6. 신기술소개

신기술소개 - 2

첨단소재 및 성형법을 사용한 조선기자재의 개발
Development of Marine Equipment Using New Materials and Fabrication Method

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Abstract

With the advanced composites technologies and designs advancing faster than ever in the past ten years, it has extremely important to keep up with technology by introducing new manufacturing techniques to advance the industy even more. Specifically, the marine related industries. The United States has preparing for the future by aerospace composite technology to the boat, canoe,kayak and naval vessel busin. This paper will describe one of the methods being implemented to improve quality and structural integrity to compete in the world market.

Introduction

The objective of the explanation is to introduce the vacuum bagging process of advanced composite materials whether it be fiberglass, graphite, or Kevlar prepreg materials systems, or wet layup systems, utilizing the same typefibers, cured by ambient room temperature, oven, or an autoclave. There are many variations and alternatives to resin/fiber matrices and we will not get into these as much as the actual vacuum bag processing and curing of these materials. The objective is to outline the procedure for fabricating components using these types of materials and to summarize the key factors influencing these fabrication techniques.

This explanation is aimed at introducing intellgent VARTM(Vacuum Assisted Resin Transter Molding)processing of composites fabrication to improve and reduce variability and cost toward ship building industry.

In the traditional RTM process, a matched set of molds or "closed mold" is used. The fiber reinforcements are usually preformed off line to enhance the production cycle time of the molds to perform at a respectable production rate. Resin is injected at high pressures and the process is sometimes assisted with vacuum.

However, VARTM is different for many reasons. First, the fabrication of parts can be accomplished on a single open mold. Second, the process uses the injection of resin in combination with a vacuum and captured under a bag to thoroughly impregnate the fiber reinforcement. In the late 1980' s Bill Seemann invented and patented a variation to the VARTM process called SCRIMP TM, which is Seemann composite resin infusion molding process. This process has been used in many new and large applications ranging from turbine blades and boats to rall cars and bridge decks. Unique to this process is the manufacuring method that allows the efficient processing of VARTM to produce large structural shapes that are virtually void-free. This process has been used to make both thin and very thick laminates. In addition, complex shapes with unique fiber architectures allow the fabrication of large parts that have a high structural performance.

Parts using VARTM are made by placing dry fiber reinforcing fabrics into a mold, applying a vacuum bag to the open surface and pulling a vacuum while at the same time infusing a resin to saturate the fibers until the part is fully cured. This process allows for easy visual monitoring of the resin to ensure complete coverage to produce good parts without defects.

With regard to VARTM laminate properties,

1. The high fiber volume fraction is due to the fact that dry fabrics are vacuum compressed completely prior to resin infusion. During infusion once the equilibrium resin content is achieved the process stops. The typical volume content 45%-55% but can be reached maximum 70% per special requirement.
2. Void content is under 1% because vacuum bagging of the dry material eliminates all voids, the dry fabrics acting as an efficient breather pack thus ensuring very low void contents.
3. Extremely low flame spread and smoke generation is carried through.
   This concludes that the outstanding results obtained are due to the high glass content.
4. Due to high fiber volume and low void content obviously results in excellent mechanical performance. These can be compared favorably with composite fabrication form not prepreg in the autoclave but RTM.
5. Economic benefits of the VARTM is reduction of labor cost, save materials due to better laminate reduces thickness requirement, save cost of protective equipment and clothing, and repeatability.
6. Comparing with traditional hand lay-up processing, the VARTM is increasing 2-3 times regarding compression on the lay-up laminate, tension, fiber volume, and flexture.

VARTM has 3 categories of laminate materials, which are fiber format, resin and core. The most widely used resins are Polyester and Vinyl Esters, mainly because of their low viscosity. Infusion of Epoxy is becoming more common.

Woven Roving, 3D Stitched Fabric and continuous fiber are available.

A very large range of fiber formats have been employed with the process.

The only limit there seams to be on what is used is what is available.

Core materials used are obviously limited by the process, Honeycomb materials can' t be used in the same way they are used with prepreg processing.

Low density foams, End Grain Balsa, Metallic and Protrusions are used by VARTM.

Foams used must have some open area to allow flow of resin the bag face to the tool face. This is achieved by either drilling the foam or by having foam tiles mounted on fabric backing.

In order to conduct VARTM, we need various bagging materials such as tool release, fiber and core placement, bag side release, resin distribution, vacuum bagging(vacuum bag film, sealant tape, leak detectors, and portable and gauges)from Airtech International Inc.(USA).

