vacuum-bagging

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Vacuum Bagging Basics

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Vacuum bagging basics.

PDF Version of the webpage (first pages)

Vacuum Bagging for Wood Products

Vacuum bagging is a method of clamping, which has traditionally been used in the composites industry, but can also be used for vacuum drying materials, including wood products.

The basics of vacuum bagging for kiln drying include evacuating the moisture laden air, while simultaneously heating wood products (via use of a heated pad or heating blanket), which encourages the movement of water from the cells to outside the wood. Depending on the temperature, you may also be able to heat treat at the same time.
The extreme pressure of atmosphere clamping, prevents the wood products being dried from warping and other distortions from the drying process.
Vacuum bagging for wood products can be applied to any wood products including dimensional lumber, slabs, whole logs, pallet boards, firewood, timbers, and more.
Vacuum bagging can also be used to bond complex curves and veneer to substrate.

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How Vacuum Bagging Works

Vacuum bagging uses atmospheric pressure as a clamp to hold laminate plies together. The laminate is sealed within an airtight envelope. The envelope may be an airtight mold on one side and an airtight bag on the other. When the bag is sealed, pressure on the outside and inside of this envelope is equal to atmospheric pressure: approximately 29 inches of mercury (Hg), or 14.7 psi. As a vacuum pump evacuates air from this envelope, the air pressure inside is reduced while air pressure outside of the envelope remains at 14.7 psi. Atmospheric pressure forces together the sides of the envelope and everything within the envelope, putting equal and even pressure over the surface of the envelope. The pressure differential between the inside and outside of the envelope determines the amount of clamping force on the laminate. Theoretically, the maximum possible pressure that can be exerted on the laminate, if it were possible to achieve a perfect vacuum and remove all of the air from the envelope, is one atmosphere, or 14.7 psi. A realistic pressure differential (clamping pressure) will be 12–25 inches of mercury (6–12.5 psi).

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Advantages of Vacuum Bagging

As with other laminating methods, you can incorporate different materials into the laminate.
You select materials to match the component's structural requirements and your choices aren't limited by the clamping method.
Provides firm, evenly distributed clamping pressure over the entire surface regardless of the material you're laminating. This allows a wider range and combination of materials as well as a superior bond between the materials. It's superior to mechanical clamping or stapling, which applies pressure only to concentrated areas, can damage fragile core materials, may not provide enough pressure to bond in some areas, and may require additional adhesive to bridge gaps.
Results in thinner, more consistent glue lines and fewer voids thanks to uniform clamping pressure across the laminate. Because atmospheric pressure is continuous, it evenly presses on the joint as the adhesive spreads evenly within.
Lets you control epoxy content and removes excess adhesive from the laminate, resulting in higher fiber-to-epoxy ratios. This translates into higher strength-to-weight ratios and cost savings.
Allows for using a greater variety in molds and creating custom shapes. With vacuum bagging, the atmosphere pushes down on the top of the envelope and pushes up equally on the bottom of the envelope or mold. Since atmospheric pressure provides equal and even clamping pressure to the back of the mold, the mold only has to be strong enough to hold the laminate in its desired shape until the epoxy has cured. This means vacuum bag molds can be relatively lightweight and easy to build.
All of the materials in the laminate are wet out and laid up at the same time, which means vacuum bagging lets you complete the laminating process in one efficient operation. Learn more about laminating in Applying Fiberglass.

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Vacuum Bagging Equipment

The vacuum bagging system consists of the airtight clamping envelope and a method for removing air from the envelope until the epoxy cures.

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Vacuum Pumps

The heart of a vacuum system is the vacuum pump. Powered vacuum pumps are mechanically similar to air compressors, but work in reverse so that air is drawn from the closed system and exhausted to the atmosphere. Vacuum pumps are designated by their vacuum pressure potential or Hg maximum (Hg is the symbol for inches of Mercury), their displacement in cubic feet per minute (CFM), and the horsepower (HP) required to drive the pump.

Vacuum Pressure

The inHg maximum level is the maximum vacuum level (measured in inches of mercury) recommended for the pump. This vacuum level translates to the maximum amount of clamping pressure that can be generated. Two inches of mercury (2 inHg) equals about one pound per square inch (1 psi) of air pressure. (Remember that 1 atmosphere = 29.92 inches Hg = 14.7 psi) If you are vacuum bagging a one-square-foot laminate, a 20 inHg vacuum will yield 10 psi clamping force or a total of 1440 pounds of clamping force over the entire laminate. If you are laminating a 4 ft × 8 ft panel, the same 20 inHg (10 psi) will yield over 46,000 pounds of clamping force spread evenly over the entire panel.

