COMPOSITE ENVISIONS KNOWLEDGE HUB
PRACTICAL AND INSIGHTFUL COMPOSITES INFORMATION

COMPOSITE REINFORCEMENTS:

CARBON FIBER

FIBERGLASS

KEVLAR/ARAMID

Composite Envisions

THE BIG THREE

There are three main types of reinforcements used in composites today: Carbon Fiber, Fiberglass, and Kevlar (Aramid). When used in composites, reinforcements 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, reinforcement selection is an integral part of the design process.

CARBON FIBER

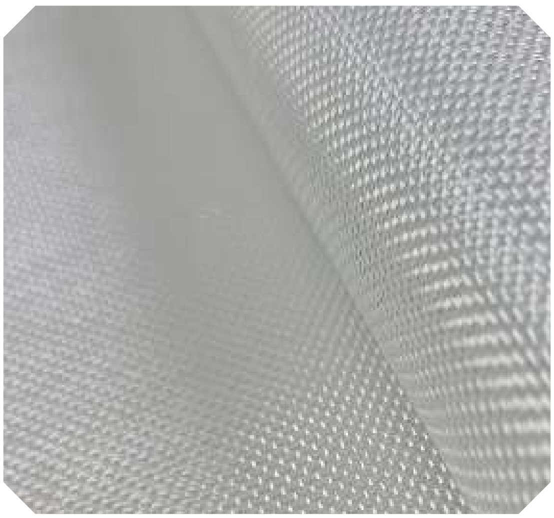
Carbon Fiber is known to be top choice in aerospace and industrial applications due to its high tensile strength, low density, high rigidity, and thermal conductivity. In fact, Carbon Fiber yields the highest material strengths across the board when compared to Kevlar or Fiberglass options. It exceeds comparable reinforcements in strength to weight and stiffness categories. For this reason, it replaces alloys in aerospace components that previously used aluminum or titanium. Carbon Fiber composites excel at keeping dimensional tolerances as loading is applied. Although these properties are great to have, this also causes carbon fiber laminates to suddenly break or splinter suddenly upon maximum values being exceeded. Carbon Fiber does not absorb energy well, however, as it transfers that energy along its fibers to other sources. This may be good or bad dependent on application. Carbon Fiber is best used with epoxy resins to achieve its maximum properties. Although special tooling and processes are not needed for fabrication purposes, vacuum equipment will greatly increase Carbon Fiber's laminate quality.

Common Applications: High Performance Aircraft & Aerospace Structures, Drones, Skeletal Tubing, Spoilers, Boats, Sporting goods (rackets, clubs, bats, sticks, arrows, bikes) Stiffeners, Racing Parts, High End Automotive Panels, Electronics, Medical Imaging, Musical Equipment, Fishing Rods and Components

Advantages	What To Watch For
• Highest Tensile / Compressive Strength • Highest Strength to Weight • Most Rigid • Low Coefficient of Thermal Expansion • High EMI Shielding Properties	• High Cost • Corrosive to metals in contact with CFRP • Breaks suddenly • Electrically Conductive • Low Impact Strength

FIBERGLASS

Fiberglass is the most used fabric type in composites today. Fiberglass's low cost and overall strong physical properties make it a work horse for economically minded hobbyists and professionals alike. Fiberglass has a footprint in nearly every industry known to man. Fiberglass composites will still yield strong, light weight parts that can be used the widest variety of applications. There are 2 main types of fiberglass used in composites today.



Upon initial use of fiberglass, E-Glass was made for electrical purposes because it is non-conductive. This cheaper option is widely used in many applications today and while not limited to, is used as an interface for secondary bonding with carbon fiber parts to metal parts.

S-Glass is signified by strengthened fiberglass. It has ~20% strength characteristics, is stiffer and more impact resistant. While carrying a higher cost compared to E-Glass, it may deliver better cost performance depending on the application or structural needs.