A number of material systems are available, and being used, for the fabrication of components made from advanced composite materials. They can generally be classified under two types of systems, wet layup and prepreg systems. Each type requires a unipue method of vacuum bagging process. The following section defines the two types of material systems that will be discussed in explanation

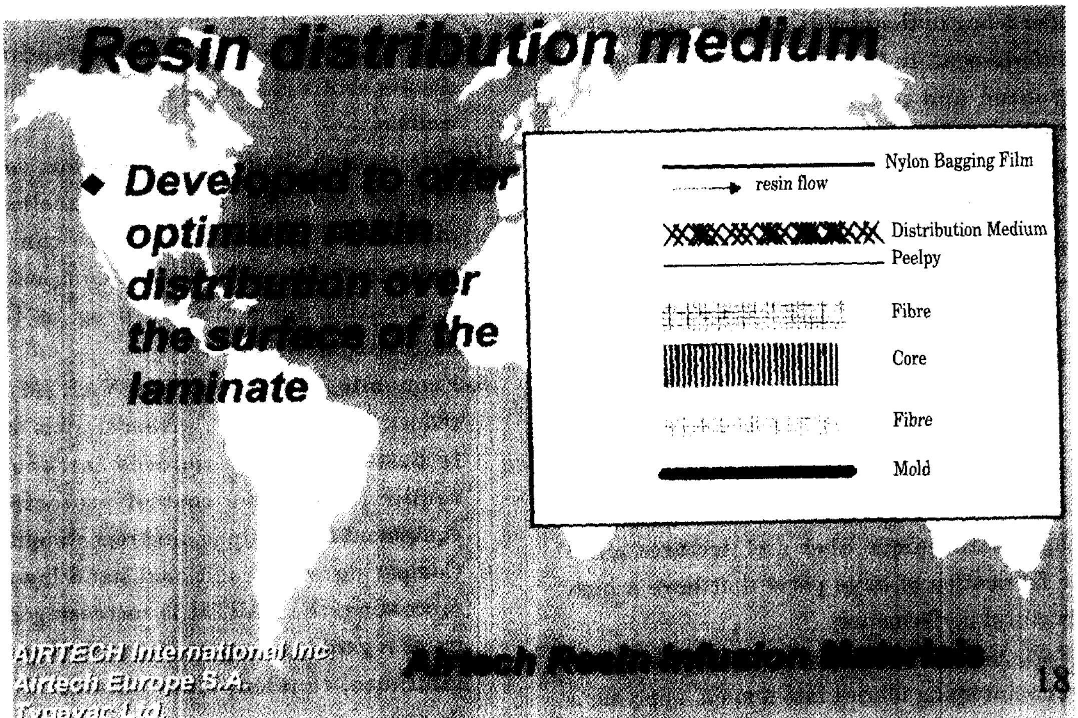


Fig. 1 Basic lay-out for the VARTM

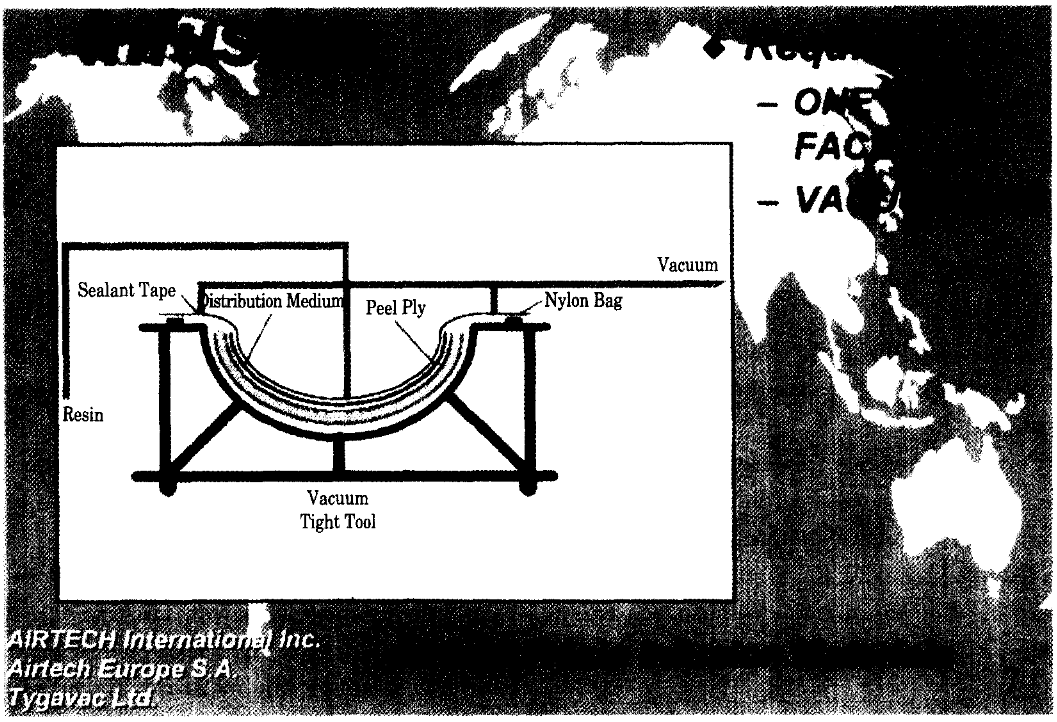


Fig. 2 Section view of vacuum bag lay-up.

Wet Layup System

A system that requires a low viscosity resin to be manually introduced into an array of dry fibers by using a brush, squeegee, rolling device, or other method, to laminating the plies into a composite component.

Pre impregnated System(Prepreg)

Fibers that have already been impregnated with resin by means of impregnating euipment, to provide a predetermined resin fiber ratio. This type of system allows you to laminate a component without having to mix resin and fibers manually.

Both systems are successfully being used to manufacture advanced composite components in aviation, aerospace, marine, and commercial areas. However, each having it' s own unique benefit, each also has it' s own shortcomings. Wet layup systems are time consuming and sometimes cumbersome, while at the same time, materials cost approximately 30% less to use.

Prepreg, on the other hand, is more expensive for material costs, but is generally less labor intensive as wet layup can provide mechanical and physical properties after curing. One must use judgment when deciding on which system to use.

Wet Layup

Under the wet layup heading, perhaps the easiest technique is to introduce a low viscosity, liquid resin into a dry fiber (unidirectional of woven fabric) by brushing, spraying, or squeegee, followed by a consolidation process where the resin is stippled into the duy fibers of rolled into the dry fibers by pressure to achieve even impregnation, The impregnated fiber/fabric can then be arranged onto a mold surface or tool, to begin the lamination process.

There other processes being used. i.e., Filament Winding, Resin Transfer Molding (RTM) and Resin Infusion Molding (RIM) that use this same basic impregnation theory.

After this impregnation operation, most resins are designed to initially cure at room temperature 72°F(22° C). Epoxy resins will sometimes require an elevated post cure to finally achieve their mechanical and physical properties.

