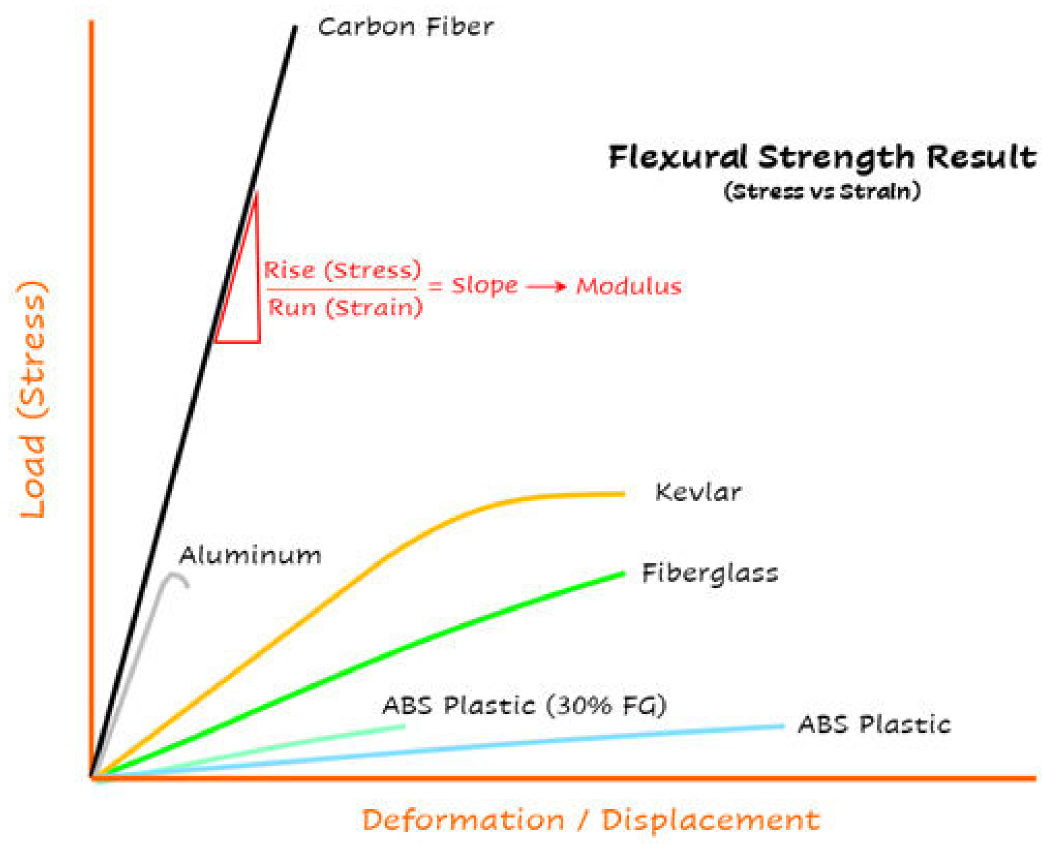
WHAT IS FLEXURAL MODULUS

Modulus is a measure of a composite's resilience while it is placed under constant increasing stress situations. In other words, the modulus tells how much a composite laminate will move or bend as it is loaded. This defines and characterizes a composite's stiffness and rigidity in terms of loading and deformation, providing a fundamental building block to designing everything between high performance composites or simply making your next composite design more effective. This modulus is taken from a cured composite or material sample.

In some materials, the modulus of elasticity may be high, seeing it easily with just the eye. As an example, take a rubber band and apply force to it with your hand. The rubber band stretches easily as the material is subjected to a load. It may stretch 10x its original length before it eventually breaks. Most composite laminates are on the opposite end of the modulus spectrum as they do not often bend very much before the eventually break. Conventional composites made with Carbon Fiber, Kevlar, or Fiberglass are generally compared with materials such as aluminum, steel, or concrete, as they do not flex or give as much as more malleable or plastic-like materials such as rubber, nylon, or ABS. Some composite laminates are designed with a low modulus, flexing upon impact such as drift car body panels that absorb energy and magically "pop" back into place after bumping into a wall. Others are engineered with Ultra High Modulus carbon fibers, providing unmatched stiffness as needed reinforcement.



A three-point flexural test or bending test for composite laminates or structures provides a great representation of what modulus is and why it's important. (In backyard terms this is the break the board over your knee test.) This destructive test of a composite laminate sample measures the deformation as loading is increased over time. A sample composite is subjected to a measured increasing stress (load) as the material's deformation is simultaneously measured. As stress is increased, the material will deform until it fails or breaks. The information is then translated onto a graph represented like that of a stress / strain curve.



