MatEdu National Resource Center
www.materialseducation.org

Composite Panel Hand Lay-up Experiment

Jean Frank
Associate Professor of Industrial Technology & Mechatronics
Thomas Nelson Community College
Hampton, VA 23666
frankj@tncc.edu

Abstract:

This experiment provides students with experience in the construction of a panel from composite materials using the hand lay-up process. The purpose of this lab is to become familiar with certain materials, their purposes and their abilities, while making a composite clipboard. This module explains the process of preparing a hand layup. To make the panel, we must gather and prepare the materials for production, then, with the many safety precautions involved, proceed to construct the panel in a step-by-step process, followed by curing. This lab is intended to provide basic skills in composites fabrication.

Module Objectives:

The hand lay-up process is a common procedure for fabricating real composite parts. This lab is the simplest and most effective way to familiarize the student with some basic composite materials and procedures. The student will also learn and understand the safety aspects of handling composite materials, and will gain an understanding of fundamental skills needed for composite fabrication: safety handling of materials, cleanliness and keeping organized in the work environment while using composite materials and associated tools.

Student Learning Objectives:

Students will be able to:

- Demonstrate how to perform a composite process, the hand layup
- Explain the role of reinforcements, matrix, and curing
- Demonstrate how to prepare, lay out materials, mix the matrix, and perform a vacuum bag process of curing
- Gain an understanding and observe the skills needed to work with composites and limits of a layup process
- Use all appropriate safety procedures during the process

MatEd Core Competencies Covered:

1C Demonstrate laboratory skills
7C Describe the general nature of composite materials
11A Describe the structure and advantages of composite materials
11B Explain basic processing procedures for composite materials

Key Words: Composites, materials, manufacturing processes, fiberglass, matrix, resin, layup
Type of Module: Introductory lab exercise
Time Required: 5 to 6 hrs. in class with allowance for an overnight cure broken into 2 days, day 1 for lay-up and day 2 for review and examination of the product.
Pre-requisites: Knowledge of general composite manufacturing processes (see **Module:** Composite Manufacturing Processes) and completion of the **Module**: Composite Manufacturing Health and Safety, complete with a signed Safety Contract.
Target Grade Level: grades 9 - 12 technology courses, introductory community college course

Accompanying Material:

- **PowerPoint** Composite panel Hand Layup Experiment (slides 1 – 7),
- **Module**: Composite Manufacturing Health and Safety
- The **Module:** Keeping a Lab Journal is also recommended
    - Both modules above are available at www.materialseducation.org

Materials required:

1. Eyewash station or sink
2. Fiberglass Fabric
3. Carbon Fiber Fabric
4. Lantor Soric®Epoxy Resin (see supplier below)
5. Polyvinyl Alcohol, or vinegar
6. Release Cloth
7. Sealant Tape
8. Bleeder Cloth
9. Breather material
10. Perforated ply
11. Peel ply
12. Vacuum Bag (if used)
13. Release wax (can use car wax)
14. Scissors
15. Mixing container and mixing sticks
16. Squeegee, brushes
17. PPE – gloves, apron, safety glasses, appropriate close-toed shoes and long pants, long hair tied back, etc.
18. Vacuum pump and hose

For the Clipboard:

1- 10" x 13" Lantor Soric®

2 - 11" x 14" Carbon Fiber
2 - 11" x 14" Fiberglass
Epoxy Resin (for amount, see below)
Epoxy Hardener

For the vacuuming process:

1- Table
1- 58" x 32" vacuum bagging plastic
1- 62" x 32" vacuum bagging plastic
2- 58" x 32" Peel-Ply
1- 58" x 32" Breather cloth
1- Roll of Vacuum Bagging Sealant
1- Pair of vacuum clamps
1 – Vacuum pump

www.Fiberglast.com is an excellent supplier of composite fiber and vacuum materials, with literature on usage.

Instructor Notes:

Having the eyewash station or sink available is critical for safety, and its location should be made clear to students at the beginning of the activity

Performing a Basic Wet Hand Layup

The most basic type of fabrication process is a hand layup. This process requires dry reinforcement layers, or plies, and applying a wet resin – matrix. They are combined together – fiber (reinforcement) material, is impregnated with a matrix – resin. There are several basic wet lay-up processes that can be used to fabricate a composite part – a flat panel lamination or mold layup, but they all follow the same basic steps (see module 3.2.2).

