FIBREGLASS REINFORCED PLASTICS (FRP) EXPLAINED

by **DAVE GIDDINGS**

This article explains why you should use epoxy resin and glue when building a composite boat and when doing repairs or refurbishment, instead of using polyester or vinylester. It concerns me that people do not understand there are different resins for fibreglassing and their applications. I must admit I was like that many moons ago, when I first started playing with boats.

I probably receive at least one telephone call a week from someone chasing polyester resin to carry out a repair or modification on their fibreglass boat or sheathing the outside of a beautiful old Putt-Putt or other carvel or clinker boat. After I have asked a few questions, it is invariably, identified that they really need epoxy resin for their project. They have no idea of the difference between polyester, vinylester and epoxy resins, other than epoxy is more expensive. What never ceases to amaze me, is when I walk into chandleries and hardware stores and see fibreglass repair kits sitting on the shelf that contain polyester resin and most of the time the sales representative will blindly sell the kit to unsuspecting customers as they do not know the difference, either.

It is absolutely wrong, as polyester is an extremely poor adhesive for carrying out repairs to fibreglass boats and other structures. The reason they do it is that polyester resin is cheaper than epoxy resin and the packager and retailer can make more margin than selling a kit that contains epoxy resin. Even if there were epoxy repair kits sitting beside the polyester version, it would require trained sales staff who could explain the difference or the epoxy kits would sit on the shelf collecting dust. I am waiting for a fatality were a repaired boat sinks due to delamination and some poor bugger drowns. Where safety of life at sea is paramount you need the best product available for the application.

When we use the term fibreglass, we mean plastic reinforced with fibres of glass commonly known as Glass Reinforced Plastic (GRP) or Fibreglass Reinforced Plastic (FRP). The fibres come in many different constructions including chopped strand, woven, knitted and sown. Then there is the orientation of the fibre bundles along with weights from 25gram that is like tissue paper to almost 1000 grams per square metre. Then there are the exotic fabrics such as carbon fibre, Kevlar, basalt, Innegra and Flax.

Do not get me wrong polyester resin is a brilliant and economical product for making odd ball shapes in a mould such as boat hulls where production requires multiples of the same structure. It should be applied wet on wet or the job completed before the polyester cures fully so that it will chemically bond to the previous layer. The problem is that it becomes very hot when laid down too thick, especially when inexperienced applicators and/or poor technique is used.

In the early days of playing with polyester, when thick was best, they would lay up about half thickness and leave the layup cool overnight. Then finish up the layup the next day which was fine if it had not fully cured. Unfortunately, when left too long or the mix was too hot it would cure off and the fresh layer did not stick to the previously laid glass.

Most things that we describe as fibreglass use polyester resin as the plastic system. Nearly all fibreglass boats are manufactured from polyester based fibreglass, unless it is high performance where strength and weight is an issue. In these applications vinylester or epoxy is used. This is usually with carbon-fibre or a composite core to reduce weight.

POLYESTER – ADVANTAGES & DISADVANTAGES

Polyester is used in most manufacturing applications as it is:

- Cheap and readily available
- Reasonably good with ultraviolet light and weathers slowly, but over a number of years, the surface does degrade and become chalky, if not polished regularly
- Relatively easy to use with a reasonable degree of success. Although, two to one (2:1) ratio epoxies, such as Bote-Cote, are easier to mix and safer to use
- Great for mass production where weight is not an issue for moulds, as it does not stick as tenaciously as epoxy resin and readily releases from prepared moulds. This is aided as it shrinks slightly as it cures.

Although, polyester resin has a number of disadvantages with:

- The most significant in the marine application, being osmosis. Nearly every permanently immersed boat, manufactured using polyester, will eventually suffer from its hideous intrusion. Osmosis is either surface blisters that form due to small defects or deep delamination within the fibreglass due to the relative ease with which water can diffuse through cured polyester. Case Study one is a classic example
- As highlighted already, it is a poor adhesive. This makes polyester an unwise choice for repairs as the repair stands a likely chance of delaminating or peeling off, if put under load or shock situations. Check out Case Studies two and three for classic examples
- It shrinks as it cures, which makes it easy to remove from a mould. This puts the laminated bond under tension and that combined with the poor adhesive qualities causes delamination when impact or bending loads are applied to a joint. Cored boat hulls and decks are classic examples of poor use of polyester resin. Some classic examples are described in Case Studiestwo and three. Plus there are many examples of foam core boat decks that sound like walking on eggshells
- Polyester manufactured products are fairly brittle and readily crack and hole if subjected to impact
- It is also heavy as quite a thick lay-up must be used to achieve adequate strength and it is best suited to building things that are not weight sensitive
- Polyester resin is only compatible with fibreglass fibres. It will not adhere to carbon or kevlar fibres
- Polyesters historically exhibit poor performance in the areas of adhesion and elongation, rendering the finished part prone to micro cracking and secondary bond failures
- It is classed as Dangerous Goods and can be quite volatile for those not careful in mixing and using immediately. There is also the increased cost of transport
- MEPK – the catalyst is a pretty nasty chemical and should be handled with caution
- Polyester is prone to over cooking or not curing when used by in-experienced users
- Polyester resin goes off in the container over about a 12 month period.

