Composite Materials Layup Lab

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Abstract
The objective of this lab is to familiarize the students with the composite materials layup process. Hand lay-up is a simple method for composite production. The process consists of building up or placing layers of composite fiber in a sequenced layup using a matrix of resin and hardener. In this lab, the students will fabricate by a sequenced two layer lay-up of composite material using epoxy resin as matrix and fiberglass woven cloth as reinforcement.

Objectives: Students will be able to

- Demonstrate the composite layup process
- Explain the role of matrix and resin
- Explain use of resin, hardener and release agent
- Demonstrate safety procedures when doing composite layup
- Gain the knowledge of how to prepare and lay out all materials and tooling to work with composites.
- Gain an understanding of how to keep the area and tools organized and clean when working with composite materials.
- Observe first hand some of the difficulties and limitations of working with a wet lay up composite structure.

MatEd Core Competencies Addressed

0.B Prepare Tests and Analyze data
1.C Demonstrate Laboratory Skills
5.A Apply Safe and Environmentally Appropriate Methods to Chemical Handling
7.C Relate the General Nature of Composite Materials
11.B Relate Basic Processing Procedures for Composite Materials
17.A Distinguish Effects of Processing and Manufacturing Variations on Material Properties
17.C Illustrate Methods for Processing of Plastics and Composites

Key Words: Composites, fiberglass, layup, resin, hardener
Type of Module: Laboratory exercise
Time required: 1.5 to 2.5 Hrs in lab

Pre-requisite knowledge: Safety discussion on composite handling at the beginning of the lab.
Target grade levels: Advanced high school, college undergraduate

Table of Contents

Equipment and supplies needed

Each group of student must have prepared:
(suggested sources noted)

- A mold (a flat table) – supplied by school
- Release agent (the plastic sheet) – source- hardware store
- Mixing container and mixing stick – source- www.fiberglast.com
- Brush and/or roller- www.fiberglast.com
- Scissors- www.fiberglast.com or hardware store
- Epoxy resin – www.fiberglast.com
- Hardener- www.fiberglast.com
- Fiber glass woven cloth- www.fiberglast.com
- Cleaning equipment-acetone, containers in a ventilated area- hardware store or paint supply store
- A designated exothermic area for the containers once the reaction gels and heat builds up in the mixing container – prefer concrete padded area or non flammable surface or non flammable sink
- Designated trash containers differentiated from the uncured resin areas (Uncured resin is considered a hazardous waste, while cured resin is not)
- PPE- gloves, lab coat, safety glasses- safety supply store or www.fiberglast.com

Note: many marine supply stores also have glass fiber and epoxy available as well.

Curriculum overview and notes for instructor

The idea of this lab is to familiarize the student with some basic composite materials and procedures. It is to also have the student understand the safety aspects of handling composite materials. The student must gain these fundamental skills before he can go on to actually use and make something out of composites. Therefore the emphasis here should be on several things:

- Safety
- Handling and understanding the materials and how they function.
- Cleanliness and keeping organized in the work environment while using composite materials and associated tools.
- Some of the handling limitations of wet lay up while using composites.

Module Procedure

A. Review with the students this material on composite layup:

SAFETY:

- Always use PPE when handling composite materials in a layup operation.
- Always use cutting gloves when using scissors, Stanley knives etc.
- Be careful and thoughtful of the resin/hardener chemical reaction, which is an exothermic reaction, and be sure to place any mixing container only in a non-flammable area. Treat all mixing containers as potentially a fire hazard and also as a hazardous waste until it is cured.
- Only perform layup operations in a well-ventilated area and always have any cleanup performed in a well-ventilated area also.
- Review all MSDS sheets prior to handling materials. MSDS sheets describe all necessary safety data about the material you are handling.
- 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.
- Designate a specific area for any mold prep as mold release agent is potentially a contaminate to the composite use or lay up area.
- Designate a specific area for working with composite materials.
- Always prepare all tools, chemicals, PPE and cut reinforcement materials prior to mixing any chemicals. Time and note the actual mixing time (2 minutes minimum) and so that you can project when gelation will occur (usually 15 to 20 minutes depending on how hot the hardener is).
- Designate specific areas for any grinding, sanding, drilling, sawing or machining of composites as this should be well ventilated and all personnel should be wearing dust masks and safety glasses in this area. This should not be an area where composite lay up or applying resin is occurring as the dust is considered a contaminate to the layup.
- Remind students not to touch face, skin, etc while handling resins. Explain how to remove epoxy from skin if exposed.

- Explain that many solvents are a potential fire hazard, while other solvents (such as citrus oil, which is non flammable and less toxic) are available.
- 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.

