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VACUUM BAGGING TECHNIQUES ON SANDWICH CONSTRUCTIONS

INTRODUCTION

The use of sandwich construction in yacht building often requires utilization of advanced construction techniques in order to gain the maximum performance from the materials. One such technique is vacuum bagging, which is well within the capabilities of most yacht builders.

Vacuum bag techniques lend themselves to all aspects of yacht construction, from fabrication of the primary structures including cored hulls, decks, super structures and bulkheads to secondary structures such as cored interior joint-work and partition panels.

Vacuum bagging is an effective, cost-efficient technique by which atmospheric pressure is utilized to provide uniform pressure. The best vacuum bag systems will produce just under 14 psi. (1 bar) or 2,000 psf (90 Kg/m2). Most FRP constructions will not require a full 14-psi but rather 5-10 psi. Note that this pressure is applied with little or no stress to the tools since the pressure on the tool is the same on all surfaces.

Atmospheric pressure is due to the blanket of gasses which envelope our earth. At sea level atmospheric pressure is about 14.7 psi and decreases roughly .5 psi with every 1,000 feet of altitude. All structures, which are not pressurized or have not had the air evacuated from them are in equilibrium with atmospheric pressure. The evacuation of air from a vacuum bag causes a pressure imbalance on the outer surface of the bag. The column of air from the atmosphere will collapse the bag until the tool surface or other side of the bag applies an equal but opposite pressure which will be equal to the negative pressure within the bag. At this point it is interesting to point out that there exists two methods of identifying the magnitude of atmospheric pressure, absolute pressure and gauge pressure. At sea level absolute pressure will read about 14.7 psi and gauge pressure will read 0. At 30,000 feet absolute pressure will read about 0 and gauge pressure will read -14.7 psi.

THE USE OF VACUUM BAGGING TECHNIQUES ON CORED CONSTRUCTIONS

The advantages of vacuum bagging are multifold and can be identified both structurally and economically.

First and most important, vacuum bagging provides equal pressure to all surfaces of the part, whether the part is made up of vertical, horizontal, curved, compound curved or any combination of these. The only limit on the complexity of the part to be bagged is the extent of the planning on the part of the builder.

Stacking lead weights or bricks will not only produce spotty bonds but will force putty out from under the weight causing a potential dry area while pooling the putty in areas of lesser weight. An inconsistent bond line, which is thicker in some areas and thinner in others, is the result.

Second, uniform external positive pressure and negative internal pressure will aid in expelling air trapped between the core and the laminate. The core should be perforated if a plain sheet is used since the PVC cores are completely closed cell and will not bleed air on their own. Contoured cores will expel air on their own through the cuts or “kerfs.” Entrapped air may produce structural as well as cosmetic problems. This topic will be covered later in this paper.

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Total bonding of core to facings is basic to sandwich construction. All predictions of strength and stiffness presuppose that the facings and core are working together as a unified structure. Any area of the sandwich, which is not bonded, will be a location for potential failure or at the very least will be structure, which is not performing to its full potential.

Next, a structure which has been vacuum bagged and is completely bonded and void free will maximize the economic value of the material. As you know, many performance materials are expensive. However, many structures, which are not completely bonded or "integral", will only perform to a fraction of their potential. This is not an efficient use of materials or an economical building practice from a rework standpoint.

Finally, tools, which have parts vacuum bagged on them rather than weights stacked, are longer lasting.

Consider a tool for an engine hatch, which might be 3 feet wide and 5 feet long. If this tool is supported at each end and is subject to the same weight that a vacuum would apply in pressure, you can imagine how deformed this tool would be. The total weight on the tool would be 30,000 lbs. It is obvious that no one would stack 30,000 lbs. on a tool of this size simply due to practicality, but it is fun to consider the stress this would impose on the tool. The tool, which is vacuum, bagged will be under little stress.

CONSEQUENCES OF NON-LAMINATION

As mentioned above, in order for a sandwich construction to perform to its maximum potential, the core must be completely bonded to the facings. Voids are locations for failures to start and potential cosmetic blemishes to appear.