The amount of resin impregnated into the fibers is very important. Too much resin can lead to resin rich laminates, and too little resin can lead to porous or resin starved laminates. There are the main reasons prepregs came about.

Prepreg

Prepreg is a general term used for fiber/fabrics that have been pre impregnated with resin, partially cured, and then frozen to stop the curing process until required for us. These materiale can be thawed at room temperature 72°F(22° C),and then be stacked or laminated onto a tool or layup mold, and cured under elevated heat and pressure using a vacuum bag process. Since prepregs are semi-cured, and not "wet", an elevated cure cycle using an oven or autoclave is necessary to complete polymerization cycle of the resin.

In addition to using a vacuum bag during the cure cycle, the use of an autoclave offers additional positive pressure to be applied to the laminate, providing thorough compaction and consolidation throughout the curing process.

Since the prepreg has been preimpregnated using the correct resin to fiber ratio, there is usually no reason to be concerned with the amount of resin in the laminate during the laminating process. Later in this paper we will discuss reasons that the resin amount can change during the curing cycle.

Vacuum Bagging Materials

The term vacuum bagging materials is a generic term used for all of the materials used during the vacuum bagging process. Some of these materials are specifically referred to as sealant tape, release film, peel ply, bleeder, breather, and vacuum bag. Each one of these materials is necessary to achieve a specific physical requirement when fabricating a composite laminate.

For example, when making a laminate using the wet layup system, you must ensure the correct amount of resin is contained in the part without retaining any moisture, air, or gasses from the resin. To achieve this, you must use a certain style of release film, bleeder, and breather material designed to facilitate this requirement.

Sealant Tape

Sealant tape is an elastomeric compound, tacky at room temperature, used as an adhesive to form an airtight seal between the vacuum bag and itself, or tooling. Sealant tapes come in several different temperature ranges, and tackiness. Sealant tape is a very critical component of the layup sequence. If your sealant tape effect of a vacuum leak could severely damage or cause your laminate to become scrap.

