ASME Human Powered Vehicle (HPV)

Team Members

Andrew Newbold
Bryan Boyes
Nathan Rippel
Scott Headley

Advisor

Dr. Drew Landman

Table of Contents

1.0 Objective

Phase 1 of the HPLV project has been completed. The drive train, frame and steering systems are functional. Phase 2 of this project involves designing and fabricating an exterior fairing and integrating a roll bar and safety harness into the design.

The fairing should be designed to reduce aerodynamic drag as much as possible. However, weight, stability and ride-ability factors also must be considered. The fairing design will most likely surround the rider fairly closely. There must be room to steer the vehicle, pedal the vehicle and put both feet down to start and stop.

The frame is in a recumbent configuration, meaning that the rider is in a sitting position while pedaling the bike. This position, while it affords the bike a lower profile, complicates the operation of the vehicle due to the lost stability. The main objective of our project is to maximize the aerodynamic efficiency and stability characteristics at minimal weight.

The document is broken down into three main focal areas of our project. First, the fairing and nose cone status will be reported, followed by the roll bar status, and then extra design challenges. Each section will discuss final progress of each aspect of the project. The paper concludes with a financial summary of the completed project.

2.0 Fairing and Nose Cone Construction

2.1 Fairing and Nose Cone Aerodynamic Design

Once the determination had been made to construct only a partial fairing, the team set about the task of designing a usable partial nosecone and stringer assembly. The first step was to determine the minimum clearances that would be required for the rider inside the vehicle. This was done simply by measuring the required clearances at several stations along the vehicle from both a side view and a top view. Clearance was provided for the rider, handlebar out-swing, pedal rotation, etc. Figure 2.1 shows a graphical representation of the result of these measurements.

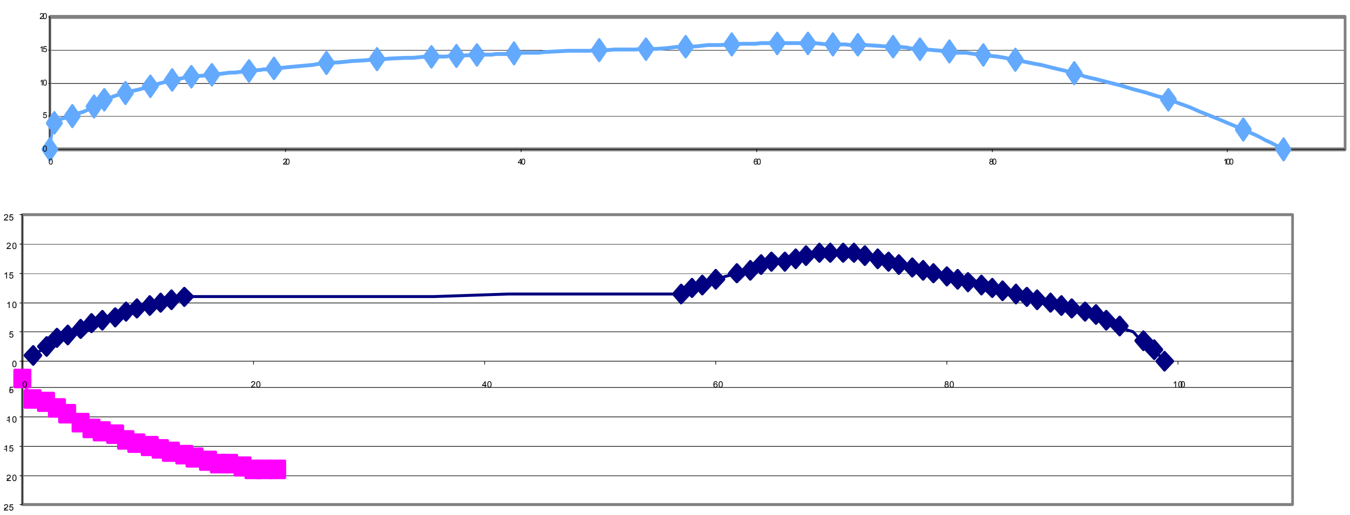


Figure 2.1: Profile Traces of HPV (Top figure is Top View, Bottom Figure is side profile. All dimensions are in inches.)

Figure 2.2 shows the rough traces superimposed atop the solid model of the vehicle. Note the clearances allowed to provide for riders of different sizes, full rotation of the crank pedal assembly and ample clearance for the out-swing of the handlebar.