Note: Commonly, a mold may be used to fabricate components during the lay-up process. Use of a mold is used to obtain the desired shape. During this lab, we will not use a mold, but instead a tabletop to hold the flat shape of the layup.

Steps of the Molding Process:

- Design and planning – material selection – fiber type, weight, orientation, and number of layers, resin system, and planning the project from start to finish
- Creation & prep – composites are used primarily because they can take any shape – unlike metal parts, primarily by creating a mold. They are formed by a mold. A well-built mold is extremely important to the success of the process, and to ensure removal – a good release of the finished part to be used again is critical. Molds allow for several composite pieces to be formed on them and thus have multiple uses instead of just being a one-time use. In this lab, we use a table top as the mold.
- Orientation of plies - Fiberglass weaves are either in one direction (unidirectional), or runs in two directions (bidirectional). Bidirectional fibers are 0 degrees and 90 degrees to each other, meaning all of the strength of the fabric is in both directions. Unidirectional fibers are 0 degrees, meaning that all the strength is only in one direction. Layering fabric alternating between, 0, 45, and 90 degrees ensures that the strength will be uniformed and transferred equally by the matrix.
- Layup – at this stage the reinforcement layers are placed in the mold to form the desired final shape of the composite piece with appropriate fiber orientation.
- Wet Out—(always follow manufacturer's instructions for resins). After layup the resin is added to the stack and manually the reinforcement can be "wet out" by the resin. All the appropriate bagging materials are then placed along and on these materials and the mold.
    - Resin/Fiber Ratio (60:40):
    - Example:
        - Fiber weight = 57.4g
        - Cured composite weight = 89.8g
        - Resin weight = 32.4 g

        - Fiber weight ratio = 63.9%
        - Resin weight ratio = 36.1%
- Curing – after layup and wet out is completed, the part needs to cure. To accelerate the cure heat can be used – oven, heat lamps, or heating pads may be used.
- Demolding - at this stage the cured part will be removed from the mold. Some parts may be stubborn and demolding can be improved during the design and planning stage to ensure adequate steps and materials were selected.
- Trimming and finishing – composite pieces removed during demolding will need trimming to remove rough edges, and flashing. Finishing with paint or polishing may be necessary.

Flat panel layup steps are similar, with a tabletop as the mold.

Review with the students the materials on Health and Safety to ensure all students will perform the lab carefully and without harm to personnel or equipment:

SAFETY: (see slide 2)

- Review all SDS sheets prior to handling materials. SDS sheets describe all necessary safety data and required PPE for the handling of materials.
- Perform layup and wet out/infusion operations in a well-ventilated area.
- Always use PPE when handling composite materials as described by the SDS.
- Use caution during the resin/hardener chemical reaction, which is an exothermic reaction. Be sure to place any mixing container only in a non- flammable area. Mixing containers are potentially a fire hazard and a hazardous waste until cured.
- Allow proper working space around each student. Resins are messy and easy to get on other people's clothes, be thoughtful about their workspace and their work as well.
- Prepare and cut reinforcement materials prior to mixing any chemicals.
- Designate areas for any grinding, sanding, drilling, sawing or machining of composites as this should be well ventilated and all personnel should wear correct PPE, dust masks and safety glasses. Designated area is away from layup so dust does not contaminate the layup.

Prompt students to be careful to not to touch face, skin, etc. while handling resins. Vinegar can be used to clean affected areas – SDS will also inform how to remove resin.

- Discuss handling and cutting of dry fibers with caution and using the proper PPE because glass or carbon fibers can cause itching or skin irritation. Carbon fibers, if they get on electronic equipment, can also short circuit such equipment.
- Make sure students know where fire extinguishers are located as well as spill kits.

Terminology:

- **Release agent** – layer of film that does not bond to resin being cured - prevents matrix from sticking to the table. In this lab, the tabletop will be covered with plastic sheeting, or PVA to act as the release agent. Some other release agents used in industry are: wax, spray releases, and other release films.
- **Resins** - The matrix of the composite to 'bind' the composite materials together and transfer the component stresses that may act on the part to the fibers in the composite. In this lab, a

two-part epoxy and hardener (accelerator) resin system will be used.

