SAE
Clean Snowmobile Competition

Snowmobile Cowling

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Introduction

With an on going trend in the snowmobiling industry and the consideration for the environment many government agencies, especially the National Park Service, have reduced the usage of snowmobiles in their parks and claim that snowmobiles cause more noise and air pollution than cars. Recognizing the difficulty in this challenge, the Society of Automotive Engineers (SAE) developed the "Clean Snowmobile Challenge" (CSC). The Clean Snowmobile Challenge is a relatively new SAE design competition held in Jackson Wyoming and in the upper peninsula of Michigan. The intent of the competition is to provide universities with an intercollegiate competition that allows them to redesign stock snowmobiles to reduce emissions and noise while maintaining or improving the performance of the snowmobile. The emphasis is on low cost modifications that are suitable for implementations in a production sled.

The cowling is a piece of the snowmobile that encompasses the mechanical components including the clutches and the engine at the front of the sled. The current cowling on the snowmobile does little to reduce the noise emitted from the engine, clutch and induction system. Most cowlings are fabricated with polycarbonates or fiberglass, which do not possess useful sound barrier properties. Many of the snowmobile manufacturers today are focusing on ways to reduce noise emitted from the cowling. Arctic-Cat recently added a multi-million dollar NVH facility as part of their snowmobile R&D. Because of this new facility, the 2004 Firecat models from Arctic-Cat have a new insert in the cowling to reduce noise. This new insert would not have been created if there were not significant gains to be made in cowling construction and sound reduction. Our approach to this issue is to construct a new composite cowling. The new cowling shall resemble a sealed design and encompass sound dampening material inside. The method for choosing the material shall consider baseline sound testing data. The measured results will aid in the selection of the proper materials to gain the desired results.

Objectives

- Sound dampening
- Aesthetically pleasing
- Aerodynamic
- Cooling effects (air flow)

Sound Dampening
A damper material was chosen to reduce the sound caused by vibration, and also reduce the amplitude of the sound that was emitted. A material made by Quiet Solutions called Quiet Coat was chosen as the damper material. The group two years ago used a product by the B-Quiet Company. This product was not used because the density was much greater than the Quiet Coat and the two shared similar transmission loss numbers.

We chose the Polydamp acoustical foam with Tedler facing which American Micro Inc. distributes. The acoustical foam was chosen to be the best way to absorb sound because it is lightweight and is easy to use. Foams from American Micro Inc. had more of the properties that we wanted than the other manufacturers. When comparing the Polydamp foam density to the noise reduction coefficient (NRC), the Polydamp foams were far superior to those from other companies. The Tedler facing on the foam was chosen because it is heat, oil, and water-resistant. Other facings didn't have the resilience to the harsh environment that we needed. Foam thickness was limited to one inch because of space requirements.

Aesthetically Pleasing
The shape will allow the sled to look good, but yet still be functional. A paint job will enhance the sled's look and easily represent our school and sponsors.

Aerodynamic
The cowling's shape will allow for smooth air flow over the sled and rider in order to cut back on the drag coefficient.

Cooling effects
The cowling will contain two vents in the front to allow air to pass through the cowling and over the engine. This will keep temperatures down and allow the engine to perform at an optimum level.

Constraints

- Fit belly pan
- Regulate air flow
- Engine clearance
- Time

Fit Belly Pan
This is the most important constraint of the project this year. Proper fitting is crucial to the aesthetics, and functionality of the snowmobile. Any discrepancies can make the hood not clear engine components, or let in outside elements that could damage other parts. Also a hood that doesn't properly conform to the shape of the belly pan is not pleasing to look at.

Regulate Air Flow
The cowling must have scoops designed into it so that the hood lets air flow into the engine compartment in the correct spots. This air is used so that the engine will properly combust and have enough air to cool the clutch, and catalytic converter to normal operating conditions.

Engine Clearance
Parts of the engine reach extremely high temperatures when the sled is under operation. The cowling must have proper clearance over these spots so as to let enough air flow by to convectively cool them. Also, the more obvious problem, any error in measurement of engine parts will make the hood not fit on the sled.