CASE STUDIES

The following case studies provide a few examples of the limitations or incorrect use of polyester resin that I have personally been involved with over the years. It was not necessarily poor skill level that created your poor results.

Figure one – Osmosis damage ground out.

Case Study One – Way back in 1997, I did some osmosis repairs on my Clansman yacht as she is an osmosis honey pot. There was an article on this subject published in *Multihull World* #130 (Jan/Feb 2015) titled 'Hindsight is Brilliant'. At the time, I was a novice and unaware of the difference between the resins and the salesman at a large marine chandlery happily sold me polyester resin to repair the areas I had ground out. I will guarantee he did not know the difference as he did not try and upsell me to epoxy. Guess what, I had to do at least 80% of the osmosis blisters again in 2011 and *figure one* shows the extent of the osmosis damage as ground out in 2011 and *figure two* a blister repair that had delaminated from my 1997 effort.

All of the blisters had pulled away (grown at a depth of 5mm. When ground out, this horrible dark brown mess sprayed out. The FRP surface underneath is gloss surface indicating the next layer of fibreglass had not adhered. Apparently, they used to lay up over two days, especially in summer, as the hulls laid were 12-15mm thick it generated too much heat, if not careful. SYLVARA is a victim of polyester's poor adhesion qualities.

Figure two – Polyester osmosis repair delaminated.

Case Study Two – A customer of ours, who is a truck repair specialist, had been using polyester resin to carry out repairs as most truck bodies these days are made from FRP. They had been experiencing heaps of warranty claims on repaired fibreglass panels due to delamination. We introduced them to Bote-Cote Epoxy Resin and EPOX-E-Glue and the warranty issues went away. We even developed a technique for them to accelerate the cure of EPOX-E-Glue. Important criteria in their situation, in case the boss fronts up in the morning and states "that truck has to be out of here by close of business today". The technicians can undertake the repair and paint it in a single day with the truck ready to drive out by 1600. No, this technique cannot be used on wood or you will end up with a horrible mess. There is good information on this subject in the article 'Finishing the Job' in *Australian Amateur Boatbuilder* #97.

Case Study Three – Another classic example of polyester being a poor adhesive occurred one Sunday morning whilst transporting our demo FRP dinghy on my car roof racks. A piece of FRP broke out of the gunnel and allowed the rope to come loose. The darned thing came off the roof rack at 70km/h and slide down the bitumen road behind me on the brass keel strip. There was very little impact damage but most of the glassed polyester seats/buoyancy tanks had delaminated along with other fibreglassed joints. See the result at *figure three*. It also backs up the statement that polyester is structurally okay when laying up with wet on wet but unable to stand up to stress or shock loads.

Figure three – Dinghy seat delamination.

Case Study four – To include a poor wooden boat restoration; a customer at Lake Macquarie restored a classic carvel hull Lake Mac fishing launch. Before he started, he asked me to have a look, as I was in the neighbourhood. The hull had been sheathed with polyester and chopped strand matt which looked very ordinary. Plus, there was quick drying cement in the bilge over a plank weeping seawater. I envisaged rotten timber between the polyester and planks. Fortunately, the damaged area must have been from hitting something and the salt water seeping in and filling the bilge had actually preserved the planking. In most cases, once sheathed with polyester resin the water lying inside is fresh water. In these situations, you might as well buy a chainsaw, as the hull is guaranteed to have rotten planks within a few years.

Figure four – Lake Mac launch before restoration.

Anyway, once he pulled the launch out he was able to easily peel the FRP off, as there was no adhesion. Figure four shows the launch before restoration, *figure five* – the FRP peeled off and *figure six* the finished restoration that is a credit to the owner as he saved another historic launch from the boats graveyard.

Figure five – Polyester fibreglass peeled off.

For more information on repairing rot refer to the article titled 'Modern Technology Rot Repair' in AABB #94. Plus, there is a full series of photos on the project at **www.BoatCaftNSW.com** under customers projects. The completed restoration is a credit to the owner, as he has done a magnificent job.