- **Reinforcing Fibers -** There are many different fibers that can be used to fabricate a composite material. The fibers are designed and selected to handle intended stresses imposed. In this lab, a standard weave fiberglass and carbon cloth will be used.
- **Work station preparation -** Initial preparation of materials and tools is standard procedure when working with composites. Once resin and hardener are mixed, the "working time" – amount of time an epoxy remains viscous enough that it can be still be easily applied, prior to the resin mix curing - is limited by the speed of the hardener chemically reacting with the epoxy producing an exothermic reaction. Student must prepare ALL materials and supplies, and set up before proceeding.
- **Mold preparation -** Before starting with the layup process, table preparation must be done. This preparation consists of cleaning the table and applying a release agent to the surface, to avoid the resin sticking to table. In this lab, the mold preparation is simply taping the plastic sheeting to the tabletop.
- **Resin Rich –** localized area of cured part that has too much resin and little reinforcement fiber.
- **Resin Starved –** localized area lacking enough resin to wet out the fiber.
- **Delamination** – separation of the laminate, along the layers.
- **Void** – air trapped and cured in the laminate. Voids will not allow the transmission of stresses to the load and can result in premature failure of the part that could be catastrophic failure.

Lay-up process:

1. The first step in constructing the clipboard is to cut out rectangles (14" x 11") of the reinforcement materials to be used. The instructor will dictate the number and weave direction of each material as indicated by the table in slide 3 (note slides are duplicated below).
2. Vacuum bag material should be cut about two inches bigger than the perimeter of the prepared work surface - cut about four inches bigger than the overall dimensions of the clipboard.

Fiberglass weaves are either in one direction (unidirectional), or runs in two directions (bidirectional). Bidirectional fibers are 0 degrees and 90 degrees to each other, meaning all of the strength of the fabric is in both directions. Unidirectional fibers are 0 degrees, meaning that all the strength is only in one direction. Layering fabric alternating between, 0, 45, and 90 degrees ensures that the strength will be uniformed and transferred equally by the matrix (**see slide 3**)

Layering using clock method

Stack fabric in the correct order and weave orientation according to the diagram provided by the instructors. Weigh the stack of fiber reinforcement in order to obtain a dry weight of the materials (**see Slide 4**).

Layer	Material	Orientation
1	Glass	0°
2	Carbon	90°
3	Glass	0°
4	Carbon	90
5	Glass	0°
6	Glass	90°
7	Soric Material	
8	Glass	0°
9	Glass	90°
10	Glass	0°
11	Glass	90°
12	Carbon	0°

1. After all of the material has been cut begin to stack the material starting with the first layer and working backwards ending with what will be the bottom layer and place to the side.
2. With the material ready the work surface needs to be properly prepared, this work surface needs to be flat and smooth. Properly prepare the surface:
   a. clean the surface with vinegar to remove any foreign materials.
   b. Suggestion, use a heavy coating of release wax (any car wax will do) and apply to the surface, then buff out, this will fill any minor scratches on table surface.
   c. Once the work surface has dried it can be prepared for the vacuum bagging process.

3. Mixing the resins – matrix. Always follow manufacturer's instructions and SDS PPE and safety instructions.
   a. Epoxy matrices are 2 parts – resin and hardener. The amount of resin depends on the weight of the cloth that you are using. Weigh the cloth, and mix corresponding amount of matrix. Or use a calibrated mixing pump, which dispenses the correct amount of matrix. Pour the resin into one container and the hardener into a separate container. Ensure you don't mix part A into part B until you're ready to start the process. When you are ready to mix, add the hardener to the resin container and mix well. Ensure all bubbles are removed before applying the matrix to the stacked fibers. Ensure you don't mix part A into part B until you're ready to start the process. Mixing Epoxy Resins, using a resin dispensing pump or maintaining a resin mixing ration epoxy parts A and B into a cup and mix completely. If no dispensing pump:
      i. **<u>If manufacturer epoxy ratio is 100:40, use 100g of resin and 40 g of hardener.</u>**

      - After the two parts are poured at the correct ratio, mix them together thoroughly for a full 2 - 3 minutes with a mixing stick, mix longer for larger quantities.
      - Scrape all sides of the cup, including corners, and bottom several times during mixing. This will ensure that all the hardener is thoroughly mixed with the epoxy and should prevent the resin from having an improper cure.

