Fabrication Procedure for Autoclave-Quality High-Temp Graphite/Epoxy Tools

Scope

This procedure describes the materials and methods for fabrication of high-temperature, autoclave-quality graphite/epoxy laminated tools. The layup will be compacted under vacuum, on the pattern, and set at room temperature. Once the egg crate backup structure has been applied, the tool will be removed for a subsequent freestanding post cure. There are many accepted methods of making these type tools. This is one procedure that has been proven successful at many different shops. It can be used as a guide and be modified to accommodate particular applications.

Discussion

Tooling Material Requirements:

PTM&W PT1995 A/B & B1 Graphite-Filled Black High-Temp Surface Coat
PTM&W PT2846 A/B2 Unfilled High-Temp Laminating System

Note: Use PT2846 B hardener for patching, repairing and tying on backup structure.

Note: If a filled system is preferred, substitute PT2848 A/B2 Black High-Temp Laminating System and the B hardener for repairs.

3K, 6.0 Ounce, .007-inch thick Graphite Fabric
6K, 10.2 Ounce, .014-inch thick Graphite Fabric
12K, 20.0 Ounce, .028-inch thick Graphite Fabric

Note: All fabric should be cut into 24X 24" squares, with half cut in the 0°/90° direction and half cut on the bias (45°).

4-inch wide Graphite Woven-Edge Tape, .020-inch thick

Process Material Requirements:

Nylon Film Vacuum Bag
Vacuum Bag Sealant Tape
Scotchbrite Pads
Solvent – company approved
10-Ounce Breather Material
Flash breaker Tape
Masking Tape
PTM&W Stiff-Bristle Tooling Brushes
Plastic or Rubber Spatulas
PTM&W PA0801 Non-Silicone Paste Wax
Thermocouple
Perforated Release Film (use P or P3 perforation schedule)
Mixing containers and sticks
Time Clock

Discussion

Before starting, make sure the layup area is protected from sources of airborne contamination, such as dust and mold release. Maintain an ambient temperature of 75° F. (within 10°) and 60% relative humidity, if possible. Employ proper safety and housekeeping standards.

Preparation of Pattern Surface

- Make sure the pattern surface is exactly what you want replicated by the finished tool. Each hour spent on perfecting the pattern will save many hours refinishing the final tool.
- Clean the pattern surface with Scotchbrite pads and solvent and completely remove dust residue.
- Check vacuum integrity of the pattern by applying a few plies of breather material under a vacuum bag and pull a vacuum. Check for leaks by monitoring vacuum drop in the vacuum gage. Track down and seal any leaks before proceeding.
- Cover the periphery of the pattern surface (from where the bag sealant tape will be applied to the edge of the tool) with masking tape to protect from release contamination.
- If the pattern is non-porous, apply a minimum of three coats of PA0801 wax to the surface, buffing between coats and the final coat. If the pattern is porous, seal with a minimum of three coats of a lacquer-based sanding sealer, apply a minimum of three coats of PA0801, and coat with a layer of PVA or PVA based barrier film.

Surface Coat

- Mix PT1995 A/B at 100:12 pbw. Pour into another cup and mix again. Make sure to scrape the sides of the containers.
- Brush or squeegee the entire working surface with the mixed PT1995 to .015-.020 inches thick. Try to apply the surface coat in one direction until the entire surface is covered. Remove excess resin as you work the material. Try to minimize air entrapment by careful brushing.
- Lightly brush in a 90° direction to the previous brushing. Watch for buildup in female corners
- Allow this coat to cure at room temperature (around 60 minutes depending upon batch size and shop temperature) until it has cured to a tacky condition, (where you can leave a fingerprint on the surface but no transfer to your finger). **Warning:** If allowed to cure to a hard glazed surface, you must either remove the coat and start over, or sand the back surface of the coat until the glaze has been removed.
- Proceed directly to the laminating steps. **Option:** Apply a second surface coat of PT1995 using the B1 long pot life hardener. Immediately start laminating the first ply of 3K fabric into this coat while it is wet. **Option:** Mix PT1995 A with PT2846 B2 hardener at 100:6 pbw. Mix an equal amount of PT2846 A/B2 at the proper ratio. Start keeping time at this point. Take these two mixtures and blend them together at a 50:50 ratio. Brush this mixture onto the back of the first surface coat while it is still tacky. Immediately start laminating the first ply of 3K fabric into this mixture.

Laminating

The most critical part of the laminated tool is the first few plies, because any air trapped there will result in blisters or delaminations during the final cure or during production cycling. Spend half of your laminating time on the first quarter of the tool thickness.

- Dry the graphite fabric for at least one hour at 225° F. in an air-circulating oven.
- Weigh the amount of pre-cut graphite fabric and try to use the same amount of PT2846 to keep the resin content of the laminate to about 50%.