Voids are caused by inadequate pressure, inadequate amount of adhesive between core and laminate, a core that is too stiff to flex under stacked weights, or by air that is trapped under the closed cell foam with no "vents" to release it.

Structurally, a void can be the location for failure. A structure, which is dynamically loaded, a hull bottom for example, cannot smoothly transfer stresses from facings to the core when voids exist. Therefore, the stresses, which would normally be passed to or shared by the core, will localize at the void and cause it to grow. This propagation of void size could lead to excessive flexing and ultimate failure of the part.

Cosmetically, the void will be a location for gas to accumulate and cause a blister. As laminate cures, it releases styrene (if made from a resin containing styrene). If a void exists, it will fill with styrene gas and expand the void to cause a blister. This process will be aggravated when exposed to heat from sunlight and will be the cause of very unsightly cosmetics.

Hulls are often cored with contoured foam. Contoured foams are designed to form into the shapely surfaces of most hulls. However, in areas where the foam must bend, causing the kerfs to open, it is common to find that, unless vacuum bagged these kerfs will not be filled with adhesive. Often a thru-hull fitting is installed without proper attention to closing off these "aqueducts". You can imagine the amount of weight, which can be locked into the hull laminate as well as the potential for delamination if the water should freeze.

Vacuum bagging will cause the putty to fill these kerfs, therefore eliminating any potential aqueducts.

DIFFERENT FORMS OF VACUUM BAGGING

Different levels of vacuum bagging exist. For quick jobs, a simple film and tape arrangement may fill the need. For the more complicated requirements, planning and use the proper materials will ensure a successful bond. Finally, for the complex builder producing multiple parts, a special set of matched die tools or reusable bags are available which will produce hundreds of parts before requiring replacement. Most vacuum bagging done in the marine industry uses relatively low cost disposable films, tapes, bleeders, breathers and peel plies. These are commonly good for only one process, then disposed. Occasionally, some materials can be reused by seldom more than twice. Some facilities will adopt aerospace techniques when the volume of reproducible parts justifies the initial cost of materials. Matched tools consisting of a top and bottom mold with a silicone seal will provide parts finished on both surfaces. These tools require considerable expertise during construction, and the actual fabrication of the part of somewhat more complicated due to the predetermined thickness of the part.

Another very interesting and practical method of vacuum bagging many parts of the same design is using reusable silicone blankets. These blankets are supplied in a range of hardness (shore hardness) and can stretch many times their original size. Further, they may be bought in a “B STAGE” state or incurred. This requires the builder to lay-up the silicone over the tool and cures it out in an oven at elevated temperature. The result is a custom preformed blanket, which will fit the tool and eliminate any pre-fitting before pulling the vacuum. Imagine a reusable, preformed hull vacuum blanket, which could be lowered into the laminated tool and evacuated within a few minutes to apply even pressure over all surfaces of the hull. This technology exists and is available to the boat builder.

EQUIPMENT AND MATERIAL REQUIREMENTS

Vacuum bagging requires some basic materials in order to successfully pull vacuum and apply even pressure.

Peel Ply — Against the surface of the last laminate, a peel ply or “RIP RAG” can be applied. Peel ply serves two functions. First, it eliminates the need for sanding or grinding prior to secondary bonding operations. Second, peel ply may be left on the laminate. This will keep it clean until the next step in construction.

Bleeder Ply — Bleeder ply is a lightweight blotter to absorb excess resins or core bonding putties, which “BLEEDS” through the peel ply. Bleeder ply is used only once and is removed with the peel ply.

Bubble Pack or Breather — Breather ply is a material, which will not compress under pressure to the extent that air cannot be drawn through it. Often, an otherwise perfectly sealed bag will not develop full vacuum pressure because the bag under the hose fitting is pinched off preventing evacuation of air from the rest of the part.