- If the mixture doesn't have a single consistency (streaks remain) continue mixing until fully blended.
- Start pouring or applying the epoxy immediately, the larger the quantity of mixed material in the cup the faster the Pot-life and working time. (**see Slide 5**)

4. Start pouring or applying the epoxy immediately, the larger the quantity of mixed material in the cup the faster the Pot-life and working time.
5. Pour a small amount of the epoxy onto the work surface and spread it out until it is approximately the size of the first layer of material (in this case the 9 ½ X 11 fiber). Press the fiber into the epoxy until you can see the epoxy coming through evenly across the entire surface. Place the next layer (glass) onto the carbon layer and press into place, if the glass surface becomes opaque no additional epoxy is needed if not add a small amount and spread across the surface. Continue this process for the remaining layers finishing, with what will become the bottom of the clipboard, the final layer of glass. **Unless you have a vacuum bagging setup, this is the end of the layup part of this lab—the layup now needs to cure overnight, perhaps using heat to complete the cure.**
6. Vacuum bag layup:

Once all the layers are fully saturated (wet out) with resin, the vacuum bagging process follows. Place sticky sealer tape all around the edges of the work area. The various layers of the bagging materials are arranged within the sticky tape area (see typical bag layup in **Slide 6**), as directed by the instructor.

a. Ensure the perimeter of where the panel will be is thoroughly cleaned. Apply vacuum sticky sealant tape, as stated above – leaving the backing paper sealant tape on until the bagging film is ready.
b. Apply edge breather (white – cotton like material) material continuously around all sides of layup. This serves as a continuous vacuum path over the part, and should not come in contact with the resin.
c. Apply one layer of perforated release film over entire layup (pink or brown – has perforations). Do not extend beyond the breather material. The tighter the film, the smoother the final part will be. This helps provide a smooth surface finish.
d. Apply nylon peel ply (green in color or clear) over perforated film. Extend this past the breather.
e. Apply breather/bleeder film over peel ply.

f. Apply bag material and remove sealant tape backing paper and bag should stick to this. Pull wrinkles out of bag, but not too tight that the bag is stretched. Work around the bag until all sides of bag are sealed without excessive wrinkles or folds.
g. Once you are confident that bag is sealed, cut a slit in one end of the bag for vacuum house probe. Apply vacuum hose to probe.

7. With the bag fully assembled, regulator, vacuum line, and gauge in place, turn the vacuum compressor on. As vacuum pulls air from bag, take time to smooth out any wrinkles and check for leaks (sound). Compress bag around tape areas to ensure a good seal. Pressure on the gauge, indicates a seal of the bag (typical arrangement shown in **Slide 6**), usually around 24 – 27 psi. Let the part sit for several hours to cure under vacuum pressure.

8. After part is fully cured (at least over night), remove the part from the bagging material (Slide 7), and inspect and trim. Trim panel of excess materials using a belt sander, a random orbital sander, or hand sand. Be careful, edges may be sharp.

Evaluation: (see slide 7)

After the layup is cured (at least overnight) students should visually inspect their part for voids, edge roughness, air bubbles, ripples, and determine if too much, or too little resin was used on the reinforcement.

Student evaluation (discussion or quiz):

1. What did you notice when cutting the fiberglass cloth?
2. How long was the working time of your resin?
3. What was the dry weight of your layup?
4. What was the amount of resin required for the layup? What was the mixing ratio?
5. When performing the layup, how did you know when the correct amount of resin was applied to each layer?
6. What did you find was the best technique for getting air bubbles out of the layup?
7. Describe what was found during examination and inspection post cure?
8. How would you describe the skill level required for composite technicians?
9. What concerns or thoughts do you have about handling composites?

This work is part of a larger project funded by the Advanced Technological Education Program of the National Science Foundation DUE #1400619