Time
Completing the cowling by the competition is a big constraint. The cowling must be completed before the team leaves for competition on March 14, 2005.

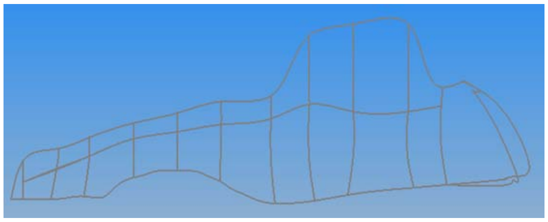
Modeling of the Cowling in Solid Works

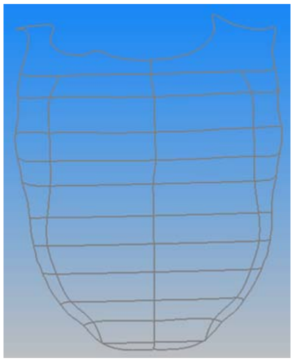
The modeling of the 2003 Arctic Cat 660 snowmobile cowling is done in SolidWorks. It is done in order to give the snowmobile a non-stock look that reflects the University of Maine CSC Team. It must serve its purpose as well as look good.

- Process
- Design Issues
- Final Model

Process/Design Issues
The original idea was to form the cowling by starting with a solid box and taking material away by way of extrusions and cuts, until it formed the shape of a cowling. The cuts would be made at the appropriate locations based on the measurements taken with the CMM and of the original snowmobile hood, as well as the maximum heights necessary to clear all of the engine components and any additional pieces of equipment added on to the engine. This however proved to be very difficult, especially with the bottom path that allows for the cowling to fit onto the belly pan of the snowmobile. In order to avoid this problem, it was decided to make the hood itself flat on the bottom (the lowest point on the hood where there is no more elevation change) and add in the bottom contoured elevations afterwards. After some basic trials and continuous problems of modeling the cowling in this manner however, it was decided not to model the cowling in this fashion.

The next idea was to take the points that were measured in the CMM manner and input them into SolidWorks (x, y, z coordinates based on our own coordinate system) to acquire the bottom contour that the hood needs to have in order for it to fit the belly pan of the snowmobile. Next, measurements were taken across the snowmobile itself to give lines that gave the highest points that need to be cleared in the same CMM manner. These points were then put into the same SolidWorks model as the bottom contour. It was attempted to sweep these individual lines in order to give them a slight thickness which would allow them to be used in a loft feature to make a solid body between the contour lines. This however did not work, and only made a few of the solid body segments between the contour lines, therefore excluding this idea from being used. It was then decided to connect the across lines with a spline with both end points having a similar point with the bottom contour line in order to connect these across lines with the bottom. The spline gives smooth curves between the points instead of abrupt straight lines. With enough lines across the snowmobile, the overall shape can be made out. This same process was then followed for lines going parallel (up and down) with the length of the sled. This produces a wire frame final model of the cowling that also contains the bottom contour (**see Figures 1 &2**).





Figures 1 & 2

Final Model
The final model designed in Solid Works accounts for the high points of the engine and any additional pieces of equipment that will be placed underneath the cowling. It will also fit the contour of the belly pan in order to fit nicely onto the snowmobile. It will serve as a sound dampener (sound dampening material will be placed underneath the cowling), to reduce the noise level produced by the engine. More or better placed vents will be placed in the hood to allow for better cooling of the engine during operation than the last years cowling. A gage cluster will also be made in order to hold the gages permanently in place on the snowmobile, which will lead to a slight modification in the designing of the rear of the cowling around the gage cluster which will be done when the full size mold and plug are made.

Making the Plug
We decided at the beginning of the semester that we would make a quarter scale model of the hood in order to practice our techniques. This decision was based on the fact that no one in our group had worked on or with composites and had experience making molds. The method we came up with for making the plug on the quarter scale was going to be duplicated when making the full scale as long as there weren't any complications or errors in our procedure.

