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Carbon Fiber Reinforced Polymer Composites

Dr. Dmitri Kopeliovich

Carbon Fiber Reinforced Polymer (CFRP) is a Polymer Matrix Composite material reinforced by carbon fibers.

The reinforcing dispersed phase may be in form of either continuous or discontinuous carbon fibers of diameter about 0.0004" (10 mkm) commonly woven into a cloth.

Carbon fibers are very expensive but they possess the highest specific (divided by weight) mechanical properties: [modulus of elasticity](#) and [strength](#).

Carbon fibers are used for reinforcing polymer matrix due to the following their properties:

- Very high modulus of elasticity exceeding that of [steel](#);
- High [tensile strength](#), which may reach 1000 ksi (7 GPa);
- Low density: 114 lb/ft³ (1800 kg/m³);
- High chemical inertness.

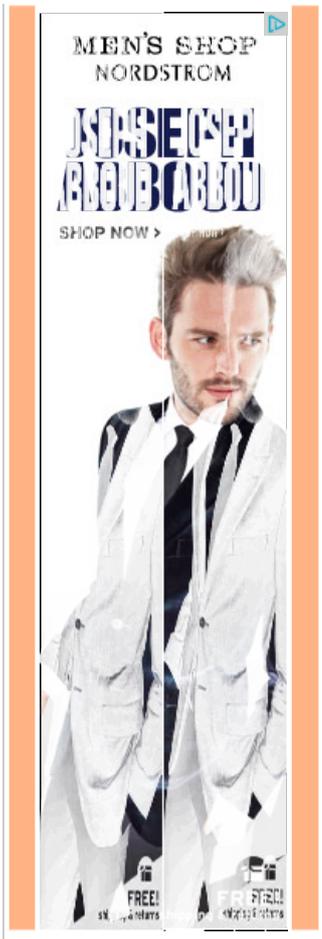
The main disadvantage of carbon ([Graphite](#)) fibers is catastrophic mode of failure (carbon fibers are brittle).

The types of carbon fibers are as follows:

- **UHM** (ultra high modulus). Modulus of elasticity > 65400 ksi (450GPa).
- **HM** (high modulus). Modulus of elasticity is in the range 51000-65400 ksi (350-450GPa).
- **IM** (intermediate modulus). Modulus of elasticity is in the range 29000-51000 ksi (200-350GPa).
- **HT** (high tensile, low modulus). Tensile strength > 436 ksi (3 GPa), modulus of elasticity < 14500 ksi (100 GPa).
- **SHT** (super high tensile). Tensile strength > 650 ksi (4.5GPa).

Carbon fibers are also classified according to the manufacturing method:

1. PAN-based carbon fibers (the most popular type of carbon fibers).



In this method carbon fibers are produced by conversion of polyacrylonitrile (PAN) precursor through the following stages:

- Stretching filaments from polyacrylonitrile precursor and their thermal oxidation at 400°F (200°C). The filaments are held in tension.
- Carbonization in **Nitrogen** atmosphere at a temperature about 2200 °F (1200°C) for several hours. During this stage non-carbon elements (O,N,H) volatilize resulting in enrichment of the fibers with carbon.
- Graphitization at about 4500 °F (2500°C).

2. Pitch-based carbon fibers.

Carbon fibers of this type are manufactured from pitch:

- Filaments are spun from coal tar or petroleum asphalt (pitch).
- The fibers are cured at 600°F (315°C).
- Carbonization in nitrogen atmosphere at a temperature about 2200 °F (1200°C).

The most popular matrix materials for manufacturing Carbon Fiber Reinforced Polymers (CFRP) are thermosets such as epoxy, polyester and thermoplastics such as nylon (polyamide).

Carbon Fiber Reinforced Polymers (CFRP) materials usually have laminate structure, providing reinforcing in two perpendicular directions.

Carbon Fiber Reinforced Polymers (CFRP) are manufactured by **open mold processes**, **closed mold processes** and **Pultrusion** method.

Carbon Fiber Reinforced Polymers (CFRP) are characterized by the following properties:

- Light weight;
- High strength-to-weight ratio;
- Very High modulus elasticity-to-weight ratio;
- High **Fatigue** strength;
- Good **corrosion** resistance;
- Very low **coefficient of thermal expansion**;
- Low **impact resistance**;
- High electric conductivity;
- High cost.

Carbon Fiber Reinforced Polymers (CFRP) are used for manufacturing: automotive marine and aerospace parts, sport goods (golf clubs, skis, tennis racquets, fishing rods), bicycle frames.

Properties of some Carbon Fiber Reinforced Polymer Composites

(Materials Data)

- **Epoxy Matrix Composite reinforced by 70% carbon fibers**
- **Epoxy Matrix Composite reinforced by 50% carbon fibers**
- **Polyether Ether Ketone B Matrix Composite reinforced by 30% carbon fibers**

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