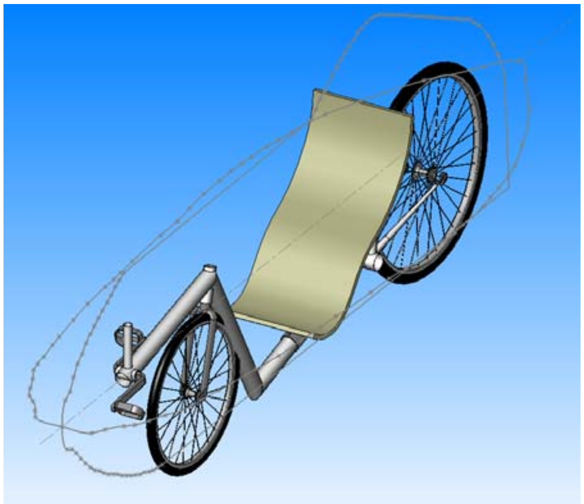


Figure 2.2: Traces of clearances superimposed over vehicle.

As can be seen by these figures, the traces are rather rough and require some cleaning up to produce an aerodynamically desirable shape. In SolidWorks, four smooth parabolic traces were created, one at each ordinal intersection, that closely match the clearance profiles generated previously. Figure 2.3 shows this below.

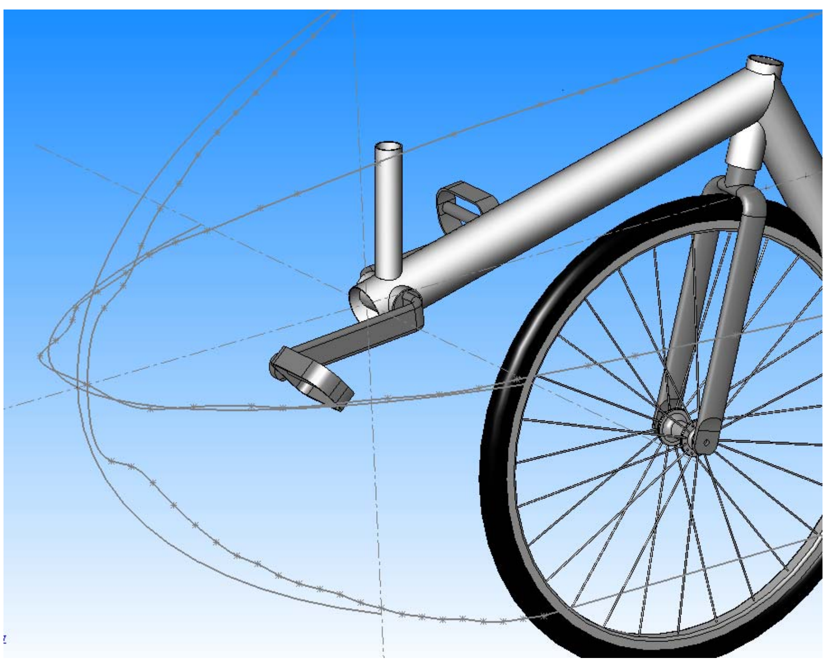


Figure 2.3: Profiles fit to clearance traces.

These four shapes were then used to create cross sectional traces at stations spaced at one inch intervals, beginning at the nose of the vehicle and progressing aft. Figure 2.4 shows this step, below.

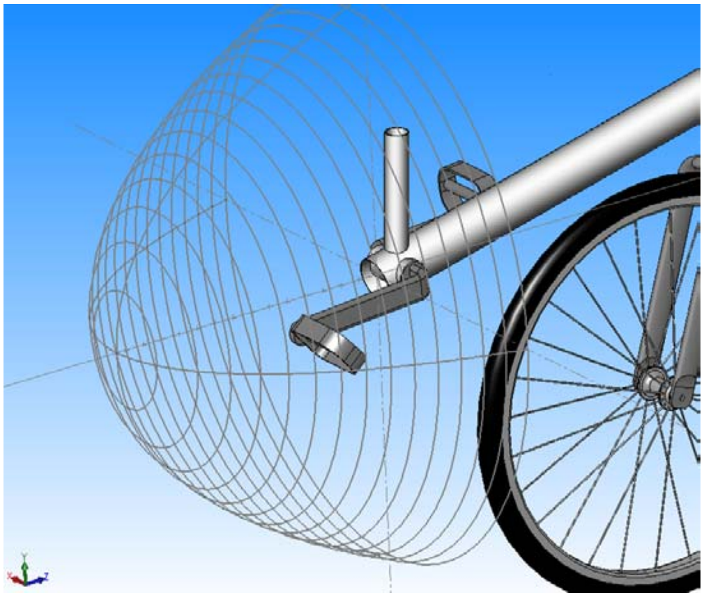


Figure 2.4: Cross sectional traces

These traces were then lofted together to form the surface of the nose cone and then thickened to give the model solid features from which to work. The final nose cone shape is shown below in Figure 2.5.