Vacuum Bagging

A vacuum bag is designed to be, when properly sealed, an airtight barrier between process materials and the outside atmosphere during a cure cycle. A vacuum bag is generally made of a heat stabilized nylon material. It is either made using a cast method or a blow mold method. There are a wide variety of nylons available, each gaving it' s own unique characteristic, and each used for a specific purpose.

A vacuum bag should be able to conform to any shape or contour, and have the ability to be drawn down on that shape using a vacuum system, and maintaining that vacuum integrity throughout the cure cycle. If using elevated temperatures, the nylon must be heat stabilized in order to withstand temperature in excess of 150° F(65° C). Nylon vacuum bagging comes in flat sheet form 1-3 mil thick, and also in a seamless shape 1-3 mil thick. There are many degrees of elongation, softness, and temperatures that nylon is desinged for.

Release Film

A relese film is primarily designed to be a non-bondable membrane made to restrict resin flow and to allow removal of other processing or bagging materials. There are several types of release film avaliable. Some are designed to be used for flat configurations, offering little or no flexibility to use on contoured shapes, of non-perforated configurations. Release films also come in a variety of temperature limitations depending of the application.

Peel ply

Peel ply materials are coated or uncoated resin porous fabrics, which not permanently bond to resin.

A peel ply is designed to allow free flow of resin and impart an impression suitable for secondary bonding without further surface preparation, and allow removal of other process materials.

Peel ply materials can be made of fiberglass, polyester, or nylon. Some are treated with a release agent, while others are heat scoured, or Corona treated. Peel ply materials should be contamination free and be easily removable from a cured laminate.

Breather

There are many types of materials classified as a breather material. A breather is a porous or woven material designed to provide air/gas evacuation pathway under a vacuum bag.

Some typical standard breather materiale are polyester of nylon felt and fiberglass. Breathers must be able to withstand temperature and pressure if used in an oven or autoclave.

The choice of breather material is especially critical when using an autoclave. When curing a composite component using augmented pressure from an autoclave, some breather materials will "trap off" air, not permitting the gasses and moisture from the resin to evacuate the vacuum bag, thereby causing porosity of voids inside end outside the laminate.

Miscellaneous

There are other materials used in the vacuum bagging process that are usually used to facilitate a particular process and to help produce a particular result. A few of these might be resin dam materials, insulation blankets, pressure sensitive tapes, and release agents.

Again, all the above mentioned process materials have their specific purpose and should not be overlooked.

General Layup Procedure

When fabricating a composite part, whether it be metel or non-metallic, a tool will always be required to obtain the specific shape or contour you require. To enable the final cured part to release from the tool, you must apply either a liquid release agent, sometimes referred to as a "parting agent" to the tool surface. This liquid release can be made from a variety of chemical base materials. It is wise to stay away from silicone based release agents are they may contaminate your laminate and prevent future secondary bonding requirements. An alternative to liquid release agents is a release film on the tool surface. This will be restricted to flat or gently contoured parts and tools.

After a good release agent has been applied, you are ready to begin the laminating process. If using the wet layup method for lamination, precautions should be taken to prevent resin from running or dripping onto the surrounding areas.

The first ply of laminating material should be supplied to the tool surface with caution. No wrinkles of "bridges" should be visible. To ensure no wrinkles or bridging, a "rub stick" can utilized to push the fibers and fabric into the contour. After the first ply is applied correctly the remainder of the laminate should be done in a similar manner.

Vacuum Compaction

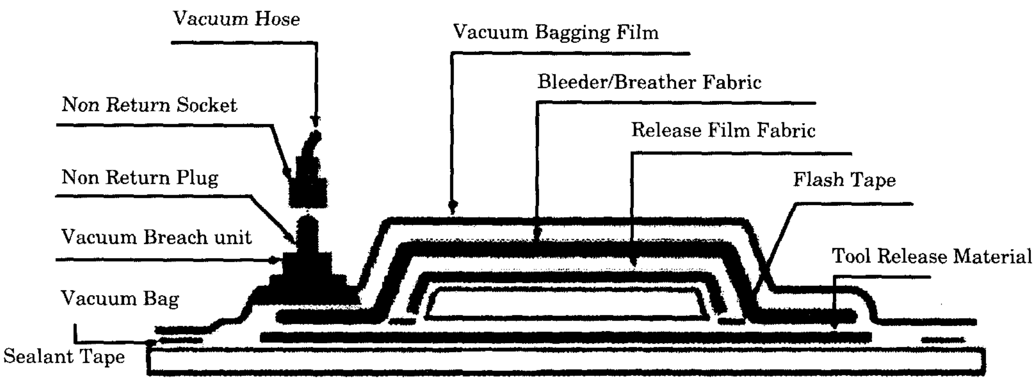
Vacuum compaction is a process that helps remove any trapped air between the plies of composite materials. A good rule is to perform a vacuum compaction every four to five plies. In some cases, this simple process can determine the difference between a good part and a scrap part.

