PSAS Composite Fuel Tank: Fabrication Procedure

Purpose and Scope:

The intent of this procedure is to provide direction for the fabrication of a proof-of-concept shrink-fit fuel tank prototype module. The tank assembly process can be found in a separate document.

Tools and Equipment:

The following materials and equipment should be collected and on hand at the beginning of the lay up procedure:

- Machinable foam mandrel (3” OD)
- Aluminum Mating Rings[1] (qty 2)
- Aluminum End Caps[1] (qty 2)
- Templates for inner carbon fiber, Nomex, and Metlbond adhesive layers (qty 3)
- Templates for outer carbon fiber, Nomex, and Metlbond adhesive layers (qty 3)
- Template for inner lapping portion of the mating rings adhesive layers
- Nomex honeycomb material(¼” and ⅛” thick)
- Carbon fiber
- METLBOND adhesive
- Goop tape
- Shrink tape
- Kapton tape
- Release film
- Acetone compound for cleaning
- Sandpaper (3 different grits 320, 800, and 1500)
- Vacuum bag material and breather cloth
- PTFE tube machined to ⅛”

Facility Equipment:

- Exhaust fans or hoods
- Freezer (for storage of materials)
- Oven (for curing process)
- Vacuum pump
- Heat gun (preferably with variable temperature control)
- Small plastic tubs or paper cups for water (for sanding)
- Circular razor blade

[1] Ordered from www.protolabs.com

- Workstation equipped with risers on which you can perform the layup procedure

Safety:

- Gloves (nitrile or latex) should be worn at all times to avoid contaminating working materials. Some materials are hazardous upon contact.
- When using possibly hazardous materials (cleaning agents, etc) have exhaust fans in place and operating or work under an exhaust hood.

Initial Tips/Suggestions[2]:

- Staying clean and organized is very important.
- A heat gun is critical for dealing with the adhesive film (METLBOND). However, be careful to keep it on the lowest setting as the adhesive becomes difficult to handle as it warms up.
- Adhesive film (METLBOND) can be difficult to from the backing (orange side), especially while wearing gloves. You can use a tongue depressor or razor blade against the edge after adhering it in place. Remove the orange side first, leaving the removal of the white side until you have positioned and adhered the layer.
- Take care when placing the carbon fiber as the adhesion with the METLBOND is strong and nearly instant.
- When cutting the carbon fiber sheets, take care to stay in line with the fiber as this will provide a stronger final structure.
- When creating the templates, cut them long enough to allow for some overlapping (~¼") of the adhesive and carbon fiber layers.

General Requirements:

This preparation procedure only reflects the steps taken in the creation of modules for testing. It does not address the steps that should be taken to prepare the aluminum parts for long term exposure to the carbon fiber and adhesive layers. For information regarding flight-ready fabrication of these parts refer to the aluminum mating rings procedure followed by the 2014 PSAS LV3.0 airframe team[2].

Materials:

1. Use the templates to cut all of the required carbon fiber, Nomex, and adhesive layers before beginning any work (place in freezer until needed to preserve adhesive properties).
2. It is critical to ensure that all work surfaces are clean. This includes all workbench surfaces and the surrounding floor space.
3. Arrange multiple workstations, each for a specific task to help expedite workflow.
4. Clean all the metal tools and part surfaces using acetone. All cleaned surfaces should leave no visible residue on a towel when wiped clean.

[2] Some suggestions listed based on process developed by 2014 PSAS LV3.0 airframe team. <https://github.com/psas/lv3.0-airframe/blob/master/doc/mfg/LayupInstructions_2014.pdf>

5. Carbon fiber: Cut one layer CF using “outer layer” template, cut roughly 2 fibers oversized. Cut one layer CF using “inner layer” template, same oversizing objective.
6. Nomex: Cut one layer from the ⅛” thick Nomex using “inner layer” template. Cut one layer from the ¼” thick Nomex using the “outer layer” template.
1. METLBOND: Cut two layers using “outer layer” template, three layers using “inner layer” template. Cut 2 strips using “ring template”

Aluminum Rings and End Caps:

1. Use the 320 grit sandpaper to sand the outer edge of the end cap until it fits easily into position in the mating ring (check this with the end cap upside down to avoid getting the shrink-fit portions of the design stuck together).
2. Sand the interior and exterior surfaces of the lapping section of the mating rings progressing from the 320 grit to the 800 grit and then to the 1500 grit sandpaper removing the tooling marks from machining.

Figure 1: Checking end cap fit inside mating ring

3. Using the 1500 grit paper only, sand the interior shrink-fit surface of the mating rings (this is a precise fit so be careful to not remove much material, the goal is to smooth the surface in order to negate the chance of a leak path developing in the seal)
4. Repeat step 3 on the exterior of the shrink-fit portion of the end caps.
5. Clean the mating rings and end caps using acetone and paper towels.

Mandrel:

1. Wrap the mandrel with a single layer of the release film using the Kapton tape to secure in place. Refer to the liner machining procedure for instructions on mandrel creation and preparation.

Fabrication Process:

Mating Rings:

1. Remove the orange backing from the METLBOND and adhere the adhesive to the inside of the lapping portion of the mating rings. (In general, the heat generated by pressing and rubbing the adhesive should be enough to hold it in place. If you use the heat gun, be careful as this can cause it to adhere very strongly to the white backing.)
2. Remove the white backing from the METLBOND.

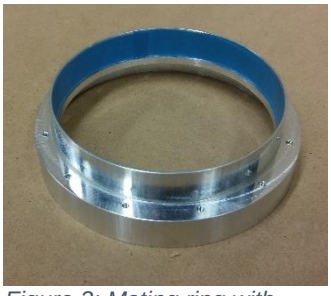

Figure 2: Mating ring with Metlbond adhesive applied

PTFE Liner Placement:

1. Slide the liner into position on one of the mating rings (use a tongue depressor or another similar tool if needed to keep the adhesive in place as you mount the liner in position).
2. Slide this arrangement onto the mandrel.
3. Using similar methods to the first step, mount the second mating ring.

