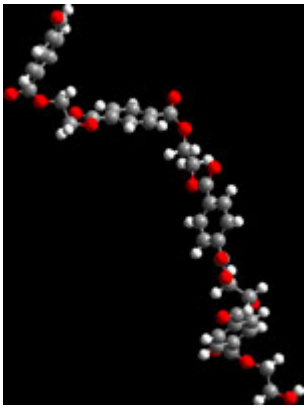
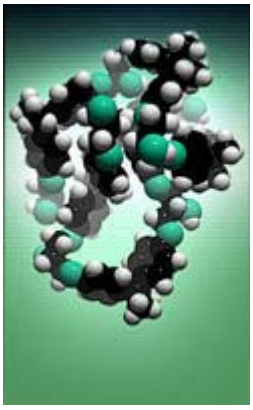
Advantages of Epoxy resin in marine composite structures

Three types of resins are used for boat construction: Epoxy, Vinylester and Polyester. Although they all are thermosetting polymers that become hard when mixed with a catalyser, huge differences exist.

In the 1960's, boat construction with glass reinforced Polyester took a major leap. Fifteen years later, boat yards started filling with Polyester hulls suffering from osmosis. As a consequence, Vinylester resins, an hybrid form of Polyester which has been toughened with Epoxy molecules, were created in the Eighties. However, although Vinylester resins have solved osmotic blistering issues, they still have the same limitations as Polyester in terms of shrinkage, bonding and fatigue.



Polyester chain: poor cross-linking and bonding



Epoxy chain: excellent cross-linking and bonding

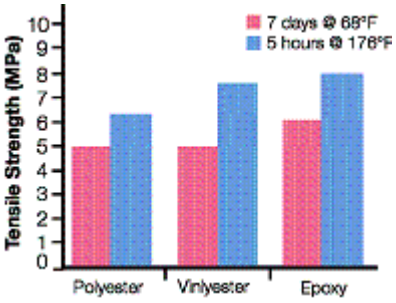
Today, 95% of pleasure boats under 60 feet are still made with Vinylester or even Polyester resin. The main consideration for materials selection for most composite builders is cost, with performance and more importantly value for money often being a secondary consideration. As a general rule, Epoxy resins are between two and five times more expensive than Vinylester resins, which are themselves twice as expensive as Polyester.

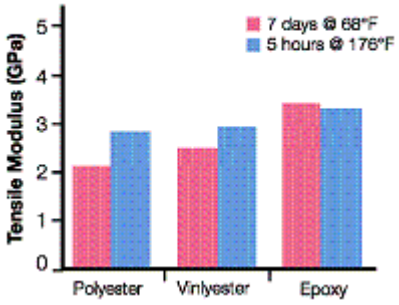
Since the resin can constitute 40 to 50% of the weight of a composite component, this price difference is seen as having a significant impact on the cost of the boat structure. However, the value of higher quality and long term gain of better durability (therefore better resale value) can be tremendous.

What contributes to this better value?

Mechanical properties

Two important mechanical properties of any resin systems are its tensile strength and stiffness. The figure below shows results of tests carried out on commercially available Polyester, Vinylester and Epoxy resin systems, either cured at room temperature or post cured at 80°C.





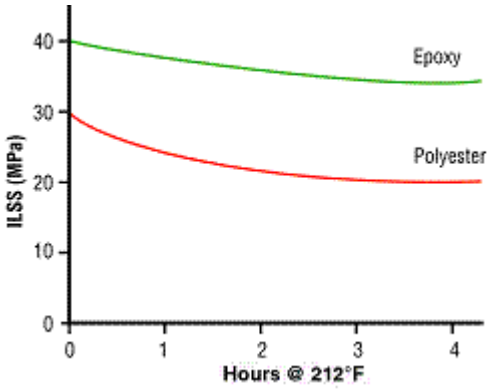
(Source: Gurit SP)

After a cure period of seven days it can be seen that the tensile strength of the Epoxy resin is 20 to 30% higher than those of Polyester and Vinylester. More importantly, after post cure the difference becomes ever greater. A post-cured Epoxy laminate will exhibit tensile strength and modulus (stiffness) close to double that of a non-post cured Polyester or Vinylester laminate. Therefore for the same required strength and modulus, the structure of an Epoxy built boat can be built considerably lighter.