Displacement

The volume of air a pump can move (rated in cubic feet per minute or CFM) is also an important consideration in the selection of a pump. If the vacuum system (the mold, bag, plumbing and all seams and joints) were absolutely airtight, any size pump should be able to eventually pull its rated Hg maximum vacuum regardless of the size of the system. However, creating a perfectly airtight vacuum bagging system is nearly impossible, especially with systems that are larger or more complex. The greater the CFM rating, the closer the pump can come to reaching its Hg maximum and maintaining an adequate clamping force against the cumulative leaks in the system. A vacuum pump with a high CFM rating will also achieve an effective clamping force more quickly. This is an important consideration if the working life of the adhesive is limited or if the laminate will not hold its position until the clamping force is applied.

Performance and HP

The horsepower requirement of the pump helps indicate how efficient the pump is. It doesn't reveal how well a pump is suited to vacuum bagging. When selecting a pump, use the Hg maximum and CFM ratings as a guide rather than horsepower. Smaller pumps designed for specific applications may trade off either vacuum rating or air displacement to suit a particular job. Generally, to get both higher Hg maximum and CFM ratings, more horsepower is necessary. For larger drying operations which require more air removal and surface area, larger CFM vacuum pumps are required.

Pump Selection

The size and shape of the mold and type and quantity of the material being laminated will determine the minimum pump requirements. If you are laminating flat panels consisting of a few layers of glass, flat veneers or a core material, 5 or 6 inHg (2.5–3 psi) vacuum pressure will provide enough clamping pressure for a good bond between all of the layers. If the area of the panel is limited to a few square feet, a 1 or 2 CFM pump will provide adequate clamping pressure. As the panel area increases, the CFM requirement increases proportionately. A displacement of 3.5 CFM may be adequate for up to a 14 ft panel. For larger jobs, a pump with a displacement of 10 CFM or more may be required.

Poor seals in the plumbing system or envelope, or materials that allow air leakage, will require a larger capacity pump to maintain satisfactory vacuum pressure. The more airtight the system, the smaller the pump you'll need. A higher Hg maximum rated pump will be required if you need more clamping pressure to force laminations to conform to a more complex mold shape. Curved or compounded mold shapes and or laminations of many layers of stiff veneers or core materials may require at least a 20–28 inHg vacuum to provide an adequate clamping force.

Again, if the panel size is limited to a few square feet, a 1 or 2 CFM pump with a high Hg rating will work, if the envelope is airtight. However, a very large panel may take a minimum of 10 CFM pump to reach and maintain enough clamping force to press all of the laminate layers to the mold shape and produce consistent glue lines throughout the laminate.

Generally, the best pump for a specific vacuum bagging operation will have the largest air moving capacity for the vacuum/clamping pressure required while operating at a reasonable horsepower.

Pump Types

Vacuum pump types include piston, rotary vane, turbine, diaphragm, and venturi. They may be either positive displacement or non-positive displacement.
We build our own vacuum pumps from parts sourced from McMaster.

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Release Fabric Vacuum Bagging Material

Also known as peel ply or release film, this smooth, woven material will not bond to epoxy. It’s used to separate the breather and the laminate. Excess epoxy wicks through the release fabric which you peel off after the laminate cures. Release fabric leaves a smooth, textured surface that can usually be bonded to without additional preparation. Sand surfaces that will be subject to highly-loaded bonds before doing additional bonding. Release fabrics and films can be designed for high-temperature applications or for controlling the amount of epoxy that can pass through them.

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Perforated Film Vacuum Bagging Material

When used with epoxy, a plastic film you can use in along with release fabric to help keep the epoxy in the laminate when you're using high vacuum pressure with slow curing epoxy systems, or creating thin laminates. Perforated films are available in a variety of hole sizes and patterns. The correct choice depends on the amount of clamping pressure and the epoxy's open time and viscosity.

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Breather Material Vacuum Bagging Material

Also called bleeder material, its purpose in vacuum bagging is to allow air from all parts of the envelope to be drawn to a port or manifold by providing a slight air space between the bag and the laminate. It provides air passage within the vacuum envelope and absorbs excess epoxy. Bleeder material can consist of a lightweight polyester blanket (a.k.a. baby blanket), mosquito netting, burlap, fiberglass cloth, or solar bubble swimming pool cover.
When using larger logs or timbers, side placed concrete blocks or other support structure may be used.