<u>MATERIALS</u>

Mold
Generally, a mold must be used for making parts using the lay-up process to place the layer in or on in order to obtain the desired shape. However in this lab, we will not use a mold, but instead a tabletop to hold the flat shape of the layup.
(A 'mold' is also called a 'tool' in industry when referring to composites processes).
- Different mold shapes are accomplished by machining material, casting material or molding material.
- Different materials may also be used as molds (metal, composites, wood, plaster, rubber etc …)

Release agent
Prevents resin from sticking to the mold. In this experiment the tabletop will be covered with plastic sheeting to act as the release agent. Some other release agents used in industry are:
- waxes
- spray releases
- release films
- internal releases (added to gel coat or resin system)

Release agents are usually applied to the composite molds or tooling in a separate designated area as they can act as a contaminate if accidentally integrated into the composite lay up.

Resins
The resin acts as 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. The fibers are designed and selected to handle the designed stresses imposed. In this experiment a two-part epoxy and hardener resin system will be used. Various speed (set up time) hardeners can be used depending on the requirements of the job. Some resins commonly used in industry are:
- Unsaturated polyesters
- Specialty and High-performance Thermosets (vinyl esters)
- Epoxies

Reinforcing Fibers
There are many different fibers that can be used to make up a composite and each material can be obtained in different formats. Both of these variables are design options that are available according to the design constraints of the final product and make up a significant part of the material selection process. In this experiment a standard weave fiberglass cloth will be used.

- Different materials (Fiberglass, carbon fiber, aramid etc)
- Different formats
- Chopped mat material (randomly oriented chopped fibers or swirled continuous fibers)
- Woven fabric material – many different weaves and weave patterns can be used to yield different desired finished properties.
- Different orientations and organization of the fibers on the woven fabric (Plain weave, satin finish, twill etc.)

B. EXPERIMENTAL PROCEDURE:

1. **Work station preparation**

An initial preparation of all the materials and tools that are going to be used is a fundamental standard procedure when working with composites. This is mainly because once the resin and the hardener are mixed, the working time (prior to the resin mix gelling) is limited by the speed of the hardener chemically reacting with the epoxy producing an exothermic reaction.

Each group of student must prepare ALL materials and supplies available and set up before proceeding.

Also, as part of the initial preparation, the woven cloth must be cut according to the shape of the part. In this experiment the student needs to have two pieces of fiberglass material cut into one foot squares.

(2) Mold preparation

Before starting with the lay up process an adequate mold preparation must be done. Mainly, this preparation consists of cleaning the mold and applying a release agent in the surface of it to avoid the resin to stick. In this experiment the mold preparation is simply taping the plastic sheeting to the tabletop. If this was an actual mold the student would do the following:

- Clean the mold with a clean cloth
- Apply and spread release agent in the surface of the mold
- Wait certain to set up the release agent
- Buff with clean cloth
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(3) Lay-up process

Once all the materials are prepared, the workstation is ready and the mold preparation done; the students can start with the lay up process.

The first step is to mix the resin and the hardener. The proportions are usually given by the supplier and can be found on the containers of the hardener or resin. The portions can be either measured by weight for by volume but it is important to follow these proportions exactly as this is a complete chemical reaction and all components must react completely for maximum strength of the matrix. It is easiest to measure proportions using the volume method and a screw in pump that inserts into the cans of resin and hardener. These pumps can be purchased along with the containers of resin and hardener. Make sure to keep the resin pump and container top separate from the pump and container top of the hardener because any contamination will initiate the chemical reaction and cause the resulting blend to harden.

The mixing is performed in the mixing containers with the mixing stick and should be done slowly so as to not entrain any excess air bubbles in the resin. Be careful to mix completely and deliberately for a full two minutes before applying. It is best to use a "flat" stick- such as tongue depressor; a round stick does not work well as it does not 'paddle' the mixture to blend it properly. Note: Plastic mixing containers may melt during the exothermic reaction, so it is best to use containers that are specifically made for the purpose of mixing epoxy resin. These are typically available from the resin vendor.

Next an adequate quantity of mixed resin & hardener is deposited in the mold and a brush or roller is used to spread it around all surface. It is important not to add too much resin, which will cause too thick of a layer, nor to add less than the necessary amount, which will cause holes in the surface of the part when it is cured. An estimate of the amount of resin needed can be based on weight of glass fiber cloth. One can assume 50 volume% resin/50% volume% fiber and then use the density of the reinforcement to arrive at the weight of the resin. It is good to then add a small safety factor so that enough resin is mixed for the layup.

The first layer of fiber reinforcement is then laid. This layer must be wetted with resin and then softly pressing using a brush or a roller make the resin that was added in the previous step wick up through the fiberglass cloth. If the fiber is not completely wet, more resin can be added over the top and spread around. At this stage a second layer of glass fiber is added and special care must be taken to eliminate all air bubbles possible. This can be accomplished by either rolling any air bubbles out with a small hand rolling tool or brushing out the air bubbles with a paintbrush. This step is repeated until the desired thickness is obtained. As the glass fiber layers are added to build laminates and total part thickness the individual layers may be oriented at varying angles to accomplish specific strength in the direction of the reinforcement weave- this is called 'clocking'. Sometimes during the buildup of successive layers of reinforcement a cover sheet of plastic can be temporarily put over the layup and rolled together with the layers underneath to reduce the mess and squeeze out excess resin.

