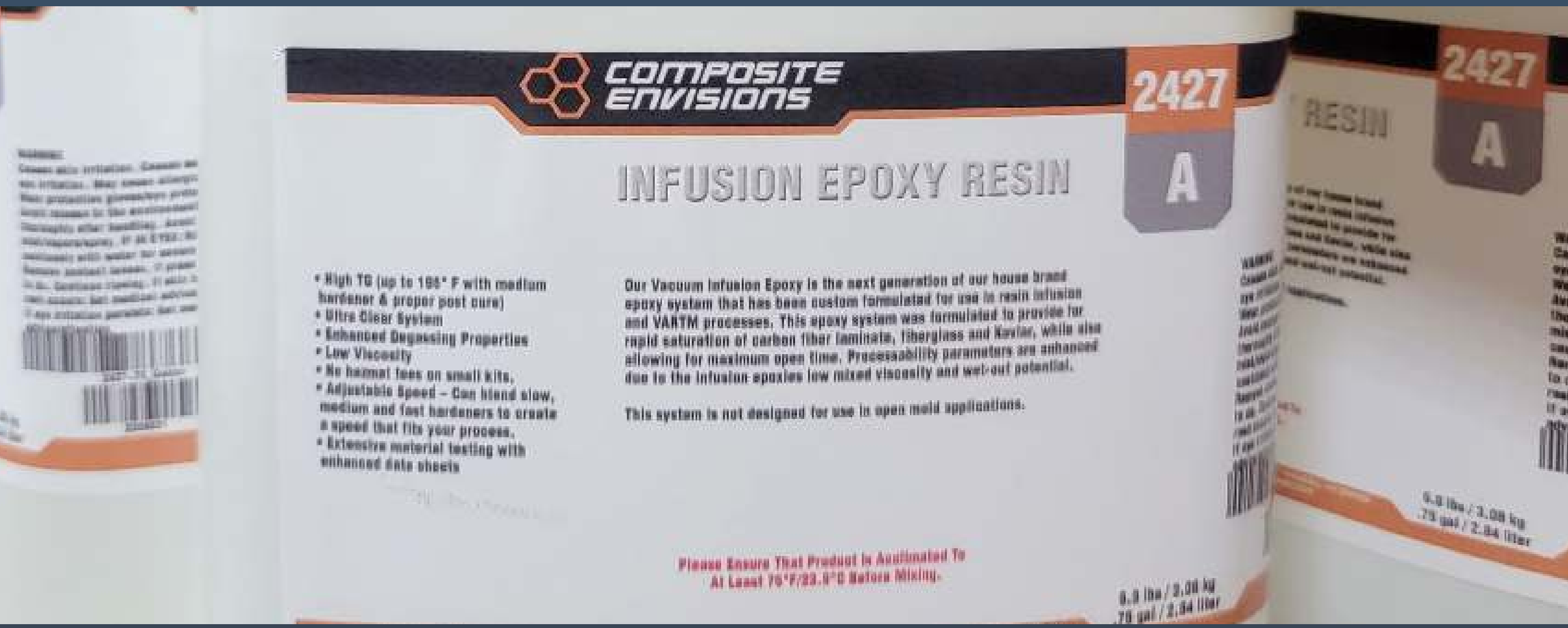

RESIN SELECTION

COMPOSITE ENVISIONS

INTRODUCTION

From the many choices of different resins, the main categories for high performance composites are Epoxy, Polyester, and Vinylester. These three resin types are responsible for fabrication in billions of aerospace, automotive, and marine applications but are not limited to home repairs or even infrastructure to buildings and bridges. Possibilities are nearly endless as resins are engineered to change the perspective on speed, efficiency, and strength.

Not all resins are created equally. Though visually sharing similarities in cured parts, resin types differ heavily by their molecular formula. These chemical differences effect the composite's final properties heavily. Curing parameters, modulus, total strength, primary & secondary bonding properties, shear strength, chemical compatibility and many other aspects are affected by the resins' type.

THIXOTROPIC RESINS

As fluids, resins fall under one of two categories, Newtonian or non-Newtonian. Newtonian fluids such as most resins keep a constant viscosity (thickness) at all shear rates at constant temperatures. (Why heating resin to makes it easier to flow) Thixotropic epoxies are different. This non-Newtonian resin starts like a gel at rest yet becomes less viscous when worked or agitated and will return to the original viscosity while standing.

Otherwise meaning that the Thixotropic resin doesn't run down parts (sag) or flow easily at rest. Thixotropic resins get easier to work into place as force is applied to cracks or vertical surfaces, but when work is done, it returns to its original gel like state. Thixotropic resins are often used to reinforce Fiberglass, Kevlar and Carbon Fiber where bonding items with irregular surfaces or gaps where most epoxies would not be able to make contact in the cure cycle. Because it acts more like an adhesive than a resin, it is used primarily for crack filling and surface sealing on several differing substrates such as metals, leather, wood, ceramic, felt, cement, most plastics and rubbers. Certain thixotropic adhesives have been known to be used in automotive manufacturing for bonding hardware onto panels because no matter where it is applied, it will not run off the surface. In addition, it takes the high bond strength of epoxy with a short setting and curing time to form a highly resilient bond (chemically resistant).

