EM 4133/6133 Composite Manufacturing Report

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Onitiana Razafimino

Junior, Department of Aerospace Engineering, Mississippi State University

1. Introduction

I never had experience in manufacturing before. Being able to actually go to the laboratory and make my own composite material was pretty fun and very exciting. Diving into the aerospace industry with some knowledge and practical experience with composite materials is definitely a plus. Indeed, two of the most recent commercial planes (the Boeing 787 and Airbus A350) are built from composite materials. Mentioning my manufacturing project on my resume would help me a lot, not only in positions related specifically to composite materials, but in any manufacturing position.

I have had several interviews pertaining to manufacturing positions before, and all the questions asked were about safety. I did not know how to properly answer them because I had zero experience in manufacturing. Now that I have some exposure to the world of manufacturing, I have an idea on how crucial safety is, and this will help me prepare for my upcoming interviews.

2. Composite Design

2.1. Prepreg details

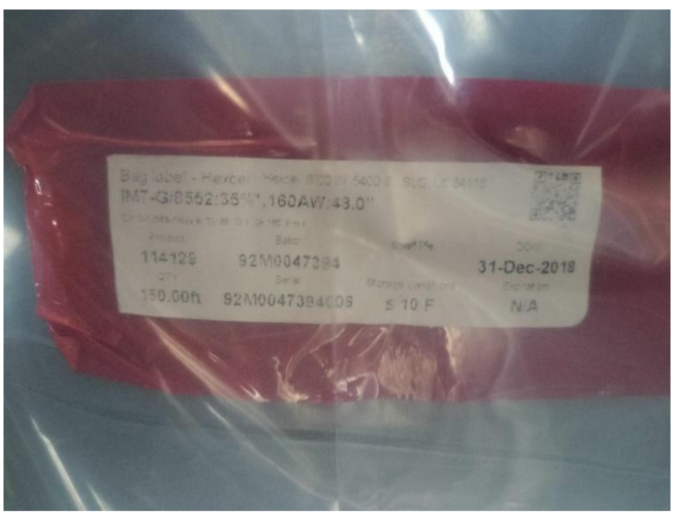

Figure 1: Prepreg card label (Picture by Mr. Cody Hardin)

Figure 2: Picture of the roll (Picture by Hayward Singletary)

The material used for the prepreg was the unidirectional carbon fiber IM7 with the 8552 matrix made of resin. HexPly 8552 is mainly used for primary aircraft structures such as the skin of the fuselage of an aircraft. That material can withstand a large impact. Three different plys with different fiber orientations were produced: plys with 0 deg, 45 deg, and 90 deg. fiber orientation, each with a size of 10.0”x10.0”.
Listed below are different properties of the IM7 8552 composite material with two different orientations” 90 degrees and 0 degree:

Mechanical Properties

Property	Temp°F	Condition	AS4	IM7
0° Tensile strength, ksi	-67	Dry	300	373
0° Tensile modulus, msi	-67	Dry	19.4	23.7
0° Tensile strength, ksi	77	Dry	310	395
0° Tensile modulus, msi	77	Dry	19.6	23.8
0° Tensile elongation, %	77	Dry	1.55	1.62
0° Tensile strength, ksi	195	Dry	293	368*
0° Tensile modulus, msi	195	Dry	19.1	23.7*
90° Tensile strength, ksi	-67	Dry	9.73	9.60
90° Tensile modulus, msi	-67	Dry	1.50	1.46
90° Tensile strength, ksi	77	Dry	9.27	9.3
90° Tensile modulus, msi	77	Dry	1.39	1.70
90° Tensile strength, ksi	200	Dry	-	-
90° Tensile modulus, msi	200	Dry	1.22	1.50
Major Poisson's Ratio, tension	77	Dry	0.302	0.316
± 45 Inplane shear	77	Dry	16.6	17.4
± 45 Inplane shear	200	Dry	15.2	15.4*
Major Poisson's Ratio, compression	77	Dry	0.335	0.356
0° Compression strength, ksi	-67	Dry	253	292
0° Compression modulus, msi	-67	Dry	18	20.5
0° Compression strength, ksi	77	Dry	222	245
0° Compression modulus, msi	77	Dry	18.6	21.7
0° Compression strength, ksi	195	Dry	184	215
0° Compression modulus, msi	195	Dry	17.7	23.5
0° Compression strength, ksi	160	Wet	203	-
0° Compression modulus, msi	160	Wet	17.0	-
0° Compression strength, ksi	195	Wet	184	173♥
0° Compression modulus, msi	195	Wet	18.1	20.7♥
Fill compression strength, ksi	-67	Dry	51.4	55.3
Fill compression modulus, msi	-67	Dry	1.56	1.53
Fill compression strength, ksi	77	Dry	38.9	44.2
Fill compression modulus, msi	77	Dry	1.43	1.82
Fill compression strength, ksi	195	Dry	-	-
Fill compression modulus, msi	195	Dry	-	-
Fill compression strength, ksi	77	Wet	-	34.2
Fill compression strength, ksi	160	Wet	-	24.6**
Fill compression strength, ksi	195	Wet	19.7♥	19♥
Compression after impact, ksi				
after 500 in-in-lb/in impact	77	Dry	50	-
after 1,500 in-in-lb/in impact	77	Dry	32	34
after 2,000 in-in-lb/in impact	77	Dry	28	-
after 2,500 in-in-lb/in impact	77	Dry	27	-

