Komposites

Filament wound data sheet

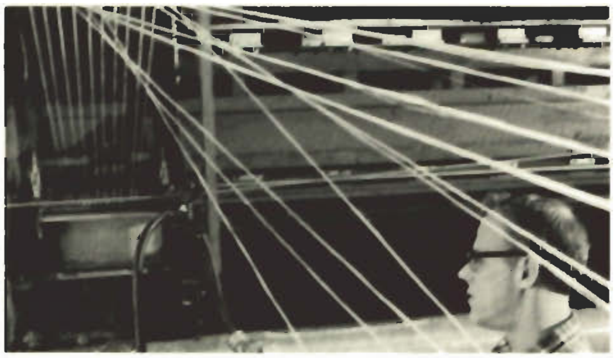
A WORLD OF PRODUCTS FOR INDUSTRY

Effective Performance—Efficiently

Industrial, aerospace and military products requiring high performance properties and extended reliability in adverse environments have achieved cost effective results with filament wound technology.

Filament wound components are designed to utilize the synergistic characteristics of reinforcement, resin systems and controlled winding techniques. In engineered combinations these variables offer:

- controlled directional strength
- high strength to weight ratio
- low density (and low overall weight)
- controlled electrical properties
  —low dielectric loss
  —insulating or non-insulating capability
- chemical and corrosion resistance
- impact and shatter resistance
- excellent reproducibility and machineability
- low thermal conductivity

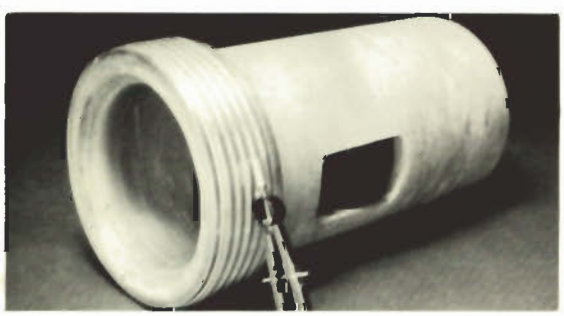


By altering the helical and hoop windings of the glass rovings, components can be designed to meet the mechanical and physical properties of any structural application.

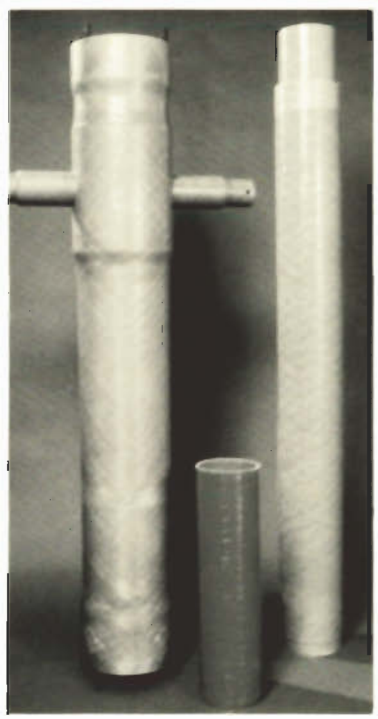
The performance and life-cycle cost efficiency of filament wound technology is reflected in:

- safer, higher capacity aerial lift devices with insulated booms
- more efficient high voltage circuit breakers
- lower field downtime with corrsion and abrasion resistant piping
- lightweight missile nose cones and rocket motor cases
- lightweight corrosion resistant torpedo battery casings and submarine radomes and faired masts
- high voltage fuse tubes
- drive shafts, control rods, structural components
- antennas, radomes
- high pressure bottles
- chemical storage tanks and chemical pump support columns

Lightweight filament wound nose cone for the AIM-9 Sidewinder missile.



An interrupter tube with metal flange.



Left to right: torque tube, frangible FAA light tower and a gun shroud for military tanks.

A helical wound pattern.

Submarine radome housing for sensitive radar equipment, receiving final inspection for service on a U.S. Navy vessel.