Once a model of the cowling was on solid works we were able to take cross sectional views at 11 different points on the hood. This gave us the basic curve of several points on the snowmobile cowling. Then the following steps were taken:

- Making the Backbone
- Making the Frame
- Reinforcing the Frame
- Application of Foam
- Forming the Plug
- Application of Bondo
    - Sanding of Bondo
- Application of Primer
    - Sanding of Primer
    - Wet Sanding of Primer
- Application of Paint
- Turtle waxing of Plug

Making the Backbone
The backbone is the piece of the plug that holds everything together in the correct places, therefore being a very important part of the plug. The backbone was constructed of six inch pieces of particle board (1.5inches of foam board for quarter scale). In order to make sure the contour of the belly pan was meet the cross sections of the hood

could not all sit at the same height of the backbone. In order to get the correct contour a horizontal line on solid works was constructed below the lowest point on the cowling. The distance from the bottom of each cross section to the horizontal line was recorded. Then we took those distances and measured the same distance up from the bottom of the backbone pieces. The distance from the top of the backbone and the point measured up from the bottom was divided by two in order to create a stronger back bone. Both the backbone and the curves would be cut the same distance so they would interlock. Once all the distances are marked on the backbone we were able to cut out the slots on the back bone pieces. This was done on a table saw using an adjustable dado blade to get the correct width of the material used.

Making the Frame

The frame consists of the backbone and the cutout sections of the cowling. The cross sections were plotted out either at ¼ scale or full scale on a laser printer or the full scale on a plotter. The curves were then traced out on the material being used for the frame (7/16inch particle board for the full scale plug or 1/4inch foam board for the ¼ scale). On the backbone 11 slots were cutout at specific locations for each of the cross sections. The same distance that was cutout at each location for that specific section was the same distance cutout of that curve. The slots were cutout of each curve in order to meet the three backbone pieces. You can find a picture of the full scale frame in **Figure 3** below.

Reinforcing the frame

Because the cuts on the quarter scale model were so small it was very had to get them the exact distance and size we needed. Therefore the frame was a little unstable and in order to fix that we took some rigid wire and connected all of the curves to the backbone and then the curves to each other. On the full scale model, because a dado blade was used the slots were cut very exact and didn't need much reinforcement. Some wood glue was applied to them just for extra support and to makes sure they stayed in place while applying the foam.

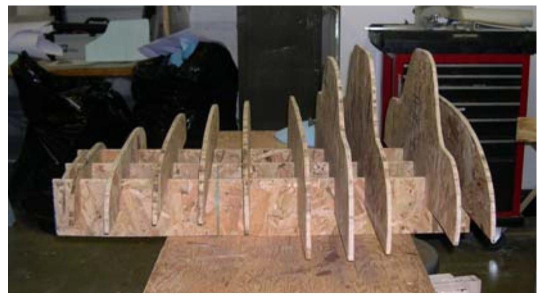


Figure 3

Application of Foam

In the building of the quarter scale plug we used expandable foam from a spray can. We applied the foam very lightly at times in order to make sure that it completely dried and didn't deform the frame. Enough foam was applied in order to completely cover the whole frame. You can see a picture of the mold after the foam was completely expanded in **Figure 4**.

In the building of the full scale plug pieces of blue foam were put in between each of the sections of the frame. Then after most of it is full with the blue foam some of the expandable spray foam was put applied in order to fill all of the spaces. This was also used to cover the whole plug because the bondo doesn't react with the spray foam but it eats away at the blue foam therefore the spray foam will be the top layer of the foam.

Figure 4

Forming the Plug

Once the foam was completely expanded we began to use graders and sand paper to cut down the foam to the curves of the frame. As you can see in **Figure 5** we have shaved the foam down to the curves. This procedure is done the same for both the quarter scale and the full scale plug.

Figure 5

Application of "Bond-O"

After the foam was shaved down to the contours of the plug you can begin to spread the first layer of bondo over the plug. You need to make sure to fill in all of the holes of the foam. To get the bondo prepared you need to mix it with some hardening compound to get a pinkish color.

