Fiberglass Engineering Mechanics

Comprehensive Engineering Services For The Corrosion Resistant FRP Industry

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FRP 101

Fiberglass Reinforced Plastic (FRP): A complex non-isotropic material, in which two or more distinct, structurally complementary substances, glass fiber and thermoset polymer resin, combine to produce structural or functional properties not present in the individual component.

CR FRP: Fiberglass reinforced plastic is used in a wide variety of applications. Some examples are: bathtubs, boats, automobiles, aircraft, radar domes, tanks, pipe, duct, etc. Different laminates are used in these varied applications. Laminates which are designed for corrosive environments are known as CR FRP and are used in chemical storage tanks, power plant chimney liners, ducting, piping, etc. Special corrosion resistant resins and special lamina construction methods are used in CR FRP laminates.

What are the advantages of CR FRP over more traditional materials, such as concrete or steel?

In most environments, CR FRP is far more corrosion resistant than concrete or steel. While coatings help the corrosion resistance of concrete and steel, the corrosion resistant coating is relatively thin. A pin hole can lead to significant corrosive attack. FRP, by contrast, is corrosion resistant throughout. Components made from FRP are lighter in weight than concrete and steel, which is often a significant advantage. A number of other advantages could be noted. In piping, CR FRP is smoother, reducing pump size and power consumption. In sea water piping, marine growth is much less severe in FRP pipe than concrete or steel pipe.

What are the advantages of CR FRP over stainless steel, Hastelloy and titanium?

CR FRP is competitive with 304 series stainless steel and is significantly less expensive than 316 series stainless steel, Hastelloy and titanium. For example, the cost savings realized by using FRP rather than Hastelloy C-276 in a power plant chimney liner is typically on the order of millions of dollars.
Another significant advantage of FRP is the ease of molding complex shapes. It is often problematic to fabricate complex shapes out of metals, while it is relatively easy in FRP.

How does one determine the suitability of CR FRP for a particular service?

Go to the FEMech Resources page and go to one of the resin manufacturer's corrosion guides. The information provided will cover many situations. For mixtures of chemicals and unusual operating conditions, call one of the Resin Technical Support numbers listed on our resources page.

What is the typical construction of a CR FRP laminate?

A CR FRP laminate consists of three lamina. Each lamina will be composed of one or more layers.

Surface Veil – This is a resin rich lamina consisting of one or two layers of surface veil. Typically, three types of veil are used: C-glass, polyester and carbon veil.

Corrosion Barrier Interior Lamina – Following the surface veil is a minimum of two 1-1/2 oz/sq ft (450 g/sq m) chopped strand glass reinforced plies. For very aggressive conditions, more plies may be specified.

Structure – Various lamina compositions are used for the structural lamina. The most common ones are filament wound and chop-woven contact molded.

What determines the mechanical properties of FRP?

The mechanical properties of FRP are determined largely by the glass fiber reinforcement scheme used in the laminate. The experienced FRP design engineer tailors these properties to the particular application. Laminate moduli, Poisson's ratios, coefficients of thermal expansion and density may be calculated using Lamination Analysis software. In some cases, laminate strengths can be predicted using the Lower Bound Method. In other cases strengths must be measured by laboratory test.

Why is FRP Non-Isotropic?

FRP laminates are non-isotropic because of the glass fibers. A common example of a non-isotropic material is wood. In-grain and cross-grain properties of wood are very different. Plywood is made using oriented layers to create a product with tailored properties. In the same way, FRP laminates are often composed of different layers to create the desired global properties.

In general, what are the properties of CR FRP?

CR FRP has a high strength to weight ratio and a relatively low stiffness (modulus) to weight ratio. Laminate strengths can range from 9,000 psi to 90,000 psi in the load bearing direction. Laminate moduli can range from 800,000 psi to 5,000,000 psi, once again in the load bearing direction. By contrast, plain carbon steel has a strength of about 36,000 psi and a modulus of 29,000,000 psi. While many FRP laminates are stronger than steel, all are much less stiff than steel. This results in FRP having a much higher elastic elongation than steel which is one reason FRP is widely used in such applications as fishing rods.

Is FRP ductile?

Elastic elongation is the stretching of a material within a range where it will return to its original shape. If a screen door spring is stretched within the elastic limit, it will return to its original length. Plastic elongation is the stretching of a material in a range where it assumes a new shape. If a screen door spring is stretched beyond the elastic limit, it will have a new, longer length than before. Shigley says, "a ductile material will be capable of a relatively large plastic deformation before fracture".
FRP has a high elastic elongation, much higher than most metals, but it is not ductile. When the laminate strength is exceeded, FRP will fracture.

Why are FRP components usually made to an ID rather than to an OD?

There are two fundamental reasons. First, most CR FRP is typically molded on a mandrel. Therefore, the ID is controlled by the mandrel size, while the OD becomes a function of the ID and the wall thickness. Second, it is convenient to use standard steel components for FRP molds. Steel vessels are made to a given OD; therefore, the FRP made on these steel vessel parts (such as a steel head used as a FRP mold) are ID parts.

Is it possible to make CR FRP abrasion resistant?

CR FRP can be made very abrasion resistant by the addition of materials such as silica oxide or silicon carbide particles. AR FRP is widely used in such applications as slurry piping in power plants.

Is there a practical way to handle static discharge issues in CR FRP laminates?

Static discharge can be a very serious concern for ducting, chimney liners, and vessels subjected to dry, windy conditions. Static discharge is very easily addressed by the use of carbon fiber surface veil and/or the addition of graphite power to the laminate. Of course, provisions must be made for grounding the conductive layer(s).

What codes and standards are used for the design of CR FRP equipment?

ASME, ASTM and AWWA all publish codes and standards for FRP. IBC and ASCE publish codes for wind and seismic which are applicable to FRP equipment. See the FEMech Resources page for

information on purchasing these codes and standards. Listed below are some of the most important codes and standards for CR FRP equipment

ASME RTP-1 - Reinforced Thermoset Plastic Corrosion Resistant Equipment

ASME Section X – Fiber-Reinforced Plastic Pressure Vessels

ASTM D5364 - Standard Guide for Design, Fabrication and Erection of Fiberglass Reinforced Plastic Chimney Liners with Coal Fired Units

ASTM D3299- Standard Specification for Filament-Wound Glass-Fiber-Reinforced Thermoset Resin Corrosion-Resistant Tanks

ASTM D4097- Standard Specification for Contact-Molded Glass-Fiber-Reinforced Thermoset Resin Corrosion-Resistant Tanks

AWWA C950 – AWWA Standard for Fiberglass Pressure Pipe

ASTM D2996 Standard Specification for Filament-Wound Fiberglass (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe

ASTM D2310 Standard Classification for Machine-Made Fiberglass (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe

ASTM D3517 Standard Specification for Fiberglass (Glass-Fiber-Reinforced Thermosetting-Resin) Pressure Pipe

ASTM D3982-03 Standard Specification for Contact Molded Fiberglass (Glass Fiber Reinforced Thermosetting Resin) Duct and Hoods

How is CR FRP equipment inspected?

In most cases, CR FRP laminates are kept translucent so that they can be visually inspected. ASME RTP-1 Table 6-1 has an extensive guideline for visual inspection criteria. In some cases, laboratory tests should be run on manway or nozzle cutouts. The two most important tests are glass content and tensile properties. Acoustic Emission testing is a valuable tool for tanks and pressure vessels. See the FEMech Testing Services page for more information.