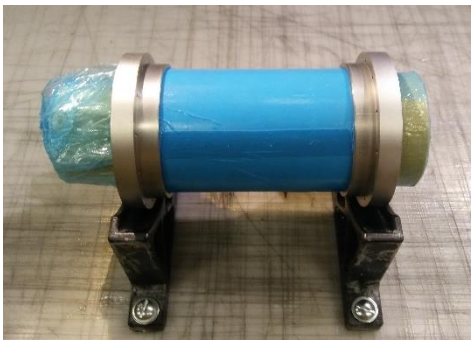

Figure 3: Mating rings, PTFE, assembled and mounted on mandrel with Metlbond applied

Lay Up Procedure:

1. Pull the working layers from the freezer, and double-check that all layers are accounted for before beginning.
    a. 2 Layers of carbon fiber
    b. 2 Nomex honeycomb core layers (⅛" for inner layer, ¼" for outer layer)
    c. 5 layers METLBOND adhesive film (2 outer layers and 3 inner layers)

Be careful in the application of these layers to apply them as straight and evenly as possible. Best practice is one person holding the layer straight and pressing it into place while a second holds the mandrel firmly and rolls it slowly. Place the seams so they are not all aligned in the same location on the layup.

2. Peel the orange backing off of the Metlbond and adhere to the exposed surface of the PTFE using the heat of your hand to help it remain in place. Stop with about ~1" gap to remove white backing before lapping adhesive layer.
3. Remove the white backing pressing firmly on any areas that seem to be lifting. *Use the heat gun briefly if necessary.*

Figure 4: 1/8" Nomex layer

4. Using the heat gun on a lower setting (~350F) warm the adhesive while carefully pressing the ⅛" Nomex layer into place. It is easiest to wrap around and adhere the seam first, then compressing in place around the remainder of the module.
5. Repeat steps 2 & 3 on the exterior of the Nomex layer.
6. Peel one side of yellow backing from the inner carbon fiber layer and carefully adhere in place.
7. Remove the yellow backing from the carbon fiber.

Figure 5: Carbon fiber and Metlbond layers applied

8. Repeat steps 2 &3 carefully placing the next layer of the METLBOND adhesive.
9. Repeat step 4 using the ¼” Nomex layer.
10. Repeat steps 2 & 3.
11. Repeat steps 6 & 7.
12. Repeat steps 2 & 3 one last time.
13. Wrap a layer of release film around finished layup and secure with Kapton tape
14. Wrap shrink tape across the length of the module so that it overlaps itself (50%) on each pass. Start the wrap on the mating rings, securing it well with the kapton tape. Use a similar 2-person application process as that employed earlier. Make sure to tension the shrink tape so that it is taught, but not tight, as too much tension will put too much compression on the layup during curing. Wrap to the other mating ring and secure using kapton tape.

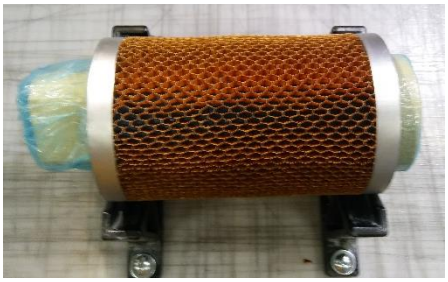

Figure 6: 1/4" Nomex layer

Figure 7: Final CF layer

Vacuum Bag Seal:

1. Create vacuum bag using with breather cloth and Goop tape, leaving one end open.
2. Insert tank module.
3. Seal with Goop tape, leaving a small section with the backing still attached through which the vacuum hose can be inserted when placed in the oven.

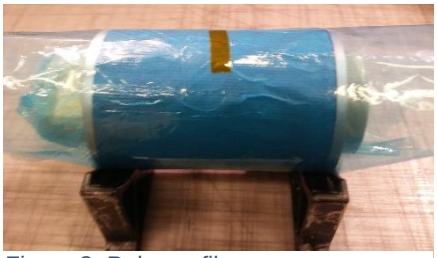

Figure 8: Release film

Figure 9: Shrink tape layer applied

Curing Process:

1. Insert vacuum bag with secured layup into the oven, and connect vacuum hose into open slot in the bag. Seal with Goop tape.
2. Connect vacuum hose to vacuum pump (or other source of vacuum pressure) and open valve to create vacuum seal. Check carefully for a complete seal.
3. Turn on the oven.
4. Ramp up 50F every 20 min, until max temp of 350F is reached.
5. When 350F is achieved, hold at temperature for 2 hours.
6. When cycle is complete, turn the oven off and allow to return to ambient room temperature slowly.
7. When ambient temperature is reached, remove vacuum bag and module from the oven.

Figure 10: Module in vacuum bag prepared for curing

8. Remove module from vacuum bag and mandrel. It may be necessary to hammer the module off of the mandrel. Although some force may be necessary, this shall be done carefully so as to not damage the aluminum rings or cause any unnecessary stress to the module.

Works cited:

Much credit must be given to the 2014 PSAS LV3.0 Airframe Team, as many of the materials, procedure, and initial ring design was developed through their hard work on their project.
https://github.com/psas/lv3.0-airframe/blob/master/doc/mfg/LayupInstructions_2014.pdf

Ref Recommended autoclave cure cycle
https://github.com/psas/composite-propellant-tank/blob/master/Materials/Data%20Sheets%20_%20Material%20Info/Carbon%20Fiber%20Layer/3900_Prepreg.pdf