Bold - 200° **Bold*** - 220° **Bold**** - 180° **Bold ♥** - 250°

Property	Temp°F	Condition	AS4	IM7
0° Short beam shear, ksi	-67	Dry	23.8	21
0° Short beam shear, ksi	77	Dry	18.5	19.9
0° Short beam shear, ksi	195	Dry	14.7♥	13.6*
0° Short beam shear, ksi	77	Wet	16.9	16.7
0° Short beam shear, ksi	160	Wet	12.2	11.6**
0° Short beam shear, ksi	195	Wet	8.25♥	8.25♥
Fill short beam shear, ksi	-67	Dry	-	-
Fill short beam shear, ksi	77	Dry	-	-
Fill short beam shear, ksi	195	Dry	-	-
Fill short beam shear, ksi	77	Wet	-	-
Fill short beam shear, ksi	195	Wet	-	-
0° Flexural strength, ksi	77	Dry	274	270
0° Flexural modulus, msi	77	Dry	18.4	22
Quasi-Isotropic 25/50/25				
Tensile strength, ksi	77	Dry	107	104
OHT strength, ksi	77	Dry	63.5	62.1
OHC strength, ksi	77	Dry	47.8	48.9
CAI strength, ksi	77	Dry	34.6	31
CBI strength, ksi	77	Dry	91.2	-

Bold - 200° **Bold*** - 220° **Bold**** - 180° **Bold ♥** - 250°

Figure 3: Table showing the different properties of the prepreg (from www.hexcel.com)

2.2. Laminate design

My fiber orientations are the following:
[0/90/±45/±45/90/0]
The details of my layup can be found in figure 4. Each prepreg has a thickness of 0.131 m. Therefore, the total thickness of my plate is 1.048 mm.

The dimensions are in mm.

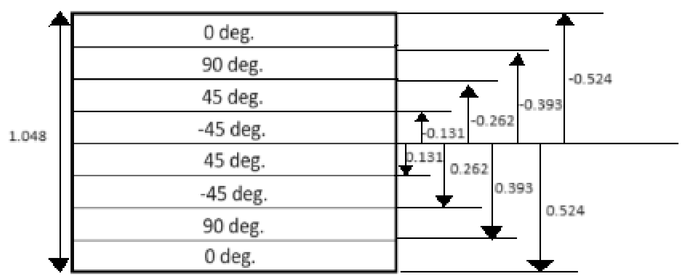

Figure 4: My fiber orientations (Onitiana Razafimino)

2.3 Curing details

Step 1.
When vacuum is created, temperature is raised from 75 Fareinheit to 360 Fareinheit in the span of an hour (60 minutes). The pressure grows from 0 psi to 92 psi 11 minutes after vacuum is created.

Step 2.
During 2 hours and a half (150 minutes), the temperature is held constant (360 deg. Fareinheit) along with the pressure (92 psi).

Step 3.
Temperature is decreased from 360 Fareinheit to 75 Fareinheit (nearing room temperature). Approximately 262 minutes after vacuum was created, the pressure goes back down to 0 psi. When temperature reaches 75 Fareinheit, this marks the end of the cure cycle.

Figure 5 summarizes those steps.