C-K Composites, Inc. 5000 Bridgeport Street ▪ P.O. Box 1087 ▪ Mount Pleasant, PA 15666 ▪ Phone 412/547-4581 ▪ Telex 866-666

FILAMENT WOUND TECHNOLOGY

ENGINEERED MATERIAL VARIABLES

Filament Reinforcements

Glass filaments are the most frequently used reinforcements, although aramid, graphite, boron and specially compounded materials are becoming more common to the production floor as proven reinforcements in specialized applications.

Unlike metals, glass reinforcements have no yield point. They exhibit perfectly elastic behavior from no-load to rupture and they do not creep under stress. See Table I for a comparison of properties of glass vs. steel.

Resin Systems

Both epoxy and polyester thermosetting resins have achieved commercial success in filament wound products. Often, the special needs of each product can be met with several resin systems and fillers. Engineers will balance these systems to achieve the most effective performance/cost ratio.

The most important functions of the resin systems are to:

- position the load bearing filaments
- distribute the load evenly among filaments
- protect filaments from abrasion
- control electrical and chemical resistance properties
- provide interlaminar shear strength

PROCESS CONTROLLED VARIABLES

Mechanical Properties

Reinforcement/resin ratios, winding tension and winding patterns establish mechanical properties of the finished product as summarized in Table II. Circumferential hoop windings and more longitudinal (helix) windings at predetermined wind angles give directional strength as required for each design. Figure 1. and Figure 2. show the relative effect of wind angle on modulus of elasticity. High directional stiffness, (high modulus of elasticity) is achieved at wind angles approaching both zero and ninety degrees.

Process/product efficiency is reflected in thin wall sections. Compared to 7075 T6 Aluminum, a glass reinforced filament wound 6" I.D. tube with a 3000 psi maximum rating, weighs half as much and has a 38% thinner wall section. For internal pressure vessels this comparison yields a 214% improvement in efficiency based upon the ratio of pressure × volume per weight of material (ie. PV/Wt).

Comparisons of structural efficiency may be shown by relative load carrying ability per unit weight of material. Table III illustrates the high strength, lightweight advantage of filament wound composites.

These mechanical characteristics are based upon values obtained in a 50-300°F operating range. For higher temperatures the strength is reduced, for low temperatures, the strength is increased. The resin system is the limiting factor at high temperatures since glass retains its strength up to 1000°F. Special resin systems are available to allow operation at temperatures in excess of 500°F. In reported cases, strengths at −424°F were 150% of strengths at 70°F, without brittle failure.

- Machineability: Filament wound components are machineable to close tolerances. Coolants and exhaust ventilation are required for dust control and to help minimize equipment wear.

- Weather resistance: High molecular weight thermoset resins in filament wound components offer excellent resistance to ultra-violet radiation, temperature extremes and moisture. Discoloration, erosion or fiber prominence are minimal on "as wound" surfaces. UV stabilizer additives and special coatings for machined surfaces help to extend product life in severe environments.

ELECTRICAL PROPERTIES

Both resin and glass are excellent insulators and are nonmagnetic. They will not interfere with radar or radio frequency signals. Under special circumstances these characteristics may be adjusted with conductive filaments, wound-in reflective shielding, or surface metallizing. Basic electrical properties are shown in Table IV.

CHEMICAL RESISTANCE PROPERTIES

With few exceptions, filament wound materials are more resistant to chemical corrosion or weakening than stainless steel, monel or titanium. Sample or prototype testing is always recommended to verify compatibility in a given environment. Resistance to a wide variety of chemical environments can be achieved by proper choice of resin and reinforcements.

PHYSICAL PROPERTIES (Glass Reinforced)

- Density.

Glass (% by wt.)	Density (lb./in³)
60	.062
70	.068
80	.074
90	.082
Typical 75-85	.072

- Thermal Conductivity: 1.92 to 2.20 BTU/hr./in/ft.²/°F (6.6×10^{-4} to 7.6×10^{-4} cal/cm²/cm/°C/sec).
- Thermal Coefficient of Linear Expansion: $5\text{-}6 \times 10^{-6}$ in/in/°F (9×10^{-6} to 10.8×10^{-6} cm/cm/°C).
- Surface finish inside is governed by the finish quality of the mandrel and care during extraction.
- Surface finish outside ranges from irregular as wound to very smooth ground surfaces.
- Special surfaces are available to meet needs for low friction or special protection.
- Hardness: Barcol 40-75.