Procedure

After properly laying four or five plies of material, apply one ply of perforated release film over the part. On top of the release film, apply one ply of breather material. After the releases film and breather material has been applied, install a vacuum bag using sealant tape around the edges. Install a vacuum port and pull a minimum vacuum of 21 Hg at room temperature. Hold for a minmum of five minutes. Repeat this process every four to five plies or as necessary.

Bagging for cure

After completion of the laminated plies, the next step is to apply the vacuum bagging and process materials to prepare for cure.



Typical sequence for vacuum bagging operation

Peel Ply

If a clean, secondary bonded surface will be required after the cure cycle, a peel ply can facilitate this. There are many grades of peel ply materials and you should consult your supplier before choosing one.

Apply a full or partial ply of peel ply in the areas requiring a clean textured surface. It is not always necessary to cover the part with peel ply when only a small is going to be bonded in another operation.

Release Film

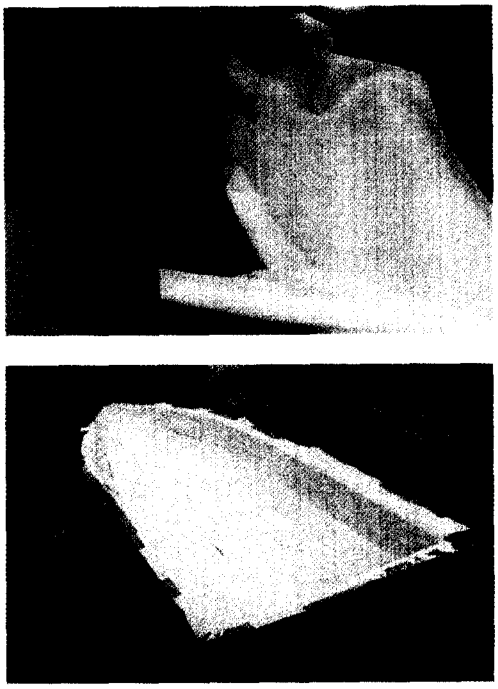
Depending on which laminating system was used, a wet layup system or a prepreg system, a perforated to the laminate or on top of the peel ply if one was used. Consult with your materials supplier to see which perforation should be used.

The release film should cover the entire part surface. Bring the release film to the edge of the part, but not more than 1-2" past the edge of part. Caution must be taken when applying the release film in order to not to have wrinkles or bridges in the film. Any wrinkle or bridge will transfer to the part surface after cure.

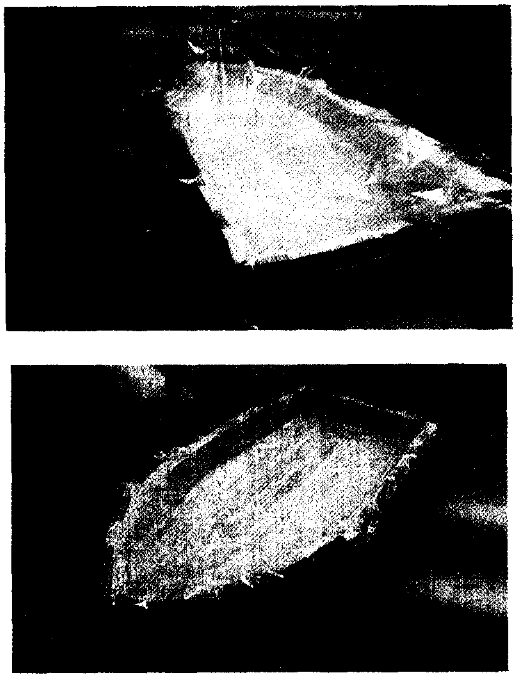
Breather

There are many different weights and types of breather materials. You should consult with your supplier for the correct breather material for your application. After selecting the correct breather material, apply one or two plies across the entire part surface to ensure even breathing capabilities and eliminating any areas for trapping off air.