The Flexural Strength recorded is the greatest stress placed on the specimen before it begins to break. Modulus is then simply defined as this ultimate strength divided by the deformation. The modulus is also illustrated as the slope in the line of a stress / strain curve. A steeper slope is evidence of a stiffer "brittle" high modulus laminate while a gentler slope demonstrates a less rigid, more "plastic" laminate.

Flextural Strength Testing

Epoxy Composite Properties	0° Flexural Strength (ksi)	0° Flexural Modulus (msi)
Hexcel IM7 12K	270	22
Hexcel IM5 12K	200	20.1
Hexcel AS4 12K	274	18.4
Toray T300 Standard Modulus	260	18
Toray T700S	245	17
Toray T700G	286	18
Aluminum	47.9	11.2
Unidirectional Kevlar	100	8.1
"S-Glass" Fiberglass	112	4.1
Kevlar	64	3.8
"E-Glass" Fiberglass	75	2.7
Abs Plastic +30% Fiberglass	17.4	1.01
ABS	10.8	0.34

On the surface, the flexural modulus is quite simple. Past modulus, these tests and graphs shed light on the determination of failure mechanisms within sample composites and go onto explaining the chemistry of the fibers and resins as the break on a molecular level.

DESIGN WITH MODULUS IN MIND

A composite is a mixture of properties shared between fabric and resin. The selection of each will have an impact on the design of your composite and its modulus. Here are some of the factors that determine whether you are getting a high modulus or more flexible composite laminate. This may help make your next part design meet your needs effectively.

FIBER TYPE AND ORIENTATION

When selecting whether to go with Carbon Fiber, Kevlar, Fiberglass, or even a hybrid fabric it is important to look at the technical information for a composite's typical mechanical properties and compare them to other choices. Ply orientation is critical to achieving the desired stiffness characteristics of any composite as a balanced layup is critical in achieving consistent mechanical properties through the laminate's cross section. Adding unidirectional reinforcement layers will add stiffness to laminates in the direction(s) in which it is laid up.

Carbon Fiber

Carbon Fiber is hands down the BEST for providing stiffness to strength as reinforcement. It will keep dimensional stability acutely until failure. It is compared to aluminum in terms of rigidity although it exceeds ultimate strength capabilities greatly. The only downside is that carbon fibers fail suddenly without much warning, often catastrophically.

Kevlar

Kevlar is known for being energy absorbent, which is somewhat counter active to rigidity, as it only holds half the stiffness of carbon fiber. Kevlar laminates will flex much more when compared to carbon fiber with the same resin. For this reason, Kevlar is often a choice in applications such as drift car body panels where the fenders would need to absorb sudden energy. When paired with a flexible resin, the parts will take a beating before splintering and needing to be replaced.

Fiberglass

Fiberglass carries the lowest modulus in terms of relative stiffness of the selection. When designing with fiberglass for rigidity, it will take more fabric to provide a stiff laminate. However, the cost factor of fiberglass still makes it a great fabric choice when budget and stiffness are compared together as it is often added to plastics to enhance rigidity and strength in components.

Hybrid Fabrics

Hybrid fabrics generally help take the best characteristics of a fiber to complement another; A Carbon Fiber / Kevlar hybrid is known to add flexibility to a composite provided by the Kevlar to a strengthened backbone of carbon fiber. It has also found use in the automotive industry for parts such as front bumpers.

BY RESIN

Epoxy resins generally give the highest performance numbers in terms of strength and rigidity. Although most epoxy resins are formulated or engineered per process (laminating, infusion, prepregs, etc), a resin's primary purpose is to "harness" a fabrics' properties effectively to meet the requirements desired.

Regarding modulus there are some that have enhanced stiffness capabilities while others are designed for energy absorption and flexibility. Be sure to check out applicable TDS sheets to find which resin fits your project the best. RDR-3212 High Impact Room/High Temperature Laminating Resin would be an example of a resin designed with modulus in mind, even if it is a low modulus as it transfers energy more effectively than general epoxy resins.

It is important to know that slow hardeners will provide a lower modulus and fast hardeners yield stiffer when used with the same resin.

Polyester resins are known to be great with fiberglass wetting and provide a great cost-effective means as a matrix to composite parts. However, polyester resins do not provide the same stiffness as formulated epoxies.

The addition of core will also enhance modulus significantly, adding a considerable amount of rigidity to any composite structure.

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