A commonly used breather ply is bubble pack, which is typically seen as a protection for packaged goods. Bubble pack is inexpensive and can be reused if not loaded too heavily with cured putty.

Sealant Tapes — Sealant tapes are used to seal the bagging film to the tool or part. They are very pliable and similar in texture to “chewing gum”. Most sealant tapes are butyl-based material which will stick to most bagging films (except silicone which is self-sealing) and to most fiberglass, aluminum, and plate glass tools.

Bagging Films — Bagging films are second only to the vacuum pump in importance. The vacuum bag material must be flexible, resistant to tearing, have good elastic or stretch capabilities, be non-porous and compatible with the resin system. Bagging films can be silicone, nylon, PVA, polyethylene or rubber. In applications where the vacuum bag will be subject to elevated temperatures, a heat resistant material must be used which will not melt or become brittle.

Vacuum Valves — Vacuum valves are the attachment points between the bagging film and the vacuum hose. "VAC VALVES" can be simple nylon thru-hull fittings or elaborate quick release valves used by aerospace, which seal positively and may be disconnected without bleeding pressure. On simple bagging operations the vacuum hose may be run through the bag and sealed with the sealant tape. This, however, is subject to being pinched off by the collapsing bag.

Vacuum Hose — Vacuum hose may be flexible or rigid. Commonly, vacuum hose is made from PVC tubing and connected to the vac-valve by a short run of flexible hose. Vacuum hose must be stiff enough to resist vacuum pressure since it too will be evacuated. Also, the vacuum hose must be compatible with the resin system, nonporous and, if used at elevated temperatures, must be heat resistant.

Resin Traps — Resin traps should be fitted in the vacuum hose between the part and the vacuum pump. This will stop any resin from migrating from the part to the pump. This is simply a closed cup with the vacuum hose entering and exiting at the top so that any resin which moves through the vacuum hose will drip into the cup before it can flow to the vacuum pump. It is important to note that the inside diameter of the vacuum hose will determine how fast air can be evacuated from the part. The larger hose will remove more air faster than small diameter hose.

Manifolds — Manifolds are required where multiple vacuum hoses and valves are used to evacuate the part. The manifold should be fitted with a valve on the pump side and a vacuum pressure gauge. The manifold should also be larger in cross sectional area than the total cross sectional area of all the hoses running to the part.

Vacuum Gauges — Vacuum gauges should be located at the pump, at the manifold if one exists, and on the part. One gauge and thru fitting should be used for every 75 to 100 square feet to surface area. This will give the builder an idea of pressure exerted on the part as well as if some portion of the bag has been pinched off and is not drawing vacuum equally from all areas of the bag.

Vacuum Pumps — Vacuum pumps are available in a variety of configurations and capacities. Most pumps use an electric motor to drive the evacuation equipment. Others use compressed air and venturies to create vacuum. These vacuum pumps are very small and quiet but are not as efficient as the motor driven models. Vacuum pumps must fulfill two capacities. First, they must be capable of a high vacuum, at least 13 psi. Second, they must be able to evacuate a large volume of air quickly. Unfortunately, most vacuum pumps will not fulfill both of these requirements adequately. The best option is to get the pump that will draw a high vacuum and connect the pump to a vacuum reservoir. The volume of the reservoir should be at least equal to the volume of the part being made. This will allow evacuation of most of the air around the part quickly and let the pump remove the remaining air and draw the high vacuum for proper bonding.

Important Note: Vacuum cleaners do not make good vacuum pumps for the following reasons. First, they are limited to the amount of available vacuum pressure. Second, most electric vacuum cleaners are not explosion proof; and since they will be operating in an environment with flammable volatiles, they may cause explosions and fire. Third, due to the high level of noise, it is very difficult for the builder to detect vacuum leaks.

PREPARATION OF MATERIALS FOR VACUUM BAGGING

Before the builder decides to vacuum bag large areas, it is important that he be proficient and comfortable with the materials and techniques involved. Planning is very important; and like other aspects of yacht construction, vacuum bagging must be performed with a high level of attention.