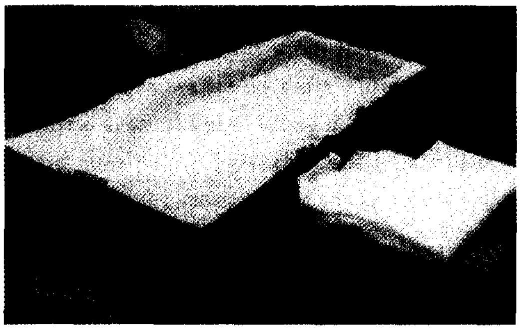
The breather material be in continuous contact around and across the part to ensure all air is drawn out of the part. To ensure this, an edge breather is sometimes used around the part. An edge breather can be made from a



Peel ply application



Release film application

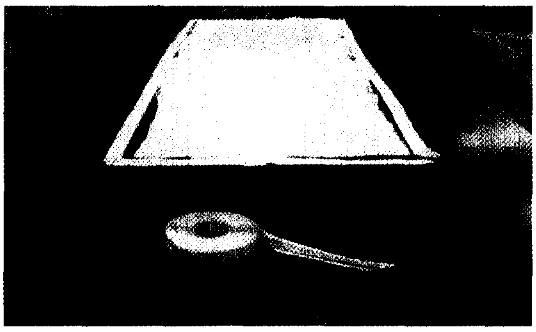


Breather application

heavier material. The theory of how an edge breather works is widely discussed and you must decide for yourself if one is required.

Vacuum Bagging Sealant Tape

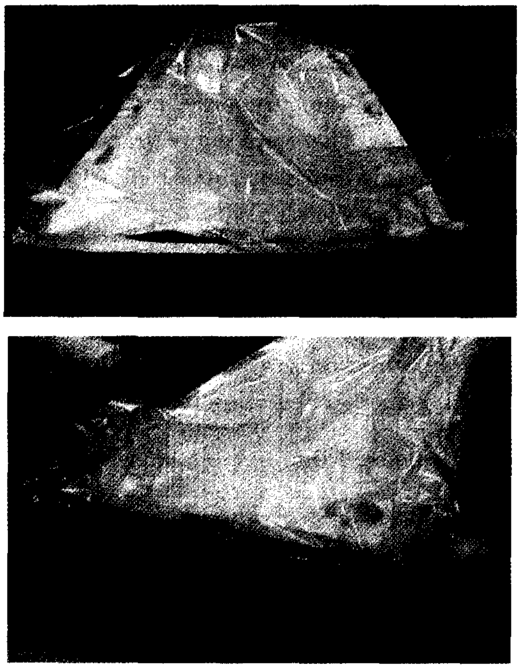
Apply a strip of vacuum bagging sealant tape around the periaphery of the part. Ensure no wrinkles are in the sealant tape. Leave the backing paper on the sealant until ready to apply the vacuum bag. This ensures no contamination and facilitates the application of the vacuum bag.



Sealant tape application

Vacuum Bag

Generally, there are two types of vacuum bagging film. High temperature and low temperature. Obviously, you should chooes the one that is suitable for your cure cycle. Vacuum



Vacuum bagging film

Typical vacuum bag pleats

bagging materials come in a wide variation of temperature ranges and elongation limitations. Precut the vacuum bag to the correct size. Be sure to take into consideration the amount of material necessary for pleats.

Apply the vacuum bag over the part, on top of the breather material. Start with one edge of the part and work your way around the part sealing directly to the sealant tape.

It is sometimes necessary to install "pleats" in the vacuum bag. A pleat will allow room for abnormal shapes and eliminate bridging of the vacuum bag.

After the vacuum bag has satisfactorily been installed, vacuum ports are necessary to enable Vacuum hoses to be connected. A good rule is to have one vacuum port for every three square feet, In some cases, a vent port is also required.

After the vacuum ports have been installed, connect a vacuum line to one port and manipulate the vacuum bag down to the part surface.

Carefully work the vacuum bag down to the contour of the part ensuring no areas of bridging.

Utilizing pleats in corners, inside and outside radii, and any area where a sudden change in part occurs, will avoid vacuum bag bridging or excessive pressure build up. This practice equalizes pressure application nad alleviates aditional stress on the material, which can cause warpage. Pleating alloys the bag to best conform to the part shape which will determine part thickness and resin placement.