Figure six – Lake Mac launch after restoration.

Case Study Five – Last but not least, my mate asked me to sort out leaks in his Careel 18 trailer sailer. The rudder pintles were identified as the source, as the 40 year old teak packing block was soft as cheese and the pintle loose. A hole was cut to fit a bung, as access was needed to the bolts to fit a new packing piece under the pintles and seal where the bolts went through the hull. Neither of us was slim enough to weasel our way under the cockpit. When I cut the section out, the fibreglass popped out separate to the plywood core. The adhesion had been very poor with no timber pulled away – the ply had delaminated from the FRP as shown in *figure seven*. Note the cross check marks in the fibreglass in *figure seven*. It has been a common practice in the marine industry to put saw marks in the plywood to try and give the polyester something to grab onto. Due to the delamination, the floor became almost trampoline like and in 2016 the floor was cut out, a new plywood insert made up and then glued in with thickened Bote-Cote. By the way, you could now have a 'see how many you can get in the cockpit competition' and the deck would not move. See the YouTube video from 'woe to go' at 'the Epoxy Guru' titled 'How to: Repair Fibreglass Boat Floor'.

Figure seven – Polyester FRP floor removed from cockpit.

POLYESTER LIMITATIONS SUMMED UP

I hope the above scenarios paint a picture on the limitations of polyester. Do not get me wrong, as polyester and vinylester have their place and that is for mass producing fibreglass structures where weight is not a major consideration and a rigid 3D structure is desired. We would not have the thousands of FRP boats around today, if it was not for manufacturers being able to speed up the boat building process by using FRP. In which case, boat ownership would remain elitist unless people have the skill to build their own wooden boat.

For wooden boat officianardos, it has seen the decline of traditional wooden boat building as the majority of us would not be able to afford a large wooden boat made using traditional techniques. Look at my Clansman as a good example, it was manufactured by relatively low skilled labour in 1972 and is still going strong. I believe she will outlive me although the gelcoat is stuffed and needs painting and I will continue to chase osmosis using Bote-Cote epoxy. The ultimate aim being to remove all of the gelcoat and seal the hull with a good layer of Bote-Cote epoxy resin and then COP-R-Bote epoxy based antifoul.

VINYLESTER LIMITATIONS – SUMMED UP

Very few people use vinylester as it is almost as expensive as epoxy with several of its own limitations. Although, there are some boat parts and even larger boats being manufactured using vinylester reinforced resin. Many yards use vinylester for repair work on polyester boats and a lot of this is driven from the fear of becoming hypersensitive using old technology epoxy. Vinylester, is actually based on epoxy molecules with polyester molecules incorporated into it to enable it to react just like conventional polyester. Unfortunately, these polyester molecules bring with them polyesters problems, as well. **The advantages of vinylester are:**

- It is a distinct improvement over polyester but it is considerably more expensive
- It shares with polyester the advantage of being reasonably resistant to UV light and it is fairly weather resistant
- It is better at preventing moisture diffusing through it than polyester, but nowhere near as water impervious as high solids epoxy
- It is a better adhesive than polyester, but again it is nowhere near as good as high solids epoxy
- It is probably the best room temperature curing resin to use in high temperature applications such as exhaust wet boxes

There are distinct disadvantages to using vinylester, as well:

- Both polyester and vinylester are highly flammable. Being 'Dangerous Goods' therefore storage and transport present significant problems and it may invalidate the users insurance

- Significant amounts of Volatile Organic Compounds (VOC) are emitted whilst it is being used and breathing protection must be used. This is due to the use of liquid styrene to thin it out (not good to breathe)
- Sometimes it won't cure if the atmospheric conditions are not right due to its sensitivity to atmospheric moisture and temperature
- It also has difficulty in bonding dissimilar and already-cured materials
- It is not unusual for repair patches on vinylester resin fibreglass to delaminate or peel off and many Vinylester hulls suffer delamination of the hull skins from core and bulkhead substrates.

Note: The modern maxi yachts that have pulled out of the Sydney – Hobart race when they have struck heavy weather and the outer or inner skin delaminated from the core is a good example.

- As vinylester resin ages, it becomes a different resin (due to its continual curing as it ages) so new Vinylester resin sometimes resists bonding to older Vinylester, or will bond and then later peel off. In other words, it is not a stable molecular structure
- Vinylester resins bond very well to fibreglass, but offer a poor bond to Kevlar and carbon fibre due to the nature of these two more exotic fibres
- Due to the touchy nature of vinylester resin, careful surface preparation is necessary, if reasonable adhesion is desired for any repair work
- Vinylester is fairly brittle compared to epoxy and is prone to cracking where high point loads are applied or when used in areas where flexing occurs
- Vinylester resin goes off in the container over about a 12 month period.

