Traumatic Brain Injury Reducing Army Combat Helmet

Team 6
Week 3
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**Work Completed**

My third week of BME 4910 was used to make the final mold for our outer shell, start making the outer shell, and to research product testing companies. After practicing mold making and composite working techniques over the last two weeks, we decided that we were comfortable enough with the processes to start making our outer shell. The first step taken this week was to remove the straps and screws from the ACH we were going to use as the mold.

After all the straps, buckles, and screws were removed, the shell was wiped off to remove all dirt and particles that collected on the surface. Mold polish step 1 was spread over the surface of the helmet using gloves and can be seen in Figure 1. After a few minutes, the polish was washed off with water. The helmet dried off under the hood after about 15 minutes. Mold polish step 2 was then applied and removed in the same manner. The helmet was allowed about 30 minutes to dry under the hood.

![Figure 1. ACH after Mold polish step 1 was applied.](image)

After the helmet finished drying, a layer of parting wax was applied and spread over the helmet with gloved hands. The wax was spread evenly and thoroughly over the entire surface of the helmet. It was placed under the hood for 45 minutes to dry. The second, third, and fourth coats of parting wax were applied as described above, allowing one hour of drying time between the second and third coats. The helmet was allowed to dry overnight before PVA release film was applied. A spray top had been purchased, which made applying the release film much easier than previously. Release film was sprayed on the mold and spread with a paper towel. It was allowed 45 minutes to dry before the second coat was applied. This process was repeated for a total of four coats of PVA release film. A picture of the completed helmet mold is shown in Figure 2.
We ran into an issue this week with layering the Kevlar. I had mentioned it previously, but we never addressed the problem as a team until this week. Due to the nature of the Kevlar fabric, it is not possible to simply drape it over the mold and apply the epoxy resin without creating folds, creases, or air bubbles. We spent time researching methods of layering fabric from composite and craft-making sources. We came up with several ideas for our helmet.

The first idea was the make each layer of two halves of fabric, alternating front and back with left and right halves. The second idea was to lay down strips of fabric, alternating the direction of the strips with each layer. The third idea was obtained from researching the World Intellectual Property Organization. WO02/043949 A3 presented us with a pattern that we believe is used to make the combat helmets we have in our possession. Figure 3 shows the pinwheel pattern found in this document.
The fourth idea we came up with was similar to that of a soccer ball using hexagons and pentagons. Our fifth idea used layers of equilateral triangles aligned over the surface of the helmet. We decided to purchase fabric from Wal-mart that was similar to Kevlar instead of cutting up more of it just for practicing layering techniques. One yard of monk’s cloth fabric was purchased along with a container of Mod Podge, totaling $13.83.

The pinwheel technique was practiced using the monk’s cloth and Mod Podge. The pattern and completed product are shown in Figure 4. This method was difficult to do and ended up only working for half of the helmet, as the edges did not align when we protected the mold by covering it with wax paper.

[Figure 4. Pinwheel design (left) and helmet layer(right).]

The equilateral triangle method was practiced using scrap pieces of Kevlar because the monk’s cloth was too flexible to simulate Kevlar. We determined that this method was easier to do and thus was the first method we tried for making the Kevlar shell.

Many equilateral triangles were cut out using a cardboard stencil created from an internet graphic of a triangle. The triangles were placed on the mold and secured with epoxy resin. After reading the instructions on the epoxy containers, we determined that our previous methods were incorrect. 300 mL of epoxy resin and 100 mL of epoxy cure were mixed for one minute then applied onto the triangles with a paint brush as shown in Figure 5. The triangles were arranged by aligning their sides into a hexagonal shape over the mold surface. Three layers of triangles were applied to the mold. The final result is shown in Figure 6.

[Figure 5. Equilateral triangles being applied to the mold.]

It was discussed in our last meeting that we would create several outer shells for our project. This is necessary to ensure we are prepared for any issues that may arise throughout the building process. We will use different patterns to create each shell, even though the various designs may decrease the strength of the shell. The main goal of our project is not to alter the fabrication of the outer shell, as current manufacturing techniques are proven to provide excellent ballistic protection.
While one of my goals for the week was to research and contact product testing companies, I got side tracked when the unexpected layering issues arose. I did however research several companies and have tried to contact them about what testing services they offer. The companies are as follows:

Percept Technology Labs - Colorado  
Intertek Testing Services – New York  
Fike Corporation - Missouri  
RIH Orthopaedic Foundation, Inc. Test Facility – Rhode Island
Future Work

Now that we started making one shell, we need to finish cutting triangles in order to add more layers onto it. This is a tedious and time consuming process, but needs to be done before we can finish this shell. After this shell is made, we need to start measuring and cutting layers of Kevlar for the pinwheel design. Once these layers are cut, the composite shell can be constructed. I would also like to do some more research into the various testing laboratories I have found, as some of them are close enough to visit if necessary.

Hours Completed

Approximately 17 hours were spent working on the project this week. I spent about 6 hours preparing and making the mold for the helmet this week. About 4 hours were spent researching how to properly layer the Kevlar fabric. 3 hours were spent practicing layering fabric over the mold. 4 hours were spent cutting and placing the Kevlar triangles onto the helmet mold.