Vacuum Valves/Ports

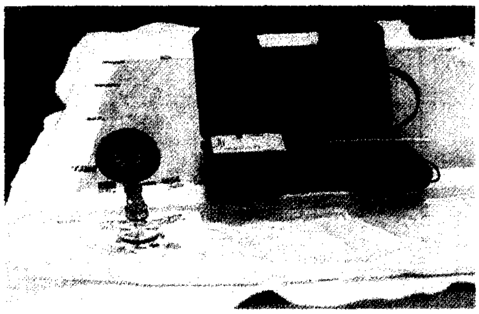
In order to evacuate air from the vacuum bag, it is required that a "through bag" valve or port be installed accommodate an external vacuum valves are inserted through the bag, cutting and X in the bagging film and inserting

Vacuum valve installation

the twist lock pressure plate.

Vacuum & Leak Check

To perform a vacuum check, a vacuum gauge is necessary. Install a vacuum gauge to one of the of the vacuum ports. Apply full vacuum. When full vacuum is obtained, shut the vacuum source off end watch for change in vacuum on the gauge. If the vacuum leaks, it should typically not be mire than 5 in Hg in five minutes.



Vacuum gauge and leak detector

This is the maximum recommended by most specifications.

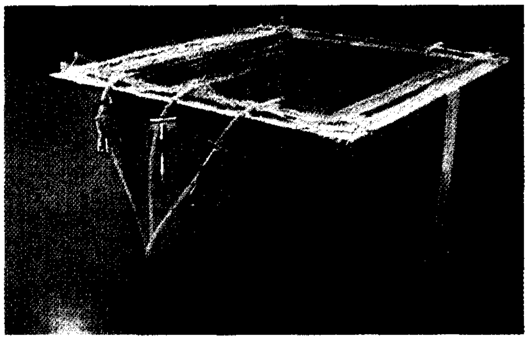
New Development Technologies

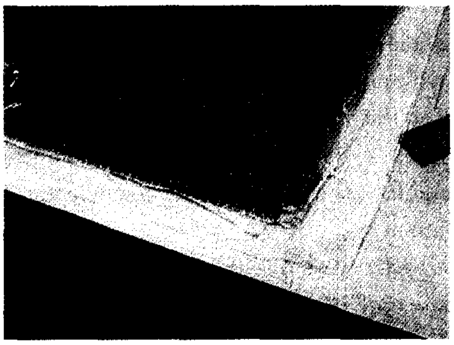
In the past 10－15 years, great strides have been made in developing low viscosity thermosetting resin systems capable of penetrating large part cavities, such as boats. In recent years, boat builders throughout the U.S.A have begun to adopt another process, which is an adaptation of vacuum bagging and wet using low viscosity resins. The process has had many terms attached to it, but all accomplish the same end result; a void free laminate with minimal resin loss. Some of the terminology used for this process has been *Vacuum Assist Resin Transfer Moding(VARTM), Resin Infusion Method(RIM), Seeman's Composite Resin Infusion Molding Process ®(SCRIMP).*

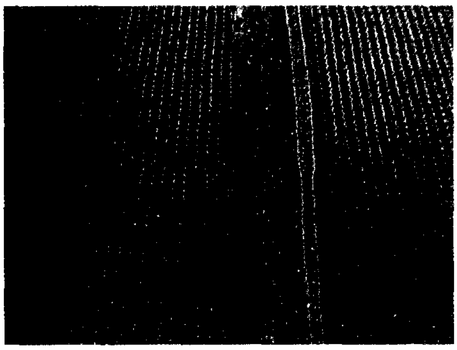
This process can used for many shapes but lends itself especially well for large laminated parts. Large boat hulls have been successfully laminated in one laminating process using resin infusion. The basic process in the same for any size part. They all involve moving resin through a reinforcement to fully saturate with resin and result in composite structure. Some of the advantages and disadvantages if using the process over standard vacuum bagging methods are shown below :

To demonstrate this process, a simple development panel was manufactured using the resin infusion method. The material used were:

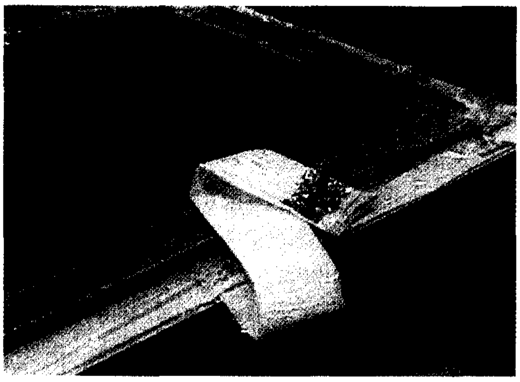
- 181 Style Fiberglass
- Polyester resin
- Peel ply
- Resin distribution tubes and distribution medium
- Vacuum bagging film