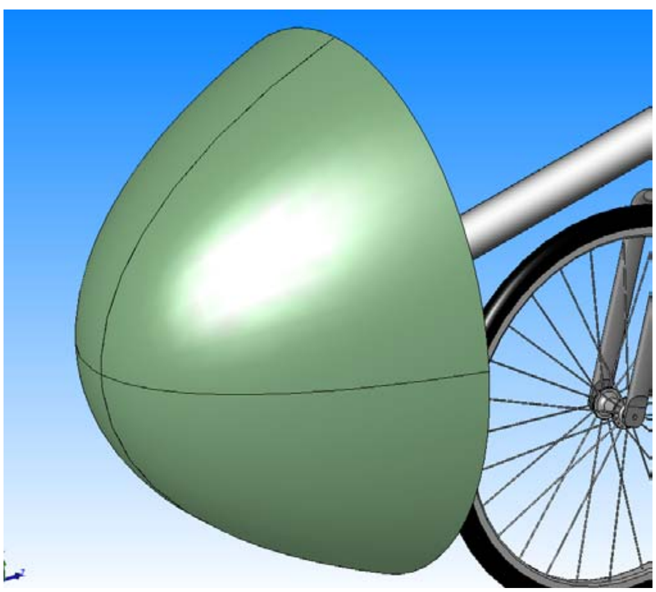


Figure 2.5: Completed nose cone geometry

The final location of the nose cone was determined at assembly in order to optimize visibility for the rider while providing maximum aerodynamic protection for the rider and steering assembly.

Determinations of thickness of the material were not considered since the nose cone is not a structural member. The nose cone simply has to support its own weight and hold its shape when subjected to aerodynamic forces, which should be nearly negligible at the speeds that the vehicle is expected to travel.

The side fairing panels were created in a similar fashion. The shape was determined by lofting from the rear profile of the nose cone to the forward profile of the roll bar. See Figure 2.6, below.

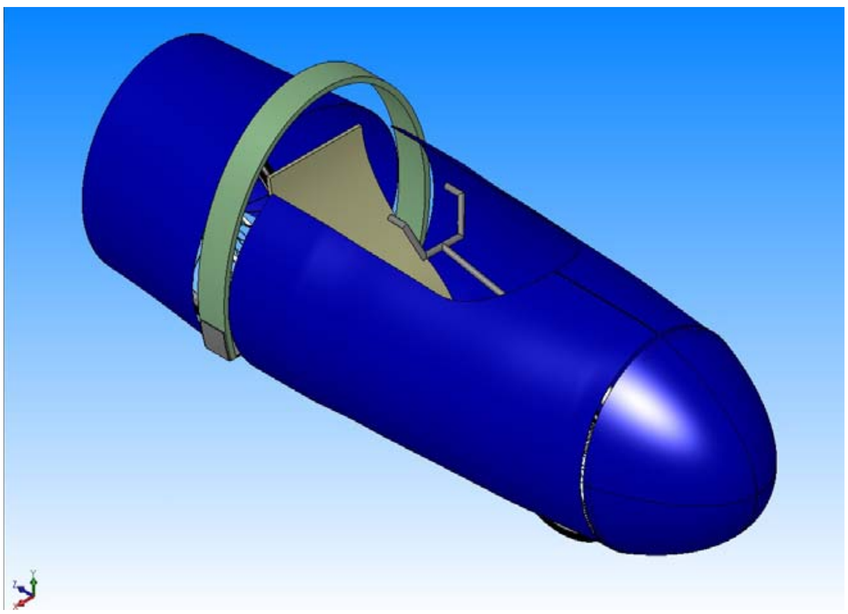


Figure 2.6 Isometric View of Faring and Vehicle

Figure 2.6 also shows the cut-outs of the fairing shape to provide clearance for the rider's upper body and the steering assembly. Similar cut-outs were made on the lower portion of the fairing to allow clearance for the rider's feet during pedaling and stopping and to prevent the fairing from bottoming out on the ground during cornering maneuvers.

Figure 2.7, below, shows a top view of the vehicle including a better view of the rear fairing panels. The rear fairing was lofted aft at ~10° to prevent an abrupt interruption to air flow around the sides of the vehicle. If this angle were extended aft ward until coming to a point at the rear of the vehicle, the aft fairing would have been approximately 8 feet long. This was deemed impractical and the rear fairing was truncated at 30 inches. While this configuration does have a blunt end, it will provide some laminar flow over 90% of the vehicle. This tradeoff, between the weight of a very lengthy rear fairing and some interruption to airflow, was deemed acceptable and practical .