- Thoroughly mix PT2846 A/B2 at 100 pbw A to 9.5 pbw B. Start keeping time from this point (if you did not previously do so).
- Brush the entire back surface of the tacky surface coat with the laminating resin, until the entire surface is covered.
- Immediately apply the first ply of 3K graphite fabric into the wet resin. Overlap the joints by a maximum of ½-inch. Use a stiff-bristle brush to work the wet resin up through the dry cloth, working out as much air as possible.
- Continue to laminate and orientate each ply according to the Ply Table. It is best to brush or squeegee wet resin onto the previous ply and then apply dry fabric onto the resin, working the resin up through the fabric. This method tends to result in less trapped air than if resin is applied to dry cloth. Build each ply in this manner.

Ply Table

Layup Stage	Ply	Orientation	Thickness (Inches)
Stage 1	1	0 Degrees	.007
	2	90 Degrees	.007
	3	+45 Degrees	.014
	4 - Bag	- 45 Degrees	.014
Stage 2	5	0 Degrees	.028
	6	90 Degrees	.028
	7	+45 Degrees	.028
	8 - Bag	- 45 Degrees	.028
Stage 3	9	- 45 Degrees	.028
	10	+45 Degrees	.028
	11	90 Degrees	.028
	12 - Bag	0 Degrees	.028
Stage 4	13	- 45 Degrees	.014
	14	+45 Degrees	.014
	15	90 Degrees	.007
	16 - Bag	0 Degrees	.007

Estimated Cure Thickness = 3/8 Inch

- While laminating, monitor the clock. You should plan to have the laminate under vacuum within a maximum of 4 hours (depending upon shop temperature) from the start of mixing the first batch. Allow time for bagging and chasing down vacuum-bag leaks. If time does not allow for four plies, only laminate two or three. The resin in the first ply must be liquid and able to move under pressure when the vacuum is applied. **Note:** As an alternate, or in addition to using the clock, make a small test laminate in a separate area. For every ply made on the working tool, laminate a small ply on the test area. Monitor the resin used for the first ply. When it starts to thicken, stop work and start the bagging procedure.
- At the stages where the Ply Table calls for a bag, apply peel-ply, bleeder, perforated release-ply, breather and nylon vacuum bag according to normal vacuum-bagging procedures. Pull a vacuum and check for leaks. Leave under vacuum over night.
- Remove the peel-ply, being careful not to disturb the laminated plies. At this point, you can embed a thermocouple behind the first laminated stage, outside of the working area of the tool. This will be used for monitoring the post-cure cycle.
- Continue in this manner, following the schedule in the Ply Table until the desired thickness of the tool is achieved. Use extra debulk stages if the tool is large and there is not time to the four-ply schedule.
- Apply vacuum and let cure overnight.

Backup Structure

- Remove bagging materials. While nesting on the pattern, apply egg-crate backup structure, preferably using pre-cured high-temp epoxy laminated graphite flat stock (either purchased or made with the same materials as the tool).
- Locate the structure within ¼-inch of the back of the laminate. Tie the structure to the back of the tool using PT2846 A/B, mixed at 100pbw A to 19 pbw B. Use a minimum of three plies of either 4-inch wide graphite tape or 6K-graphite fabric with the resin. Tie-ins should be attached six-inches (minimum) to the structure wall and laminate back. Hole-saw round holes in the egg-crate walls to allow air circulation.
- If the pattern will accommodate it, cure the tool overnight on the pattern at 120°F., with the backup structure attached. If that is not possible, cure at a minimum of 75° F. for 48 hours.

Post Cure

- Using the proper post-cure cycle can control shrinkage and warpage. Being in a hurry at this point can cause a tool to become scrap. Slower heat-up rates and longer dwell times minimize problems.
- Place the tool into a cool oven. Make sure the tool is adequately supported on its backup structure and is not racked in anyway.
- Connect the optional thermocouple to a monitor. All temperatures suggested below should be from the thermocouple readings, not from oven gages. All heat-up rates should be 3° F./minute or less.
- Heat to 150° F. Dwell at 150°F. for 4-hours to stabilize the tool.
- Raise the temperature in 50° F. increments and dwell for 2-hours at each stage, until reaching the final temperature.
- The final stage should be 25-50° F. above the expected operating service temperature of the tool. Dwell for 4-hours.
- Turn off the heat, crack open the oven door and allow the tool to return to room temperature before removing.

Prepare Tool for Service

- Inspect the tool for any blisters or cracks in the surface coat. Make any repairs using PT1995 A/B. Make sure to remove any mold release before repairs are made.
- Make a vacuum-leak check of the tool using the standard vacuum-bagging procedure. If the tool fails the vacuum check, repair by using the method described in “Using PT2210 A/B to Restore Vacuum Integrity of Tools”.
- Clean the working surface with an approved solvent. Do not sand the tool surface unless absolutely necessary.
- Apply a good quality tool sealer, like Chemlease MPP117, according to the manufacturer’s directions.
- Place the tool into service.

There are many other ways to build high-temperature autoclave-service-quality laminated graphite/epoxy tools. This is just one proven method. Other hardeners are available which provide 8-hours or more working time. These usually have to be made on patterns that can withstand heat cures.

If there are any questions about the procedures outlined here, or if you have an application that does not fit with this method, please call us at 800 421-1518 and we will be glad to confer with you on an individual basis.

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