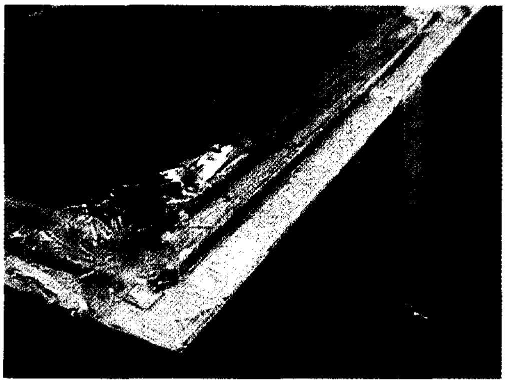


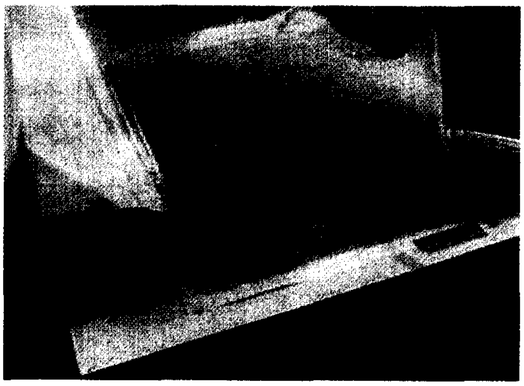


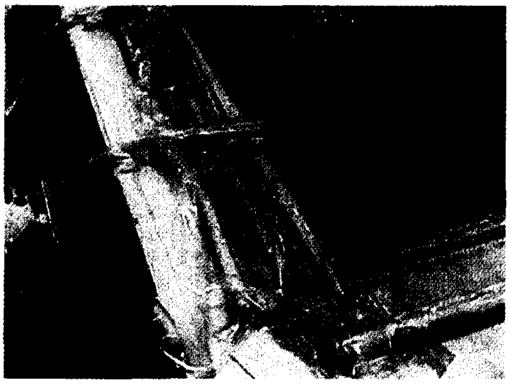


ADVANTAGES	DISADVANTAGES
• Better tolerance control	• Preform location is critical prior to infusion
• Shortened cycle times	• Mold and tooling design critical for good resin flow
• Lower labor costs	• Only low temperature capabilities at this time
• Improved mechanical properties	• Low pressure application only
• Near net molded parts	
• Lower void content(＜1%)	
• Volatile emissions(e.g Styrene's) greatly reduced	









- Vacuum system

The first step is to apply the peel ply or release material to the surface, laminate your material to the tool surface, laminate your part using dry fabric or perform and install the resin tubes. The distribution medium was applied on top of the part and tudes.

Breather tubes were installed to accommodate a full vacuum for the resin infusion.

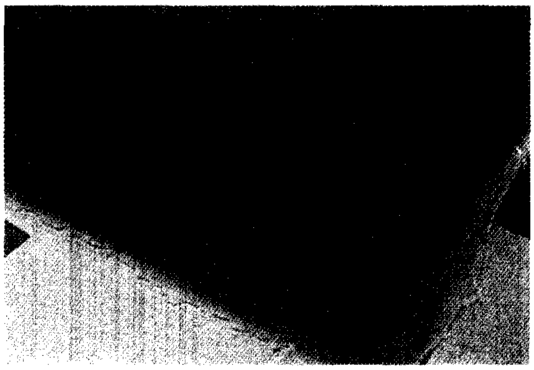
An edge breather was installed to ensure full vacuum throughout the part.

The breather tubes and resin flow tubes were all sealed under the vacuum bagging film using a vacuum bag sealant tape. Using full vacuum and incrementally releasing the resin from the resin pod accomplished even resin distribution throughout the part laminate.

After part was infused and cured at room temperature, the bagging package was removed to reveal a void free laminate.

Excellent results were obtained with this simple demonstration panel.

Much larger panels are and boat hulls are now manufactured using this same basic process. Below are examples of a large boat hull being made in the U.S.A using resin infusion process.



Conclusion

The vacuum bagging and resin infusion process is being used more and more for sporting goods, aerospace, marine and electronics. The ideas and suggestions mentioned in this paper are opinions, suggestions, and facts collected and derived from past experiences of both the author and many other people in this industry.

There are developments happening everyday throughout the world with advanced composite designs, processes, and tooling. This information is intended to introduce the new comer in advanced composites to the vacuum bagging process for fiber reinforced advanced composite fabrication.