Often, both types of glass are utilized in a structure. S-glass is known to be an excellent for the outer layers of a structure as it provides rigidity and strength to a structure. E-glass then reinforces and provides energy absorption to the composite. Fiberglass can be used with all thermoset resin applications. (Polyester/Vinylester/Epoxy)

Common Applications: Boats, Insulation, Auto Parts, Pools, Waterslides, Piping, Cooling Towers, Slip Resistant Surfacing, Aerospace, Fishing Rods, Pressure Vessels

Advantages	What To Watch For
• Best Cost Performance • High Tensile Strength • High Energy Absorption • High Availability in differing patterns • Widely Used, High Knowledge Base • Chemically & Moisture Resistant • Widest Variety of Resin Types • Electrically Insulative	• Lowest Strength to Weight Ratio • Comparably Lower Strengths than Carbon Fiber • Less Rigid than Carbon Fiber and Kevlar

KEVLAR

Kevlar is the lightest weight and toughest fabric type widely used in composite industry. It is used today as a fabric alone in bullet proof vests, impact and cut resistant safety equipment, and used as a fire retardant. Kevlar has the highest benefit between being used as fabric or composite. In composite form, Kevlar is used to produce structures that provide the best impact and abrasion resistance characteristics in comparison to other fibers. Kevlar fills the gap of stiffness between fiberglass and carbon fiber while providing high strength reinforcement. Kevlar can be difficult to cut and process unless the correct tools are used. Kevlar composite parts are almost always painted as they will degrade over time when exposed to UV radiation and sunlight.

Common Applications: High Performance Aircraft & Aerospace Structures, Body Armor, Surf boards, Motor Sports Protection, Kayaks, Canoes, and Pressure vessels, Boat Hull Transoms, Automotive body parts

Advantages	What To Watch For
Lightest Weight / Density Highest Toughness Highest Energy Absorption (+Vibration) Highest Impact Resistance Highest Crack Resistant High Strength to Weight ratio Chemically Resistant High Level of Workability	Low Compressive Strengths Fibers Absorb Water (~3.5%) High Cost Toughest challenge to process / cut / prep Poor UV Resistance

COMPARING THE OPTIONS

All composite reinforcements have clear advantages and disadvantages. Even with the information above, selection of a composite material can still be tricky. However, there is nothing to say that a component or structure cannot have the best of all materials.

Take a kayak for example. Using Kevlar as the material will yield a light weight, energy absorbent kayak. However, it may not be very durable once it crashes upon a rock resulting in compression damage. Use of S-Glass fiberglass layer on the outside reinforced with a layer of E-Glass can make a huge difference in the lifespan of the kayak. Using the lightweight advantage of Kevlar in the inner layers may produce the best kayak ever seen. A carbon fiber kayak alone will provide weight savings as the strength to weight ratio is the best and provides a means to engineer a highly rigid and strong hull. The kayak will end up very costly and still may not provide the impact and fatigue resistance needed for a long life. Hybrid materials using CF / FG and Kevlar/CF are also made. Using a Kevlar/CF hybrid could yield a lightweight kayak that takes advantage of both the materials strengths, being stiff while still being able to absorb energy.

The overall beauty of composites is that there can be a thousand different ways to achieve a goal. Composites provide the world an opportunity to use creativity to solve problems using an endless array of weaves, fibers, yarns, twills, and resins.

Characterization	Carbon Fiber	Kevlar	Fiberglass
Cost	1	3	10
Tensile Strength	10	8	7
Strength to Weight	10	9	5
Compressive Strength	10	3	6
Rigidity	10	6	6
Fatigue Resistance	6	10	8
Abrasion Resistance	7	10	7
Processing	7	6	10
Conductive	Yes	No	No
Corrosive to Metals	Yes	No	No
Heat Resistance	10	10	10
Moisture Resistant	10	5	10
Chemical Resistance	10	7	10
UV Resistance	Yes	No	Yes

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