Car 4 Battery Pack Manufacturing & Considerations for Car 5

This serves as a comprehensive journal of our manufacturing processes for Car 4 and what could have been improved, as well as remarks on what can generally be done better for Car 5.

Box

- DXFs were created for the sides and bottom of the box to get an idea of how big we needed to make the sandwich panels and if we had core (divinycell was chosen because of availability) that could fit the parts we wanted to cut out.
- 0.25" thick core was chosen over the 0.125" to be on the safer side.
- After measuring out what could theoretically fit on the core available, 2 slightly oversized sheets of fiberglass weave were cut out.

Prepping the work surface

- A large sheet of polycarbonate was cleaned with alcohol and wiped down.
- Then waxed smooth and let dry (this is to not allow the glass to cure and stick onto the polycarb

Layup

- One layer of glass placed down onto the polycarb and wetted out with the mix of resin and hardener.
- Squeegees were used to evenly spread the resin all over and into the fiberglass.
- The next layer was put on top and then wetted out similarly.

Curing

- We had two methods for this next step:
  1. Peel ply then some large plate (could be wood even) to distribute the weight

2. Another clean waxed piece of polycarb

- Either way, a large weight was placed over it, making sure to get any air bubble out before.
  - This is not the best method for this, that would be vacuum bagging with peel ply and breather (ask aero or structures)
- Then it was left for 24-48 hours to fully cure.

Other Side

- The steps above were repeated for the other laminate
- Then one laminate was covered in a thin film of [ea 9430]() using squeegees and the core was placed onto it and pushed down for full contact and to remove any air bubbles. Then the next laminate was similarly coated and placed, adhesive side down, onto the core and any air bubbles were pushed out.
- Then it was weighed down in a similar manner to when the laminate were curing.

Water Jet (WJ)

- After the panel was fully cured we water jet at MAE C and let the cut out parts and let fully dry at the lowest temperature a home oven could go for 15 minutes.

Assembly

- After all the sides and bottom were WJ they were assembled at their box joints (after being sanded — for roughness — and cleaned) with ea 9430 and filler (to make the adhesive easier to work with).
  - We did not take into account the radius of the water jet to there were small fillets that did not allow the box joints to fully join. Take that into account next time.
- After the joints were all joined together, a thicker mixture of the ea and filler was used to fillet the edges inside.
- This was repeated for the lips and we had been running low on ea so we used regular epoxy.
- The lid was manufactured the same exact way just out of thinner core.
- 3D printed alignment guides were glued onto the lips to help in placement and securing of the lid. No latch design was needed since chassis would constrain the pack sufficiently in that vertical direction.
- For the straps, we used epoxy to stick them to the bottom of the pack.

Integration with Chassis

- The box was sanded and scraped down for any extra glue or adhesive and chamfers were sanded on all the edges to allow for easy insertion into chassis.
- The box was then placed inside chassis and cutouts on either side were made with an angle grinder.
- One side for battery pack to be slid in, the other side not large enough to let battery box slid out but enough to let someone push the box or pull the straps to make it easier to

place within the car.
- Pin and grommet fasteners mounted on brackets will prevent battpack from sliding out the way it came in, and the other side is constrained by chassis itself.
- Same with the other 2 degrees of freedom, there are other chassis panels that prevent battpack from translating in those directions.

Modules

- The modules has 3 main aspects to manufacture/assemble:

1. Cell assembly
2. Waterjet (copper/HDPE)
3. Module 3D printing

- The 3D printing proved to be the most time consuming considering it was not in our control.

Cells

- We originally wanted to test all the cells, but after realizing we started way too late to realistically finish and finding that our variation was barely 50 mAh over the error of the cell testers, we decided to just spotweld the cells.
- Spotwelding took no more than 15 hours in total.

Waterjet

- The copper was one of the first things to be manufactured.
- Waterjet at MAE C then bent at the SDC
- Next was the cell spacers from HDPE (much longer process because of all the holes)
    - Used 2 different HDPE sheets, the thicker (0.25") was much stiffer and nicer to hold the cells in.
- For the spacers, we tested different diameters around the nominal diameter of the cell to see which fit the way we wanted before fully WJ an actual spacer. More testing to see how the federate affected the tolerancing might have been beneficial.

3D Printing

- We sent the prints to Rapid Proto (because they have a large enough printer for what we needed to print) and it took significantly longer than expected (especially in between the spring and summer semesters).
- The prototypes we did receive bent more easily than we would have liked which could have introduced failure points where the copper was not in contact with he nickel at some points because of the bending.
- We implemented 2 solutions:
    - Struts WJ from HDPE that distributed the load of 2 screws along the width of the modules

    - 3D printed rods to prevent the flanges from flexing downwards.
- This added a couple extra layers of protection to a very critical part of the assembly
    - But it would definitely be worth considering stiffer materials (Delrin?) and possibly manufacturing using other methods than 3d printing to allow us to dictate our own timelines.

Electrical Components & Assembly

Car 5 Considerations

- The biggest obstacle when manufacturing was the time it took to 3D print the modules and rails with rapid proto, we even sent it to Jeff's lab as well but in the future, it might be worth finding other manufacturing methods. Considering the size and the importance of the modules to the functionality of the pack, manufacturing using a non-prototyping method and material. One idea is to CNC the modules out of Delrin or some other hard plastic to avoid issues of bending we had with the 3D printed ASA. This would also introduce another manufacturing technique that members would greatly benefit from gaining experience in.
- Another manufacturing consideration is the time it took to make the fiberglass sandwich panels for the box. Vacuum bagging seemed to be more time upfront but it may have allowed us to do multiple panels side by side.
- Tolerancing should have been more of a priority and thought out fully. Including tolerancing within chassis, holes for the flanges in the modules as well as the voltage tap holes. Also the radius of the WJ wasn't accounted for in the box joints. Things like that have to be double checked.
- Overall, timeline should have been sped up. It would have been nice to give electrical months to test on an actual pack instead of weeks. Design, barring any unforeseen design overhauls, should be finished by the spring of the first year in the cycle. Summer should be for finalizing any small design features. And fall should be all out manufacturing. By winter break ideally, module prototypes should be printed and enough cells spotwelded to check functionality of the design. Box manufacturing should have at least begun if not finished entirely. Then in spring, ideally within a month or two, battery pack should be fully assembled, giving electrical 3+ months to fully test their architecture. *Do not underestimate how long things actually take.* If you can do something, do it. Don't wait around.

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