EPOXY RESINS

Epoxy resins when used in traditional methods are made of two parts; the liquid resin and a selected hardener, based on desired cure time. Through proper mixing and application of this resin, epoxy will yield the highest in strength to weight ratios of compared resins. Epoxy resins will simply outperform other resins on many applications. One reason it is placed in everything from general artwork, aerospace grade engine components, and some marine applications. Possibilities are nearly endless up to a service temperature up to 350F on some designed epoxies. Epoxy resin provides strength, better primary and secondary bonds than other resins, also making it ideal for small repairs. However, it is consequently more expensive. For larger parts, such as a boat hull or kayak, a different resin may need to be considered if cost is a factor of design.

Optimal Epoxy Usage: When used with Carbon Fiber, Kevlar, or Fiberglass woven or unidirectional fabrics, epoxy provides strength advantages over any other resin. However, when used with Fiberglass CSM (Chopped strand mat) the resin can be tough to wet out completely, especially without assistance of a vacuum bag. This can lead to a resin starved condition that will not meet expectation or needed strength characteristics.

POLYESTER RESINS

Because Epoxy resins are so expensive, much of the marine industry uses Polyester resins for larger parts and for fabrication of boat hulls. However, polyester resins are not limited to boat hulls or the marine industry, it is in fact the most common resin used in the world. Polyester resins generally have a lower viscosity and have a two-part curing system that is not controlled by air to cure. A “laminating resin” provides tack for layup and generally allows for heavier build up of fabric layers before applying a final coat of “finishing resin” for cure. Polyester resin uses an acid to allow for accelerated curing at room temperatures. The selected mixture of these resin components allows for cure times to be manipulated for time needed of the part’s layup process. Overall, polyester resins provide a lower cost solution that is compatible with impressive surface finishes such as gelcoat. However, polyester resins are weaker and have a shorter shelf time than epoxy. Shelf life of most polyester resins are less than a year compared to the three years of most epoxies. Polyester resins are typically not as waterproof as epoxies.

Optimal use of Polyester: Most polyester and vinyl ester resins carry a much lower viscosity. This allows it to run through even the thickest Fiberglass (CSM). When used together the material will wet out easily, provide strength to a composite that will take a beating, all while providing a lower cost solution.

VINYL ESTER RESINS

Vinyl Ester resins perform optimally when in conjunction with polyester resins. Vinyl Ester and Polyester are highly similar in chemical makeup and bond well to each other. For instance, It can be as an outer layer to provide chemical protection and additional strength and blister protection in a polyester resin system. These advantages together provide the opportunity for a high-performance composite whether using Kevlar or Fiberglass. High performance boat manufactures across the nation continue to use these resins to push the limits of water is possible on the water.

PUTTING IT ALTOGETHER

On the surface, it is simple to say that epoxy is superior to vinyl ester & polyester. In many ways this is the case; In aerospace applications especially, epoxy is hard to beat where having the strongest, lightest composite is desired with cost being implicated with efficiency. However, there are many applications in which polyester & vinyl ester are better for a given process.

Resin selection varies heavily upon what fabric is to be used and the final use capability needed out of the final composite part. Most common fabrics used are Carbon Fiber, Aramid (Kevlar), and Fiberglass.

In the marine industry for example, FG CSM's advantage lies within its ability to utilize the friction between each fiberglass strand to absorb most any energy placed upon it. Application polyester or vinyl ester resin is the most effective way to utilize this material.

SELECTING THE CORRECT RESIN

Choosing the correct resin will make or break your project. While there are any number of things to consider, determining the answer to these five questions should set you straight.

How much time is required for layup and bagging processes?

Important factors of the layup process can may control what fabrics are used due to design constraints in the part. Any wet layup with a given resin is going to have a working time or "pot life" or gel-time. Though these times differ slightly, the "pot life" is a tested amount for a resin's viscosity to double, this amount of time allows for layup to be complete and optimally for bagging processes to have neared completion (if using vacuum bagging). This time is extremely important to know for any project as layup & bagging processes should not be rushed through.

How large is the part?

For many large parts such as boat hull, kayak, large fairings etc; polyester or vinyl ester resins provide an advantage. While smaller can be achieved with Epoxy resin. Unless utilizing prepregs whose curing variation opens limits to a heat only cure process, providing layup times in the factor of days instead of hours.

Is a repair being performed?

If selecting a resin to use for repair, epoxy will provide peace of mind when not knowing the molecular makeup of any component below. Epoxy resins can be used to provide a bond between properly prepped gelcoats and polyester / Vinylester surfaces. Repairs with Poly/ Vinylester can be made to like surfaces but cannot be made on epoxy surfaces.

Will the final part be painted or will be composite be exposed to water or sunlight?