It is important when the proper amount of resin has been used for the layup that any excess resin in the cup is placed on and in an area that does not have any flammable material, such as a concrete sink or slab. The students should watch the exothermic reaction that is taking place as the resin 'gels'. Typically the cup gets hotter than the composite panel, because of the heat of reaction that is being transferred to the cup.

(4) <u>Curing</u>

The part can be cured at elevated temperatures using an oven (usually somewhere around 160 degrees F) or at room temperature. Generally, the proper curing time of each type of resin-hardener, as well as the working time, is given by the supplier on the back of the containers. If the part is left on plastic sheeting be sure to use proper plastic sheet that will survive the elevated temperature. Most plastic sheet available from hardware stores (polyethylene) may melt. If planning the layup part is going to be moved to a curing oven, then layup should be done on a caul plate- generally a sheet of aluminum or steel >1/8" thick .

For the purposes of this experiment and using an epoxy resin system, room temperature curing is adequate.

(5) Cleaning

Once that part is ready to be cured, it must be moved to an adequate location. In this case it can be moved to a curing oven or simply left to cure in place until the next day. Then a cleanup must be done before leaving the class. All the materials used (brushes, rollers, mixing tools, scissor), including the table, must be cleaned using acetone and cloth. Also, the rest of the fiberglass woven reinforcement must be collected from the table and floor.

How to dispose of acetone: Soap and water can be used on skin if exposed. Some shop hand cleaners (Go Jo) work well also. Any excess acetone should be properly disposed of, it is a good idea to put it in a proper disposal can with lid and disposed of correctly.

Supporting Information:

1) Have a designated clean up area so that part of the lab incorporated clean up of the tools and equipment. Have acetone cleanup stations and materials laid out ready for students to use so that tools do not get hardened resin on them. Note: scissors, rollers etc., are particularly susceptible to damage if not cleaned immediately after use with resin. Usually, all paintbrushes and squeegees are thrown away, be sure to leave them in a non-flammable area until the resin is cured so they can then be properly disposed of.
2) The lay up will harden after about an hour, but leave the lay up overnight and then have the students evaluate them sometime after that curing period.
3) SME video on 'Manual Composite Layup and Spray Up' Product ID: DV05PUB5 from www.SME.org

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Picture of lab doing hand layup.

Bibliography:

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2. Callister, William Jr. Materials Science and Engineering An Introduction. Seventh Edition. 2007
3. CRC Practical Handbook of Materials Selection by James Shackelford, William Alexander & Jun S. Park

Historical Note: "Fiberglass" is a term used commonly today; this material was invented in 1938 by Russell Games Slayter of Owens-Corning as a material to be used as insulation. It is marketed under the trade name **Fiberglas,** which has become a generic trademark.

Fiberglass is still used commonly as insulation but is also used as a reinforcing agent for many polymer products; the resulting composite material, properly known as fiber-reinforced polymer (FRP) or glass-reinforced plastic (GRP), is also called "fiberglass" in popular usage. The fiber reinforcement can also be called 'glass fiber' and one of many polymer resins is 'epoxy' resin together they are a very common form of the FRP fiberglass.

Evaluation Packet:

Student evaluation questions (discussion or quiz):

1) How long was the working time of your resin?
2) What did you notice when cutting the fiberglass cloth?
3) When performing the layup, how did you know when the correct amount of resin was applied to each layer?
4) What did you find was the best technique for getting air bubbles out of the layup?
5) What did you think about the heat generated by the chemical reaction and do you think this represents a potential fire hazard?
6) What other concerns or thoughts do you have about handling composites in a production environment?
7) After the lay up is cured (at least overnight) have the students look at them and examine them. Particularly have them look for voids, edge roughness, air bubbles, ripples, and too little or too much resin in and on the reinforcement.

Instructor evaluation questions:

1. At what grade level was this module used?
2. Was the level and rigor of the module what you expected? If not, how can it be improved?
3. Did the lab work as presented? Did they add to student learning? Please note any problems or suggestions.
4. Was the background material composite layup sufficient for your background? Sufficient for your discussion with the students? Comments?
5. Did the lab generate interest among the students? Explain.
6. Please provide your input on how this module can be improved, including comments or suggestions concerning the approach, focus and effectiveness of this activity in your context.
7. Have the students write a 'one minute paper' on their examination of their lay up after the lay up has cured and they have time to carefully look it over.

Course evaluation questions (for the students)

1. Was the lab clear and understandable?
2. Was the instructor's explanation comprehensive and thorough?
3. Was the instructor interested in your questions?
4. Was the instructor able to answer your questions?
5. Was the importance of materials testing made clear?
6. What was the most interesting thing that you learned?