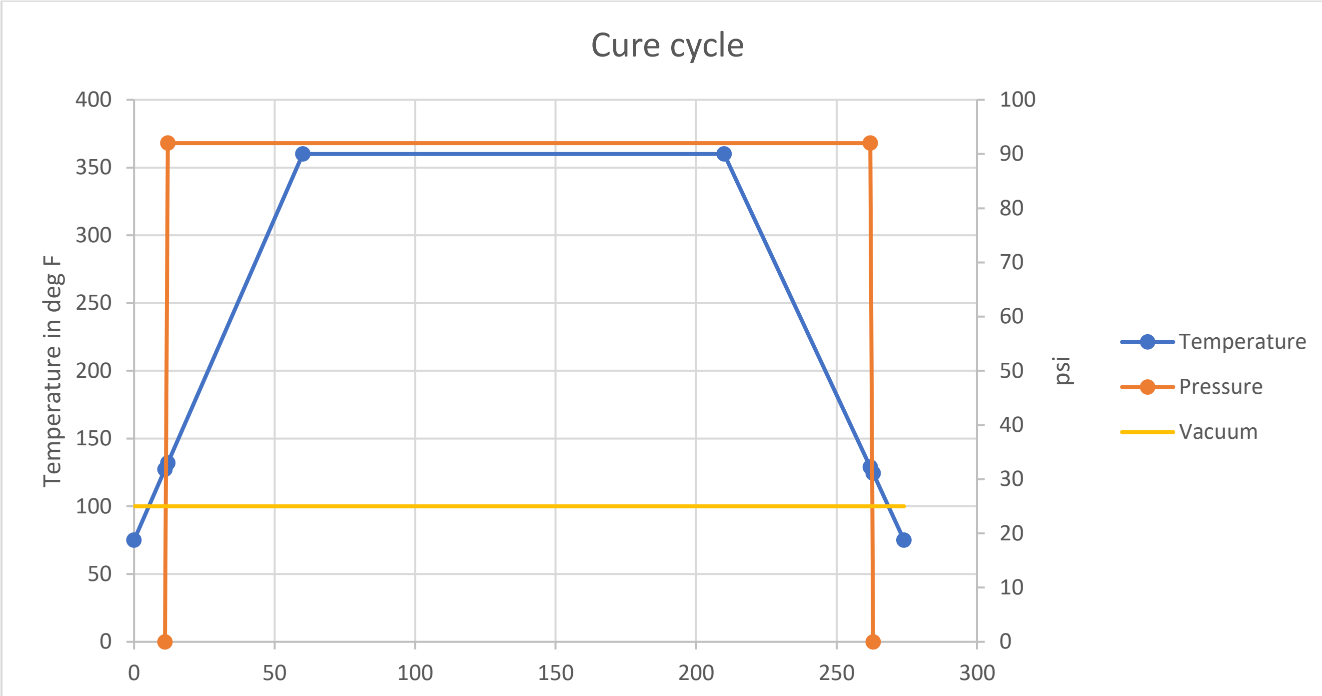

Figure 5: Temperature and Pressure during Cure cycle (Onitiana Razafimino)

3. Composite manufacturing

3.4 Laying up the cut prepregs

Before laying up the prepregs, the caut aluminum needs to be cleaned. For that, we used isopropanol alcohol and needed to make sure sure that we are wiping the plate in only one direction.

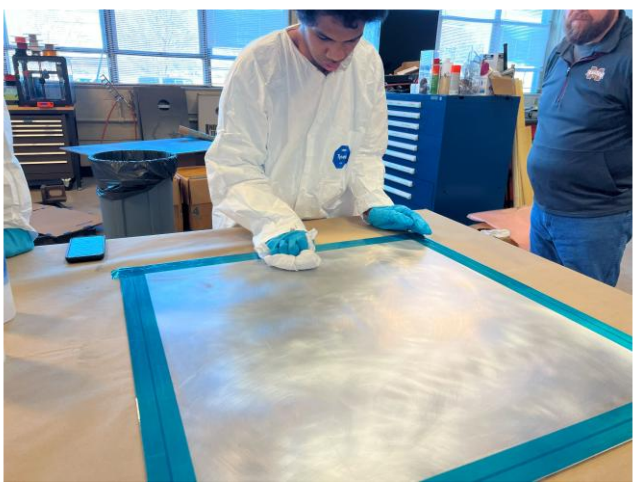

Figure 6: Wiping the caut aluminum (Picture by Allison White)

For the layup, we stacked the prepregs on top of each other with respect to the orientations of fibers. The orientation is determined based on a pre-defined x-y axis. It is important that, after picking a prepreg with specific orientations, the transparent film is peeled off before setting it up on the caul plate. Debulking is done after stacking the first ply, the fourth ply, and seventh ply. Vacuum bagging is done after the final ply.

