An increasing number of boat-builders are turning to vacuum bagging when laminating wood veneers, synthetic fibres, and core materials. Modern vacuum bagging techniques can be used successfully with room temperature epoxies.

Vacuum bagging is a proven construction method for large and small applications, and will deliver firm, evenly distributed pressure over the entire surface of the laminate. Vacuum bagging also allows the builder to laminate multiple layers of composite material in a single bonding operation - a real time-saver.

Unlike using staples or screws, vacuum bagging produces a relatively fair laminate, that can save considerable cleanup and surface preparation time. In addition, once it's under pressure, the resin is squeezed to the edges and surface, where peel ply or absorbent bleeder draws the excess from the laminate. The result is a stronger, lighter laminate with a higher fiberglass-to-resin ratio than might otherwise be possible with conventional methods of clamping.

The Principle

In vacuum bagging, the builder uses atmospheric pressure to provide clamping pressure over the entire surface of the laminate. The laminate is sandwiched between an airtight mold and an airtight bag. When the bag is first sealed, the air pressure on both sides of this envelope is equal to atmospheric pressure: approx 101.4 kPa/14.7 psi. As the vacuum pump evacuates the air from the inside of the envelope, the pressure inside is reduced, while the outside pressure remains at 101.4 kPa/14.7 psi. The pressure differential between the inside and the outside of the envelope determines the amount of clamping pressure, and the pressure is distributed evenly and firmly across the laminate surfaces.

Theoretically, the maximum possible pressure that can be exerted on the laminate is one atmosphere, of 101.4 kPa / 14.7 psi. To achieve this, all the air would have to be removed from the envelope. A realistic pressure differential (clamping pressure) would be approximately 41.4 kPa to 69 kPa / 6 to 10 psi.

The Pump

The heart of the system is the vacuum pump. Pumps come in a variety of sizes and types. Contact ATL Composites for your specific project.

The Vacuum Bag Film

The vacuum bag itself is an airtight, plastic material that is sealed over the laminate. Because it is plastic, the epoxy will not bond to it. It is usually clear, so you can inspect the laminate as it cures. The vacuum bag should always be larger than the part and allow for the depth of the part. When a wider bag than the standard width is needed, a larger bag can be created by splicing two or more pieces together with mastic sealant.

Wrightlon 5400 Nylon Vacuum Bag Film
0.050mm thick : 177°C max. temp tolerance: 1520mm and 3040mm widths: Roll lengths: 10, 50 and 300 Lm

Don't skimp on the bag: the better the airtight seal and bag material, the smaller the pump you will need. Poor seals or bag will allow air leakage and therefore require a larger capacity pump to maintain satisfactory vacuum pressure.

Bleeder Material

If the bag is drawn tight to the laminate in one area, other sections may not receive sufficient vacuum to provide adequate clamping pressure. To prevent this, a "bleeder" cloth, placed between the laminate and the vacuum bag, provides air channels by preventing the bag from prematurely sealing against the laminate.

V7240 Econobleed Polyester Breather/Bleeder
1450mm wide : Roll length: 24 Lm

Perforated Release Film

A perforated plastic film may be used in conjunction with the release fabric. This film helps hold the resin in the laminate when high vacuum pressure is used in slow curing resin systems or thin laminates.

DAHLAR® Perforated Release Film
0.025mm thick: 120°C max. temp tolerance: 1520mm wide : Roll lengths: 50 and 300 Lm

Release Fabric/ Peel Ply

Release fabric is a smooth woven fabric that will not bond to epoxy. It is used to separate the breather and the laminate. Excess epoxy can wick through the fabric and be peeled off after the laminate has cured. It will leave a smooth textured surface that, in most cases, can be bonded to without additional preparation.

V760 Peel ply
1120mm wide : Roll length: 10, 50 and 100 Lm

Sealant Tape

Mastic sealant is the stuff that makes vacuum bagging work. This thick, tacky, tape-like material is used to seal the bag edges to the mold. It is also great for repairing leaks in the bag.

V702Y Yellow Vacuum Bagging Tape
40 rolls per carton : 19mm wide : 7.62 Lm

The Plumbing System

The plumbing system provides an airtight passage from the vacuum envelope to the vacuum pump, allowing the pump to remove air from and reduce air pressure in the envelope. A basic system consists of flexible hose or rigid pipe, a trap, and a port that connects the pipe to the envelope.