VINYLESTER CASE STUDIES

Case Study One – A good example of Vinylester's unstable molecular structure was a 20+m motor cruiser I saw at Bobbin Head Marina a few years ago. It was dark green hull colour and I could see the print of the 600gram fibreglass used in its lay-up. Unfortunately, I did not take a photograph, as it was a classic example of vinylester instability. When 'stickybeaking' about marinas with larger yachts and motor cruisers look along the hull and check whether it is made using vinylester. Although, these days, it is possible to hide the problem with vinyl sheeting instead of painting.

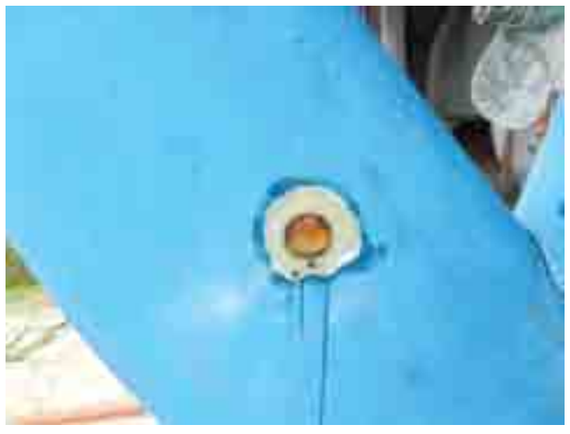

Figure eight – Vinylester FRP repair rework.

Case Study Two – My only other experience with vinylester, was when I was conned into using it to restore the rudder on my Clansman as it was in poor shape due to water ingress, many moons ago. Even the polyester bog inside the fibreglass skin was saturated with moisture. The vinylester was a pain to use and guess what; it has delaminated in several places and needs some serious surgery to sort out the leaky mess as shown in *figure eight*.

Again, I was convinced by the salesman that it was the ideal resin to repair and waterproof the fibreglass mess / rudder, I had. I later understood the reason he recommended the vinylester, the company manufactured vinylester resin, so logic was to sell more resin, not necessarily the correct one. Fortunately, they are no longer in business. I wonder why!

Case Study Three – I was recently at a caravan show in Sydney and escaped from our stand to have a look at caravans. I was wondering through and saw the classic vinylester fabric print through. I interrogated the sales rep and sure enough they are using a vinylester skin each side of a foam core. It will be interesting to see how these caravans stand up to going bush on rough Aussie roads with tree branches whacking into the sides. It will be interesting to see how they hold up over time. See the print through at *figure nine*.

Figure nine – Vinylester print through on a new van.

EPOXY RESIN – ADVANTAGES

Epoxy is known in the marine industry for its incredible toughness and bonding strength. Let me qualify this as it needs to be a high solids epoxy and one developed for high strength applications in a marine environment. Do not buy industrial grade epoxies that are designed for holding bolts in concrete as it is very brittle and usually only around 30Mpa in tensile strength.

Old technology epoxies are notorious for making people hypersensitive. Bote-Cote epoxy resin is a modern formulation where the hardener is partially catalyzed eliminating many of the risks associated with using old technology epoxy resins and the *AABB* #89 article 'Working with Modern Technology Epoxies – A Safer Way to Work' articulates the advantages of modern technology epoxies.

EPOXY OFFERS EXCELLENT RESULTS IN REPAIR-ABILITY WHEN IT IS USED TO BOND TWO DIFFERENT MATERIALS TOGETHER **AS IT STICKS TENACIOUSLY**

By the way we have many customers who have become hypersensitive to old technology epoxy but can still safely use Bote-Cote epoxy resin with a couple of testimonials on You Tube on the 'The Epoxy Guru' channel.

Marine grade epoxy is the best product to use when carrying out fibreglass composite boat building and repair work on all fibreglass structures for the following reasons:

- It is extremely effective as a moisture barrier, therefore ideal for composite boat building and good at reducing the risk of osmosis
- It is a superb adhesive. It sticks to other materials with 2,000psi (around 50Mpa) vs. only 500psi (12-14Mpa) for vinylester resins and even less for polyesters
- In areas that must be able to flex and strain with the fibres without micro-fracturing, Bote-Cote marine epoxy resin offers much greater capability than most other marine grade epoxies
- Epoxy resin will bond dissimilar or already cured materials thereby making repairs that are very reliable and strong
- Epoxy offers excellent results in repair-ability when it is used to bond two different materials together as it sticks tenaciously. Poly plastics (plastic garbage bins, plastic containers, etc) are the only materials that epoxy will not glue successfully, but use this to advantage when gluing by using plastic tape to dam liquid epoxy and pieces of plastic as backing pieces and formwork on large areas of epoxy
- High solids epoxy (most reputable marine grade epoxy resins) is considerably stronger than polyester or vinylester and this reduces the cost and weight of repair when compared to polyester/vinylester as less product is required to beef up the area.