3.6 Vacuum bagging

Since we did the laminating by hand, the process is not accurate. We stuck the plates of laminate by pushing our plys against each other with the force of our hand. Therefore, we proceeded with vacuum bagging to get rid of the air in between the different prepregs so that they become more compact.

Step 1: What we did first was cut the same amount of release film and breather to cover the layup. We used the release film to cover the laminate and taped it to the edge of the mold so that it doesn't move. We then put the breather on top of the release film that covers our entire laminates. We cut an additional 4"x4" square of breather cloth and taped it on top of the previous breather. We then taped the vacuum port base on top of that square.

Figure 7: My teammate Andrew Walters and me cutting the breather cloth (Picture by Allison White)

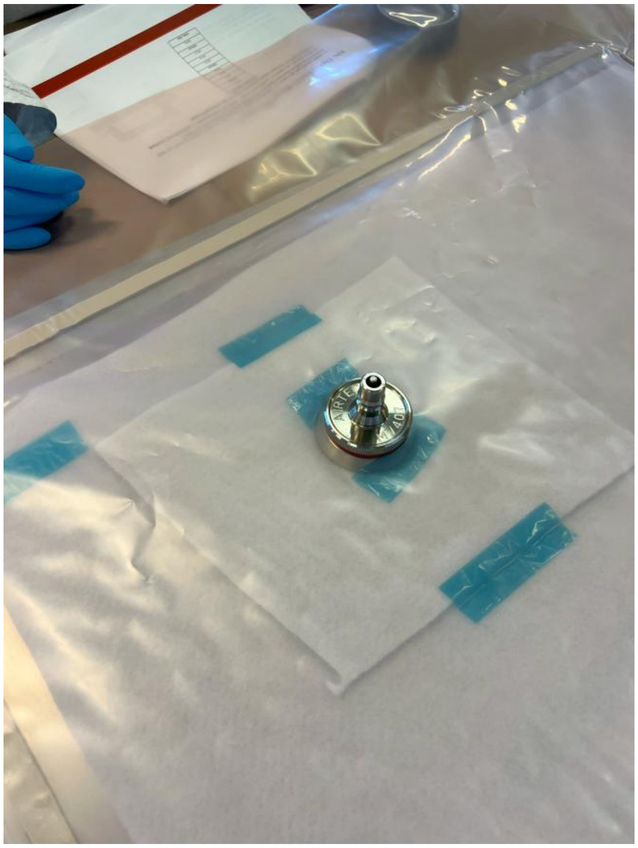

Figure 8: Vacuum port taped on breathing cloth with vacuum port base (Picture by Allison White)

Step 2: We cut a sufficient amount of bagging material (plastic bag) to cover the entire perimeter of the part and taped it to the edge of the aluminum with the help of a bag sealant tape.

Step 3: We connected the vacuum port to the vacuum port base and started vacuuming.

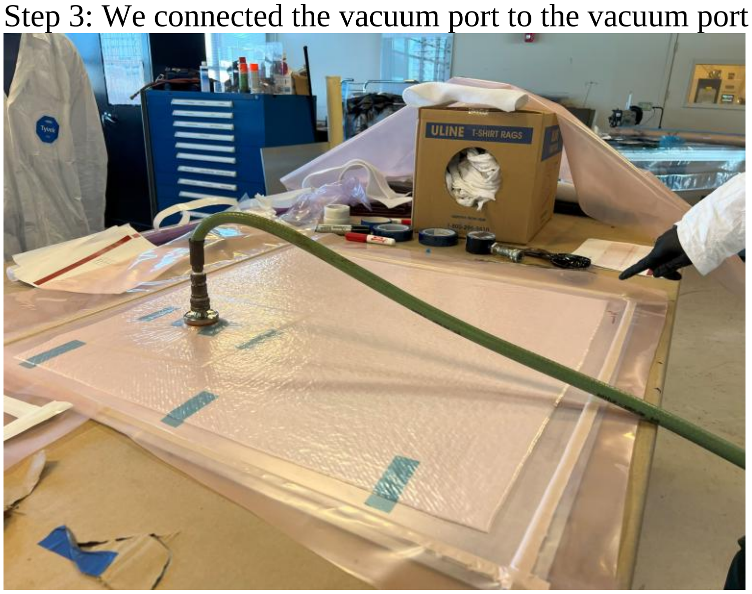

Figure 9: Vacuuming (Picture by Allison White)

To make sure that the laminate is compliant, we needed to verify that the bag pressure did not fall more than 2 in*Hg in 5 minutes.