Epoxy provides great protection from water however; additional measures need to be taken if the epoxy is bare (no paint) to a fabric on a part. Certain epoxies will "yellow" or degrade over time in sunlight. This can be mitigated or eliminated by usage of some epoxy resin additives.

What temperatures will the part see during its life?

Service temperatures and glass transition points should be noted when in design of a part to be sure that a given resin will perform under needed conditions. Glass Transition (Tg) is one of the most important properties of any material. The Tg is the temperature in which the rigid cured polymer turns into a soft rubbery material. Yes, it can be exceeded in some senses however, as a thermoset, it will not never return to the same material properties as before.

General Service temperatures of commonly used two component epoxies are around 250F. However, certain epoxies have been engineered to reach service temps up to 600F. Polyester and Vinyl Ester Resins are usually in the ballpark between 180-250F for a service life.

If service temperature really becomes a factor, there is a solution for that: BMI resins are typically used in the aerospace industry where high service temperatures are required. Having all the strength capabilities of composites, BMI resins are capable of service temperatures above 450 F. This categorizes for uses such engine inlets, body panels, and any structural area that will likely see a higher temperature. For example, it is used in the tail sections of some leading helicopter companies.

Polyimides resins used above BMI resin service temperatures. These applications include missiles and various defense systems. However, it is extremely expensive, and the materials used are toxic. In addition, processing these composite parts are hindered by a condensation reaction that causes water to be formed during cure. Polyimides are chemically restrained to a brittle composite when formed.

THERMOSET POLYMER RESINS

Each one of the above resins are categorized into what is called a thermoset polymer. Thermosets are one of two systems used in categorizing every crosslinked polymer structure that is the entire existence of resins themself. Thermoset resins (or polymers) are cured by crosslinking of molecules (Explaining why most resins have a “Part A” and “B”) or cured by the mechanism of heat. (Used in Prepregs) Once thermosets are cured, the molecules are SET. Exposure to high heat conditions, above its Tg, will cause material degradation and the composite will become very brittle.

If the term thermoplastic is new, look no further than a water bottle, trash can, computer mouse…. Endless amounts of plastic are simply all over the world. Plastic is not only used to name many of these things used in everyday life but also to classify polymers by category. The second category of polymers, Thermoplastics, start as pellets that are processed by melting. When application of heat is applied at a respective temperature, the pellets become liquified and fill a cavity for nearly any mold design. Once heat is removed, the liquid returns to its glass-like form in the shape the liquid took. (Plastic manufacturing in a nutshell) However, thermoplastics do not degrade in high temps, when heated, thermoplastics re-melt. The cycle can be repeated a limited number of times before the material properties are degraded beyond use. Thermoplastics are generally not known for high ultimate strengths or for high temperature capability. But they are tougher and are more flexible. In addition, thermoplastic manufacture is cheaper by complete economies of scale.

In resin terms, thermoplastics alone are generally nowhere in the ballpark of stiffness / ultimate strength / heat capabilities when compared to a thermoset resin-based carbon fiber laminate. However, when plastics are reinforced by something as stiff as Carbon Fiber, the result is ideal for many applications. Low weight, high strength and stiffness, high chemical resistance, and added fatigue strength make CFRTP attractive to many industries. Advantages of thermoplastic Carbon Fiber parts include increased impact resistance and ability to reform the composite at the end of its lifecycle.

There are a few different ways to process CFRTP. (Carbon Fiber Reinforced Thermoplastics) One is a modified Resin Infusion process in which the thermoplastic pellets / powder is to be heated to liquid form before pulling it into the mold surface to the carbon reinforcement plys. These plys may be laid up using a “binder” resin to aid with the layup process. Another, building upon the “simple” resin infusion process, being molded by a heated “injection molding” press. (Which is generally where the process would see its greatest amount of expense) A dry layup composed of carbon fiber plys or chopped CF (but still available with a binder resin for ease in layup) are placed onto a mold and heated resin is brought through with aid of a vacuum. This is also known as RTM. (Resin Transfer Molding) Often the press itself is used as a heating mechanism which controls the temperature of the thermoplastic resin coming through the tool. In addition, the press will provide mechanical pressure for tighter surface finish tolerances and will yield a near net shape composite laminate.

CFRTPs are also available in prepreg, multi-ply sheets that can be heat pressed into a final desired form. Building from older metal technology, heat stamping of these prepregs are redefining how the world looks at carbon reinforced materials and their ability to be mass produced. CFRTP processing has the potential to change the way industry views carbon fiber laminate manufacture. The decrease in such cycle times for mass production equates to affordability not limited to aerospace, automotive, technology, marine and industries. The automotive industry has been looking for lower cost solutions for incorporating composite reinforced materials for decades!

Some types of Thermoplastic resins: Polypropylene (PP) & Polyethylene (PE) provide a resin that is strong and not water sensitive. These two lower cost resin solutions are however limited by their lower service temperatures of around 200 F. PEEK & PEI offer higher temperature capabilities but generally limited to the aerospace industry due to cost.

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