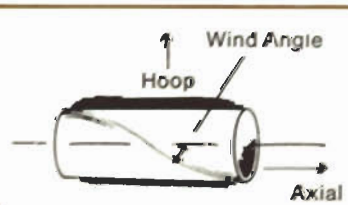


fig. 1

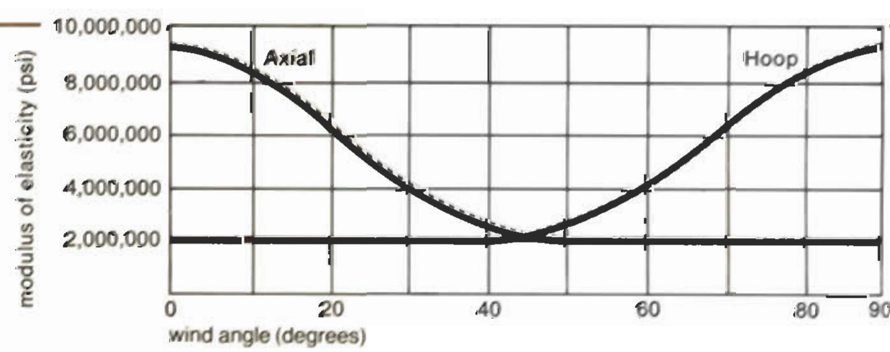


fig. 2 VARIATION OF EFFECTIVE MODULUS WITH WIND ANGLE

DESIGN CONSIDERATIONS

Deflection (stiffness) may be increased or decreased in filament winding by changing the winding pattern. Homogeneous materials (non-fibrous) are only capable of changing this property by increasing or decreasing the cross section.

Frangible joints. C-K can offer a system of controlled force breakaway joints in filament wound light towers. This technology is applicable to other products which require controlled force breakage.

Interlaminar shear stress. In good design practice, the reinforcement filaments carry all static and dynamic loading without transferring appreciable stress to the resin system. "Integral Winding" technique provides high shear strength.

Liners, coatings and inserts. Some applications require properties that cannot be achieved with filament winding alone. In these cases materials that will perform properly are added either inside or outside as liners or coatings. Inserts are frequently used to overcome fastening problems.

Common shapes. Sections of revolution such as round, square, rectangular, oval, teardrop or any convex shape can readily be wound. Concave or intersecting surfaces are difficult and should be avoided for filament winding.

Size. Finished products up to forty feet in length and forty-eight inches in diameter are within our present capability.

Cost/performance. Tooling complexity and tight tolerances add to the overall cost of any design. By combining mechanical functions or assemblies into a single filament wound component, cost/performance benefits can be achieved. Greater use of filament winding properties will yield better performance at lower cost over other materials and processes. Tables V and VI summarize property utilizations and costs of typical filament wound products.

PRODUCT CONSISTENCY

Process integrity and part to part uniformity are assured by computer controlled winding equipment, a high capacity profile sander, a wide range of cutting and machining equipment, and most importantly by skilled craftsmen who are proud of their work.

Quality assurance and testing standards are an integral part of our manufacturing procedures. Complete documentation and government certification requirements are routine.

WORKING WITH C-K

Our skilled engineers and field representatives are available to discuss your application. With their evaluation it may be possible to improve efficiency and performance while reducing the cost of your product through redesign in a filament wound component.

Table I Properties of High Strength Glass Filaments Vs. High Strength Steel Filaments

Grade or Type	Composition	Youngs Modulus (psi)	Tensile Strength (psi)	Density (lbs./in.^{3})	Specific Tensile Strength (in.) (ten. str./density)
E	Calcium Alumina Borosilicate	10.7×10^6	450,000	.092	4,900,000
S	Magnesia Alumina Silicate	12.4×10^6	650,000	.090	7,220,000
Music Wire	Drawn Carbon Steel .004"	29.0×10^6	590,000 Ult. 500,000 Yield	.283	2,300,000

Table II Mechanical Properties of Filament Wound Products (Glass Reinforced)