We got it right on the first try.

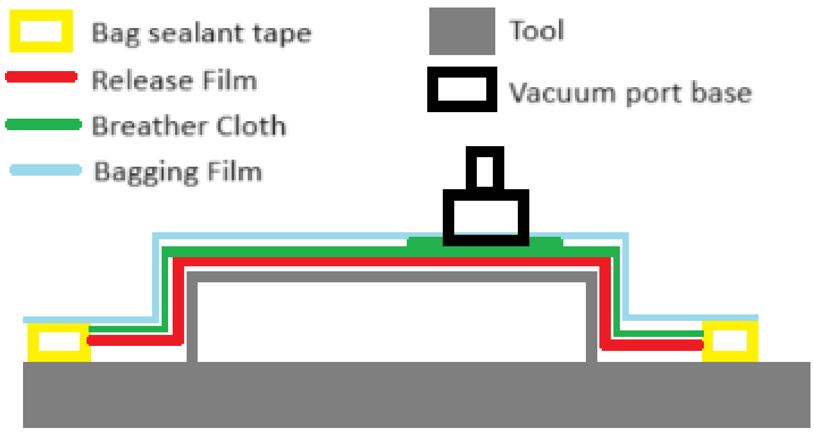

Figure 10: Vacuum bagging stack sequence (Onitiana Razafimino)

4. Discussion

I really enjoyed this manufacturing project. Even though it is an individual project, my ACI group and I did it together, and we made sure that we helped each other at every step of the way. We were given a sheet of set of instructions from Mr. Hardin, and I had trouble understanding it at first, but with the help of my teammates, I was able to pick up quickly. The manufacturing process is very long and requires a lot of patience. It also requires accuracy and an ability to use our hands!

Indeed, when doing the vacuum bagging, we needed to make sure that there was no leak. Otherwise, the vacuum process would not have been done properly. This would also have impacted on the pressure reading. The mistake that I have made relates to the vacuum bagging: when tapping the vacuum bag to the edge of the mold I did not pleat it properly on the corner. That required the intervention of Mr. Hardin. He corrected the taping a little bit, but it was not a big deal. As mentioned before, my taping would have made the vacuum process inaccurate, and may have altered the pressure reading. A way to prevent this issue is to be more careful while taping, not rush, and make sure that I bend over so that I get my face closer to the plate. This way I can see it more closely.

The manufacturing project was enjoyable and the manufacturing environment we were put in at ACI was excellent. However, one thing that would need improvement is the accessibility to tools. When we were in the process of removing the plastic film from the ply, we were sharing one tool among four people, so we had to wait until the other person is done, so that the next member of the group could use the tool. If we had three more of that tool, it would have been perfect and it would have accelerated the process of manufacturing.

One thing that I would like to point out is that the plys were not exactly the same size, so when we stacked our plys over each other, they were not perfectly aligned. To make sure that the laminates have the same strength on the whole surface, I think that the plys need to have the same size. However that is not very important because the edge does not really matter at the testing stage (since beams are cut off from the middle of the laminate).

The fibers orientation of my laminate are not perfectly symmetrical, yet the orientations of the two top plys and the two bottom plys are symmetrical. Therefore, I would say that my laminate is anisotropic since the fiber orientations are unbalanced. Also in some problems worked in class , we sometimes consider void as negligible. During the process, I did not notice any sign of void. It must be microscopic so it could not see it. Therefore we can ignore voids in some cases.

All in all, in my opinion, I think that the manufacturing process was very rewarding. I have an idea of what manufacturing really is, what the safety measures need to be taken, and actually have practical experience in working with composite materials. I look forward to seeing the results of the testing phase.

Figure 11: Me holding my plate (Picture by Allison White)

Figure 12: Picture of my beams (Onitiana Razafimino)