Vacuum hose

A vacuum port connects the exhaust tubing to the vacuum bag. It can be designed specifically for the purpose or built from commonly available materials.

A control valve should be incorporated into the vacuum line to allow you to control the volume of airflow at the envelope.

A vacuum gauge

A vacuum gauge should be attached to the laminate during vacuum bagging to monitor the level of vacuum. After the laminate material, peel ply, bleeder, manifold and bag are in place, the gauge is sealed over a small hole punctured in the vacuum bag.

Molds

There are virtually hundreds of mold variations possible in vacuum bagging. The mold can be a simple, flat, rigid table or a complex shape with compound curves. In repair work, the side of a structure (a hull, for example) can be used to closely approximate the exact shape and contour of the area to be repaired.

Flat table molds are usually faced with a smooth plastic laminate, such as Formica. The surface is waxed so that the adhesive won't adhere to it. All or part of the table can be used at one time, permitting multiple layups of differing sizes or materials to be bagged at one time. Half-cylinder, or cone section shapes can be used as molds, provided you can achieve an airtight seal around the perimeter. If the mold surface is porous (plywood for example) it should be coated with several applications of epoxy, or sheathed in fibreglass cloth if the mold is to be used many times.

Male molds are easily fashioned with stringers over mold frames. Two layers of 3mm veneer bonded over the framework and then sheathed with fibreglass will provide a smooth surface and provide an excellent, airtight bonding surface. Male molds are generally used to build large, one-off hulls.

Bagging Methods

The keys to sealing bag penetrations are straightforward:

- Solvent-wash the hose where the tape will contact it, to enhance sealant tape adhesion
- Always apply at least two rows of sealant tape to the hose for sealing the bag
- Always wear gloves. Do not handle the bag or hose with bare hands in the area to be sealed
- Always use fresh sealant tape and check its resin resistance to "wet" work such as infusion or bagging wet laminates. Make up a small wet layup, bag it, and check that the tape doesn't lose its seal before the resin gels. When in doubt, use a double row of tape.

Fitting the bag – The simplest way to begin the process is to peel away the release paper on the sealant tape, just at the part's corner. Lightly touch the corners of the bag down at these points, and take a moment to evaluate where the pleats should be located. Pleats – or handle-like ears – are normally placed to correspond to the contours of the part under the bag.

ATL recommends the pre-fitting of pleats, especially for wet-layup laminates or core installation, where bag sealing time is so critical. When you're in a rush, having all the tape for the pleats pre-cut and pre-fitted to the tooling perimeter really speeds up bag sealing.

By determining where the ears will fall at the bag's perimeter, and then pre-fitting sealant-tape lengths in those locations, you can close up the bag more efficiently.

Pleats should fall on inside and outside corners, so that their surplus bag film can prevent inside corner bridging and outside corner hard spots. The whole purpose of all the wrinkles in the bag film is to ensure that the film is loose enough to fit into and around every corner and contour of the part. When the bag bridges across an inside corner, bond-line voids and puddles are inevitable.

Shuffling the bag around as the vacuum first pulls it down will help prevent bridging. Open the air bleeder valve and run the vacuum under the bag at -30 to -50 kPa. There will be plenty of squeeze, but you'll still be able to re-position the bag. Obviously, a bag fitted with pleats at the appropriate places will pull down evenly over all the part contours.

Bagging up a Laminate

We will now look at a specific vacuum-bagging procedure for a small part in a female mold – this is intended to demonstrate the basic principles of vacuum bagging. Keep in mind that vacuum bagging materials, molds, equipment and laminate schedules will vary from these procedures.

Thorough preparation is the key to successful vacuum bagging. Check all equipment beforehand, making sure that everything is in good order and that the pump is well lubricated (if it is the oil-lubricated type). Prepare a plastic covered work surface near the mold to wet out laminate materials. Establish the maximum working time available, based on the resin/hardener you will be using and the ambient temperature. Be sure all of the steps can be completed within the working time.

All the laminating materials should be cut to size and then checked for size. The vacuum bag, bleeder and peel ply should be cut to size and rolled or folded. Place your working materials in a convenient location near the mold, ready for lamination.