Sanding the Bondo

After the bondo dries you can begin to sand the bondo in order to get a nice smooth surface. Any type of sand paper is okay to use here because you are just trying to get the entire plug a consistent smoothness. **Figure 6** shows a picture of the plug after a few layers of bondo and sanding has been completed.

Figure 6

Application of the Primer

The primer that was applied to the plug is just a spray primer. The primer was applied in a room with a hood in order to exhaust all of the fumes of the primer. As you can see in **Figure 7** the primer is being applied by team member Kate Charles.

Figure 7

Wet Sanding the Primer

After letting the primer dry we then used fine grit sandpaper to sand the plug. Then wet sanded it by wetting the fine grit sandpaper in order to make the grit finer. The wet sanding of the plug makes the plug a lot smoother. After sanding the plug you need to repeat the primer and wet sanding about 3 times in order to get the plug extremely smooth.

Application of Paint and Turtle Wax
The plug then needs to be painted with a glossy paint as uniformly as possible. Once the paint has dried we then had to wax the plug with turtle wax. This step is the final step in order to make the plug very glossy so the fiberglass applied to the mold will release from the plug easily.

Gage Cluster

In past years the snowmobile cowling would encompass all of the external gauges hooked up to the engine, such as speedometer, tachometer, oil pressure, etc. This posed a problem when the dynamometer group would have to perform tests on the sled when the hood was not present. If for any reason the cowling was removed for work, or so parts of the engine could be exposed for maintenance while running, the gauges had to be removed. There was no way to keep track of what the engine was doing without holding the gauges awkwardly in free space while running it if there was no hood. So a separately mounted gauge cluster was to be made so the hood could be removed and all the engine performance could still be monitored easily.

Objectives

- Blends in with plug
- Clears all internal components
- Easy access and removable

Constraints

- Sturdy
- Aesthetically Pleasing

Blends In With Plug
The Gauges cluster must be designed so that when the hood is present, the two mesh together as seamless as possible. An incorrect measurement will lead to the cowling not fitting, or elements being able to leak into the engine, not to mention it would look horrible.

Clears All Internal Components
Another important factor is making sure that the cluster when completely set up does not get in the way of other engine parts such as cooling hoses, or the light fixture. This way nothing has to be remounted or rerouted inside the engine.

Easy Access and Removable
We want to be able to easily take the cluster out so that any major hood work can be done and since it’s a new part that wasn’t originally designed for, taking it off to do other modifications will become a factor. So the less complex the mounting procedure is, the easier it will be to work with for other teams.

Constraints
Some things to think about, while not necessary to the functionality of the cluster, is how it looks. People being impressed by the look of it is a nice bonus. Also the stronger it is mounted and the more beating it can take is a plus too.

Materials
The gauge cluster is going to be made out of three materials. The panel itself will be plywood with carbon fiber over it. This was chosen because the plywood is easy to work with and shape. The carbon fiber over the top will add a real nice look to the cluster when

finished. The mounting brackets are aluminum rods that will just be drilled out and screwed into the plywood. Existing holes in the snowmobile will provide places for the bars to mount.

Conclusion

The milestones set for the project have been changed throughout the semester. At the current stage of the design project, the status of the milestones is as follows:

Advanced Snowmobile Fairing Team Milestones

Trevor Jenkins, Steve Cook, Kyle Spratt, & Kate Charles

(Updated 12/14/04)

- 9/09/04- Obtain and review last year's competition results.
  - ☑ - Milestone met.
- 9/16/04- Become Lab Safety Certified.
  - ☑ - Milestone met. Machinery, composite and safety.
- 9/21/04 - Measure last years cowling and see why it didn't fit. Compare and measure parting lines for the sled. Start concept sketches. Start lay-up of fairing, Specifying materials for ¼ scale model.
  - ☑ - Milestone met. Couldn't access last year's measurements so we moved on and measured the parting lines by hand.
- 10/19/04- Computer Modeling. Complete final model of fairing in Solid Works.
  - ☑ - Milestone met. The solid works model was finished and used for making cut outs for the back backbone of the ¼ scale and full-scale plugs.
- 11/15/04- Complete cutting and gluing layered foam for ¼ scale model.