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Vacuum Bag Vacuum Bagging Material

This bag typically forms half of the airtight envelope around the laminate. If you plan to use vacuum pressure of less than 5 psi (10 hg) at room temperatures, 6-mil polyethylene plastic is sufficient for the bag. Clear plastic film is better than opaque material to allow easy inspection of the laminate as it cures. For higher pressure and temperature applications, use specially manufactured vacuum bag material. Film Technology, Inc. offers a wrinkled film that channels air and eliminates the need for breather material.

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Mastic Sealant Vacuum Bagging Material

Mastic is used to provide a continuous airtight seal between the bag the perimeter of the mold. Mastic may also be used to seal the point where the manifold enters the bag and to repair leaks in the bag or plumbing. Poor seals, or material which allows air leaks, will require a larger capacity pump to maintain satisfactory vacuum pressure. Mastic (typically two sided tape specific for this application) is used to to seal the perimeter of the vacuum bag.

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The Plumbing System Vacuum Bagging Material

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 a flexible hose or rigid pipe, a trap, and a port that connects the pipe to the envelope. A more versatile system includes a control valve and a vacuum throttle valve that allow you to control the vacuum pressure in the envelope. A system is often split to provide several ports on large laminations. Or it may include a manifold within the envelope to help channel air to a single port. We use parts from McMaster and Automation Direct.

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Pipes or Tubing Vacuum Bagging Material

You may use a variety of pipe or tubing for plumbing as long as it is airtight and resists collapsing under vacuum. Vacuum hose is designed specifically for vacuum bagging and autoclave laminating. It is available along with fittings, pumps, and other vacuum bagging materials from manufacturers specializing in vacuum bagging equipment. Because of its higher cost, this type of plumbing system is most appropriate for large scale or production laminating operations. Other types of wire-reinforced hose may work, but they should be rated for crush resistance or tested under vacuum for the expected length of your epoxy's cure time. Semi-rigid plastic tubing with adequate wall thickness can be used for a plumbing system, but it is often awkward to handle. If you plan to post-cure the laminate during vacuum bagging, the tubing must also be heat resistant. Plastic tubing that can withstand vacuum at room temperature may soften and collapse when heated.

Rigid 3/4 inch PVC or CPVC pipe, elbows, T fittings, and valves work well. They are low cost and available at most hardware or plumbing supply stores. The pieces do not need to be cemented together and can be rearranged to suit any configuration. Low cost and versatility make this type of plumbing system ideal for small scale or occasional laminating.

We also use pressure rated PEX tubing.

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Ports Vacuum Bagging Material

A vacuum port connects the exhaust tubing to the vacuum bag. It can be designed specifically for the purpose or made from commonly available materials. One of the simplest ports is a hollow suction cup that sits over a small slit in the vacuum bag. Cups designed for use with car top carriers can be easily adapted by drilling through the center of the cup.

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Control Valves Vacuum Bagging Parts

A control valve into the vacuum line so you can regulate the volume of airflow at the envelope. The control valve affects the rate of air removal without affecting vacuum pressure.

In addition, you can place a vacuum throttle valve between the control valve and the envelope. This valve, incorporated with a T fitting, acts as an adjustable leak in the system to control the envelope pressure. For convenience, valves should be placed close to the envelope. Incorporate a trap into the line as close as possible to the envelope. This trap will collect any excess epoxy or water that gets sucked into the line before it can reach the valves or pump, and prevents a buildup of epoxy or water in the line. You can easily build a trap with a small section of pipe, a T fitting, and an end cap.

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Vacuum Gauge Vacuum Bagging Parts

This device is necessary to monitor the vacuum level and clamping force during the cure time of the laminate. Most vacuum gauges read in inches of mercury from zero (one atmosphere) to 30 (inches Hg below one atmosphere). The reading of negative pressure inside the bag equals the net pressure of the atmosphere pressing on the outside of the bag. To approximate this reading in pounds per square inch (psi), simply divide the reading by two. A vacuum gauge, available from McMaster or Automation Direct, is modified by threading a hollow suction cup (similar to the port) to the base. A 1.5 inch PVC pipe cap, with a hole drilled and tapped to match the gauge, will also work. The end of the cap is sealed to the vacuum bag with mastic.

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