1. Begin by applying three coats of automotive paste wax to the mold surface. Since epoxy will not bond to it, the wax will act as a release agent for the cured epoxy gelcoat. Buff the last coat so that excess wax will not be picked up by the laminate. Prepare the gelcoat by thoroughly mixing a batch of resin and hardener according to the manufacturers instructions, and then slightly thicken it with collodial silica. *(Note that these instructions only apply to epoxy gelcoats).* The mixture should be just thick enough so that it won't run, yet thin enough to allow it to be rolled onto the mold surface with a roller cover of high density foam. Allow the gelcoat mixture to cure.

2. After the gelcoat has cured, wash the surface to remove amine blush to ensure a good bond between the gelcoat and the laminate. Sand smooth all rough areas to assure that the laminate will lie flat in the mold. Remove dust from the surface. Apply the mastic sealant to the mold perimeter, leaving the protective facing on the exposed side of the sealant. Overlap the ends of the mastic so there are no gaps. Be sure to press firmly to assure good, airtight adhesion to the mold, leaving plenty of room between the inner edge of the sealant and the laminate area.

From this point on, you'll be working against the clock.

3. Dry fitting the fibreglass fabric in the mold first and then wetting it out, is the usual method for small part manufacture. Begin in the middle of the fabric, at one end of the laminate, and pour a small amount of epoxy on the fabric. Use a plastic squeegee to work the adhesive into the fabric, moving excess epoxy into areas of dry cloth. There should be no puddles of epoxy, or air pockets under the fabric, and the wet-out fabric should have a dull matt appearance. When properly wet-out, a puddle of epoxy will appear around the edges of a thumbprint after pressure has been applied with a (gloved) thumb.

4. Place a layer of release fabric over the laminate. The release fabric will peel off the cured laminate leaving a fine-textured surface. Excess epoxy which has bled through will be removed along with the release fabric.

5. Place breather material over the release fabric. Press all of the layers of material into contact with the mold to avoid "bridging" when vacuum pressure is applied.

6. Place the vacuum bag over the mold and seal it to the mold's perimeter. Starting at a corner of the mold, peel the protective paper from the mastic. Press the edge of the bag firmly onto the mastic while pulling the bag taut enough to avoid wrinkles.

When cutting the bag to size, allow enough excess bag material within the sealant perimeter to avoid stretching the bag or bridging areas when the vacuum is applied. Because the bag perimeter is greater than the sealant perimeter, you should create several folds or pleats of excess material as the bag is sealed around the mold.

7. Seal the pleats of excess bag with a strip of mastic from perimeter mastic to the inside top of the pleat, then press the bag to both sides of the strip forming a continuous airtight seal. Repeat this procedure wherever there is a pleat around the mold.

8. Connect the vacuum line to the bag with a vacuum port. The vacuum port used here is basically a suction cup with a hole through it, attached to the end of the line. Puncture a small hole in the bag and attach the port to the bag over the hole. Breather fabric provides a path to the port inside the bag over a wide area. Place an extra layer or two of breather under the port. On smaller molds, place the port outside of the trim line on the mold flange or shelf. Multiple ports may be necessary on larger parts.

9. Turn the vacuum pump on to begin evacuating air from the bag. If necessary, temporarily shut off the vacuum to reposition the laminate or adjust the bag. As the air is removed from the bag, listen for leaks around the bag perimeter, especially at folds in the bag, laps in the mastic and at the vacuum line or port connection.

Where leaks are found, push the bag into the sealant or, if necessary, plug the leaks with pieces of mastic or tape.

10. Attach the vacuum gauge to the vacuum bag over a puncture in the vacuum bag. A hissing sound will indicate that enough air is leaking through the puncture to draw a vacuum on the gauge. Place the gauge away from the exhaust tube or port connection.

Allow the laminate to cure thoroughly before turning off the vacuum pump.

11. After the laminate has cured thoroughly, remove the vacuum bag, breather and release fabric.

Vacuum Bagging Techniques, published by Gougeon Brothers Inc, is a definitive guide to the principles and application of vacuum bagging techniques for laminating composite materials with epoxy. Complete instructions describe various techniques, materials and equipment. Softcover 52 pages. Available from ATL Composites.

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