Property	Typical Values	Predominant Process Variables*
Modulus of Elasticity (Tension)	3,000,000-6,000,000 psi	Glass Type, Wind Pattern
Tensile Strength: Helical Windings	50,000-150,000 psi	Glass Type, Glass/Resin Ratio, Wind Pattern
Compressive Strength: Helical Windings	40,000-80,000 psi	Glass/Resin Ratio, Resin Type, Wind Pattern
Shear Strength: Interlaminar	3,000-20,000 psi	Resin Type, Wind Pattern,
Cross	8,000-30,000 psi	Glass/Resin Ratio, Resin Type
Modulus of Rigidity (Torsion)	1,600,000-2,000,000 psi	Wind Pattern
Flexural Strength	50,000-75,000 psi	Wind Pattern, Glass/Resin Ratio
Bearing Strength	2,000-35,000 psi	Glass/Resin Ratio
Density	.068-.082 lb./in.^{3}	Glass/Resin Ratio

*The Predominant Process Variables are those which have the greatest influence upon the range in the particular values reported.

Table III Comparative Strength to Weight Ratios (Specific Strength)

Material	Density (lb./in.^{3})	Tensile Strength (psi)	Tensile Modulus (10^6 psi)	Specific Tensile Strength (in.)
Filament Winding (Glass Reinforced)	0.072	150,000	4.5	2,080,000
Aluminum 7075-T6	0.10	82,000	10.3	820,000
Stainless Steel 301 Full Hard	0.29	185,000	29.0	637,000
Titanium Alloy Ti-13 V-12 Cr-3 Al	0.165	185,000	16.0	1,120,000

Table IV Electrical Properties

Table IV
Typical Electrical Properties of FWRP Tubes

Dielectric Constant (ASTM Test D 150-64T):
- 60 cps 4.7
- 1 Mc 4.5

Power Factor (ASTM Test D 150-64T):
- 60 cps .85%
- 1 Mc .0135-.0170

Insulation Resistance (ASTM D 257-61):
10^8 meg ohms

Arc Resistance (ASTM Test D 495-61):
150-180 sec.

Dielectric Strength (ASTM Test D 149-61):

Step-by-step, perpendicular
350-420 v/mil

Short time perpendicular
400-550 v/mil

Loss Tan. (ASTM Test D 150-64T):
.018

Table V Product Value Improvement Analysis

Application	Utilized Properties*	Previous Design
Rocket Motor Case	1, 2, 3, 7, 8	Welded Steel
Chemical Storage Tanks	3, 4, 7, 9	Coated Steel
Radomes	1, 3, 4, 5, 6, 8	Glass Cloth-Reinforced Plastics
Torpedo Battery Housing	1, 3, 4, 5, 7, 9	—
Rocket Launcher Tube	1, 3, 4, 7	Aluminum
Electrical Arc Interrupter Tube	1, 3, 5, 6, 9	Paper-Based Phenolic
Railway Tank Car	3, 4, 7, 8, 9	Steel
Chemical Pipe	3, 4, 7, 8, 9	Coated Steel or Stainless Steel
Truck Mounted Booms (Electrical Work)	1, 3, 4, 5, 7, 8	—

*Key to Properties

1. High strength to weight ratio
2. Directional strength
3. Low density
4. Corrosion resistance
5. Excellent electrical properties
6. Low dielectric loss
7. Impact and shatter resistance
8. Good reproducibility
9. Chemical resistance
10. Low thermal conductivity

Table VI Relative Costs

Part	Engineering & Development Costs	Quantity	Mandrel Cost
Pipe	Low	Large	Low
Tubes, Electrical Grade	Moderate	Large	Moderate
Pressure Vessels	Moderate-High	Small	Moderate
Rocket Motor Cases	High	Small	High

C-K Composites, Inc. 5000 Bridgeport Street ■ P.O. Box 1087 ■ Mount Pleasant, PA 15666 ■ Phone 412/547-4581 ■ Telex 866-666

C-K Composites of Canada, Inc.
2870 Slough Street, Mississauga, Ontario L4T 1G3
Phone 416/677-2090 Telex 06-968-565