It is to be noted that boats are rarely post cured in the workshop. The core and laminates of the Spirited "ATL Duflex" panels are co-cured in a hot press, a method that consolidates the laminate under pressure, increasing the fibre volume and therefore the strength of the finished panel.

Porosity

Epoxy resin is in average four times less porous than a Vinylester resin, and seven times less than Polyester. In addition, both Vinylester and Polyester resins are prone to water degradation due to the presence of the esters in their molecular structures. As a result, a Polyester laminate can be expected to retain only 65% of its inter-laminar shear strength after immersion over a period of one year, whereas an epoxy laminate immersed for the same period will retain around 90%. Therefore you can have the comfort of having your boat all year round in the water, without being worried of any moisture penetrating the core, or any loss in laminate strength.



Effects of period of water soak on resin - Inter-Laminar Shear Strength (from Gurit SP)

This allows the immerged parts of the hulls to be built with a composite sandwich in the same way as the rest of the structure. Yachts built with Vinylester or Polyester resins generally have a monolithic laminate hull under water, which results in a heavy and brittle structure. Additionally, most shipyards offer an "anti-osmosis" treatment (as an option !!), which is merely composed of two coats of Epoxy. Comparing this with an epoxy-built yacht is like comparing zinc-coated steel with stainless steel...

Bonding

Bonding between an Epoxy laminate and the core is four times stronger than with Vinylester : 14 MPa versus only 3.5 MPa for Vinylester resins, and even less for Polyesters. In addition, as Epoxy cures with three times less shrinkage than Vinylester and Polyester, the surface contacts between the laminate and the core are not disturbed during cure, ensuring that the structure will be able to flex and strain without micro-cracking or delaminating.

Unlike Vinylester and Polyester resins which are compatible with uncured fibreglass only, Epoxy resin will bond dissimilar or already cured materials, which makes repair work that is very reliable and strong. Epoxy actually bonds to all sorts of fibres very well, and also offers excellent results when it is used to bond two different materials together.

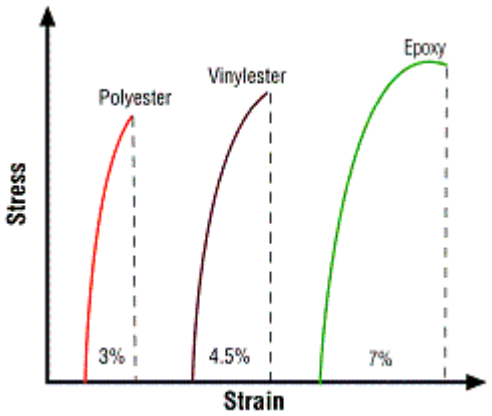
Resistance to fatigue

When navigating, with each wave and movement, the structure suffers from repeated small shocks and stress, which cumulate to millions during the life of the boat. Fatigue failure results from the gradual accumulation of very small amounts of damage.

Long before ultimate load is reached and failure occurs, the laminate will reach a stress level where the resin will begin to crack away from those fibre reinforcements not aligned with the applied load. This is known as ‘transverse micro-cracking’ and although the laminate has not failed at this point, the breakdown process has commenced.

The strain that a laminate can take before micro cracking depends strongly on the toughness and adhesive properties of the resin system. For relatively more brittle resin systems, such as many Polyesters and Vinylesters, this point occurs a long way before laminate failure, and so severely limits the strains to which such laminates can be subjected. In an environment such as water or moist air, the micro-cracked laminate will absorb considerably more water than an uncracked laminate. This will then lead to an increase in weight, moisture attack on the resin and fibre sizing agents, loss of stiffness and with time, an eventual drop in ultimate properties.

The superior ability to withstand cyclic loading is an essential advantage of Epoxies vs. Polyester resins. This is one of the main reason for which Epoxies are chosen almost exclusively for aircraft structures.



Typical resin stress/strain curves (from Gurit SP)