☑ - Milestone met. The ¼ scale backbone was done with foam board and fastened with wire. It was then filled with spray foam.

↳ 12/01/04- Assign primary responsibility for coordinating and implementing four aspects of project.

- Kyle- Gauge cluster, layout, mounting of the external shape. Fitted by 12/17/04.

  ☑ - Milestone not met. Panel Built and fiber glassed, all mounting hardware is in but still has to be milled down to proper sizes by MET's before it can be mounted.

- Kate- ¼ scale plug done and test of mold release- 12/19/04. ¼ scale mold complete- 1/12/05.

  ☑ - ¼ scale plug complete. Test still in progress as of 12/14/04. On schedule to have mold complete by 1/12/04.

- Trevor & Steve- Printing sections and cutting out full-scale support panels. Purchase materials. Design a strong back for and finish assembling the rough sections of the full-scale plug- 12/17/04.

  ☑ -Sections and printouts are complete. Strong back complete. On schedule to finish the rough scale sections of full-scale plug.

↳ 12/19/04- Full-scale plug cut and first layer of bondo applied.

☑ - Milestone will be met over winter break.

↳ 12/17/04- Complete and hand in midterm report.

☑ - On schedule to meet milestone.

↳ 12/24/04- Complete the ¼ scale model. Evaluate lightweight design concepts.

- 1/12/05- Complete plug for final fairing over winter break.
- 1/17/05- Test of mold release on plug.
- 1/31/05- Complete mold and remove from plug.
- 2/18/05- Part from mold.
- 2/28/05- Complete final fairing.
- 3/14/05- Have fairing painted and ready for competition.

Appendix

Ideas to Avoid Last Year's Problems

- Double check that the measurements match the belly pan.
- Don't make hood too stiff. Use 2 sheets veil mesh and 2 medium sheets.
- Test the adhesive used to attach sound dampening material for heat resistance.
- Spray the Quiet-Coat, don't use brushes or spatulas.
- Plan time wisely. The bodywork takes more time than one might expect.

Measurement of Snowmobile (CMM)

In order to make sure that the cowling that we create matches the belly pan of the snowmobile we had to first start by measuring the contours of the belly pan. In order to do this we could have used a few different methods.

- CMM – Coordinate Measuring Machine
- Surveying Equipment
- Manual Measurements

After looking at last years cowling and their data from the CMM on campus we decided that their interpretation of the data could have been why the cowling did not fit the belly pan. The CMM had an extremely complex data output and would have been extremely hard to transfer that information to a solid modeling CAD program. Another senior group used surveying equipment because one of their members had previously used it but because no one in our group was familiar with the equipment we decided to not use this method. We decided to set up our own type of coordinate measuring machine. We used a copper rod along with two ring stands and a few clamps. We positioned the snowmobile and then taped out x-coordinates on the floor. The y-coordinates were the distance over the snowmobile and were measured on the long copper rod between the two ring stands. The z-coordinates were the height of the belly pan contour above the ground. The measurement was taking above the snowmobile so the distance was subtracted from the height of the rod to the floor. You can see our setup in **Figure 8** below with some of the group members performing the measuring.

Figure 8

We measured points around the belly pan where the cowling had to meet the snowmobile. X, Y and Z coordinates were taking for every point and imported into Excel in order to get a spread sheet of the points. Only one side of the belly pan was measure because the belly pan is symmetrical. You can find our excel spreadsheet of the measured points along the belly pan at the end of this report.

Goals to Complete in Future

The milestones that are in the future for our group to accomplish are as follows:

Complete ¼ scale model
Evaluate lightweight design concepts
Complete full scale plug
Test of mold release on plug
Complete mold
Complete final cowling
Paint Cowling

The dates of these milestones can be found on our milestone sheet in this report or on our website. The project thus far has gone on schedule and we are happy with our progress.