The above factors make epoxy the resin of choice for repairs and for over coating a fibreglass boats hull to resist osmosis. Plus, it is the only choice for composite boat construction and repairs.

EPOXY RESINS – DISADVANTAGES

The disadvantages of epoxy resin are few and using correct techniques negates them and puts high solids epoxy head and shoulders above polyester and vinylester resins for composite boat building and repairs. ***The disadvantages are;***

- Epoxy does degrade in strong ultraviolet light and it in turn must be protected with a UV resisting paint and polyurethane two pack paints work every well. The Aquacote water based polyurethane topcoat sticks tenaciously to epoxy and provides very good UV protection
- Epoxy cannot be used with normal chopped strand mat as the binder used to hold the mat together is not melted by epoxy. Woven or knitted fabric/ cloth should be used with epoxy anyway as it ensures a stronger and more economical structure than chopped strand mat
- Cost – If used with chopped strand mat or built up in many layers like polyester or vinylester it is a waste of money and will prove expensive
- Old technology epoxies are classed as 'Dangerous Goods' for transport purposes to use along with polyester and vinylester due to the nasty chemicals used in the hardener/catalyst
- Polyester flow coat will not stick tenaciously to epoxy and painting with a two pack marine grade polyurethane should be adopted.

EPOXY CASE STUDIES

The advantages of using epoxy resins and glues for composite boat building are well known in industry and they are used extensively in all sorts of industries, such as;

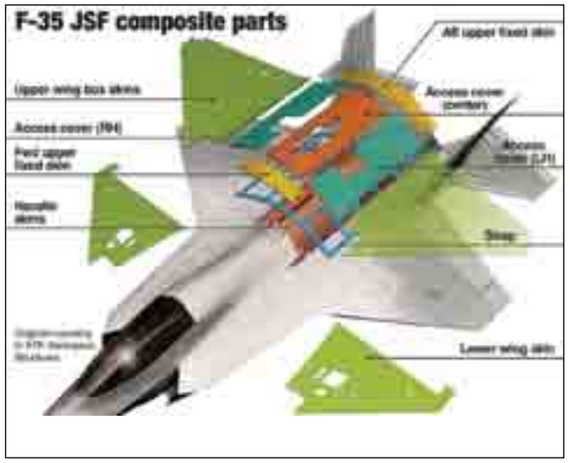

Figure 10 – F35 epoxy FRP components.

- Manufacture of military and commercial aircraft where durability and strength has been considerably increased. The Boeing 787 Dreamliner uses 50% composites materials in its construction and the new F35 fighter aircraft contain 35%+ composites in their construction. Examples of composite use in the F35 are shown at *figure 10* and are used as they are lighter than aluminium and stronger than steel
- Wind turbine blades which can be up to 60m long where epoxy has enabled a light weight, durable construction with a blade shown at *figure 11*.
- Concrete bridge repairs and increasing load capacity of bridges and other structures using epoxy/carbon composite layers in load bearing areas
- In general construction applications such as anchoring studs and many other metal components into concrete
- Another epoxy product developed and manufactured by BoatCraft Pacific is ACE epoxy mortar. It comes into its own for sealing the tendons on pre-stressed bridge and building beams plus other construction applications. It will even stick to damp concrete putting it head and shoulders over other products available as it is much safer to use.

Figure 10 – Large wind turbine blade.

The advantages of epoxy composites in modern manufacturing applications are growing at a rapid rate. This is a major reason why carbon fibre and other exotic composite fabrics are at a premium price.

There are several videos on using Bote-Cote epoxy in various uses on our You Tube Channel – The Epoxy Guru. It has a library of almost 100 videos with myriad information on how to use the BoatCraft Pacific range of products plus heaps of other good information to assist you in your boat building and other projects. There is even a video on correct lines to use when berthing your boat and the disadvantages of using polyester and silver rope for berthing and anchoring, let alone the damage caused to your boat and fittings – use nylon as it will stretch up to 50% of its length.

I am continually surprised and motivated to do more videos based on the positive feedback from our many customers. We look forward to you subscribing and making comments. Also let us know if there are any subjects you would like to see a video on.