In order to be successful in bonding laminates and cores under vacuum, several basic steps should be taken in preparing the materials before the vacuum is applied. The following recommendations are for bonding PVC core to cured FRP laminates.

Preparing the Cured FRP Laminates — Prepare the surface of the cured FRP laminate by sanding and grinding following by vacuuming the surface. It is important to note that surface debris should be removed with a vacuum cleaner and NOT compressed air since the air may be contaminated with water or oil. If the cured laminate was covered with peel ply, the builder need only remove the peel ply and continue. When using a styrene suppressed polyester resin, the surface must be sanded to remove the inhibitor even though a peel ply may have been used.

Dry Fitting and Labeling — As mentioned previously, the success or failure of a vacuum bagging process relies almost completely on planning and forethought. Dry fit the core, peel ply, bleeder ply and bagging film.

The core should be dry fit and marked for cutting to the proper outside dimensions. If any fillets are required, they should be cut at this time and included in the area designated for vacuum bagging. The bagging film should be 10 to 15% larger than the area to be bonded. This will allow the bag to conform to complex surfaces of the part, allow for darts and pleats, and eliminate the bag from pulling away from the sealant tape while under vacuum.

The peel ply and bubble pack should be cut to the inside surface of the sealant tape. A six-layer buildup of peel ply or bleeder ply should be placed under each thru fitting to ensure proper airflow around the fitting. These need only be 6 inches square.

At this time the sealant tape should be applied to the perimeter of the bagging area leaving the paper carrier in place.

When using a polyester-based core bedding putty, all cores should be primed with a medium viscosity, low exotherm, and low shrink resin containing no more than 40% styrene by volume. Priming acts as lubrication allowing the putty to flow into the cells perforations and kerfs of the foam. When using contoured foam in excess of **3/4** inch, apply one-half the recommended thickness of core bedding putty to the core. The remaining putty shall be applied to the laminate with a gauged trowel.

Position the core; peel ply and bubble pack onto the coated laminate. Place the vacuum bag onto the core and seal the bag by removing the paper carrier from the tape. Remove only the paper carrier, which will be immediately applied to the bag. Continue around the perimeter of the core installing darts and pleats at corners or as needed to conform to the shape of the core.

After the bag is installed, connect the vacuum hoses and open the valve to the vacuum reservoir. Within I to 2 minutes the vacuum gauge should read at least 5 psi; if not, check for leaks. It is important to maintain an even pressure over the entire surface. Localized leaks cause decreased pressure which can lead to non-lamination of the core of the cured FRP laminate. The general public may perceive this as a delamination of the sandwich panel.

If the bag is drawing air properly, all vacuum gauges should be reading the same. If one or more gauges are lower than the gauge at the pump, then a "pinch off" is indicated meaning air is not being removed in the areas of low readings. This may be corrected by adding more breather or more thru fittings as needed. A stethoscope may be used to aid in detecting leaks. Correct the leaks as necessary. During the course of bagging, periodically check for leaks as they may develop while the bag stretches.

Maintain vacuum until the core bonding putty has cured.

After the putty has cured, remove all bagging materials and visually check core surface for resin putty bleed through. In addition, physically check by simply running a coin over the surface of the core. A dull or hollow sound indicates a void and non-laminated area, which must be corrected.

SUMMARY

A. Vacuum bagging provides uniform pressure and eliminates putty pooling or putties starved areas as a result of unequal clamping pressure.
B. Vacuum bagging eliminates random bonding. Complete bonding of the core to facing will be structurally sound and will not produce blemishes due to voids.
C. Vacuum bagging produces total attachment of core to facings allowing the sandwich to develop maximum mechanical properties.
D. Vacuum bagging is easier on tools in that it produces very little stress on the tool itself. By contrast, stacking weights imposes considerable bending stresses on the tool.
E. Vacuum bagging is easier on the fabricators in that they are not lifting and positioning heavy weights.

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