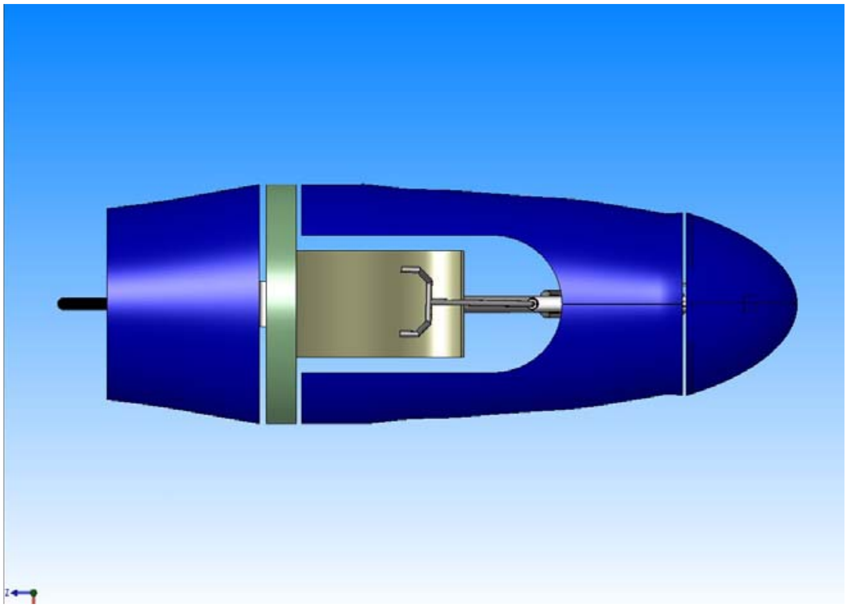


Figure 2.7 Top View of Fairing and Vehicle

2.2 Nose Cone Fabrication Process

The challenges of creating a complex surface, modeled after a precise desired shape created a challenge. There were several fabrication methods that were considered, but after reviewing each method one was chosen, for its simplicity and financial sense. A CAD model was created on the computer, and the model was electronically sliced every inch.   These cross sections were printed, full-size, on paper.

The paper templates were transferred to foam, and cut out. The foam was one-inch thick, corresponding to the virtual one-inch sections. A sturdy base was built and the foam was layered on top, creating a terraced cone. This initial step is shown in Figure 2.8

For the sake of simplicity the foam sections were covered with a "skin" of duct tape (Figure 2.9). This method worked well, it allowed us to skip out on a possible 6+ hours of shaping the foam itself before glassing. Two layers of 10 oz. woven fiberglass and polyester resin were laid on the mold. Given the outside temperature of 20-30 degrees Fahrenheit , special preparations were made in order to insure the proper curing of the polyester resin, which, ideally, should be applied in temperatures above 60 degrees Fahrenheit.

Figures 2.8 & 2.9 Foam plug & Foam plug smoothed with duct tape

Following the layers of glass, several layers of body filler were applied to the mold. The idea is to get a mold that is exactly what shape you want the finished product to be. A good deal of care went into obsessing over the details of the subtle rises and lows of the nose-cone contours. 80-grit, 120-grit, and finally 220-grit sandpaper was used to fair down the nose cone into exactly what we wanted.

In preparation for the layers of fiberglass used to create the female mold, the male mold, shown in Figure 2.10, was waxed and smoothed to perfection. Approximately 6 coats of special purpose mold release wax were applied to the mold. An application of gel coat was applied to the mold, and two layers of chopped mat fiberglass were applied. Chopped mat style glass was chosen for its omni directional strength as opposed to woven fabric, which generally has more strength, but only in specific directions.

Figures 2.10 & 2.11 Waxed male nose cone & Female mold

A major concern of several of the group members was how easy was this female mold going to be separated from the male counterpart. After doing what we felt was a sufficient job stiffening the female mold by applying two layers of chopped mat glass, we attempted to remove the female mold from the plug. This proved very difficult, and, in the process of separating them, the male plug was destroyed.

What we ended up with was a female mold that needed a lot of additional fairing before it could be used to make a product. This was all faired down and the molds were coated with primer and gel coat ready for a finished product to be pulled off.

After investigating the cause of the aforementioned difficulty, we settled on the theory that the mold release wax that we used was not being used properly. We modified our process to accommodate that and had positive results. We were treating the mold release wax like car wax, when in fact the mold release wax needed 2 hours to dry, as opposed to the 20 minutes that we were allotting it.

The mold was coated with gel coat, waxed and two layers of 10 oz. fiberglass bonded with polyester resin. With the modified process the nose cone pulled out of the mold with minimal difficulty. It was then primed and painted. The structural integrity of the nose cone was important. We wanted something that was very stiff, yet not too overbuilt. Nosecone structure was achieved by bonding a vertical stiffener in the centerline of the nose cone. This accomplished two things, it provided structure to the cone, and it gave us a place to affix the nose cone to the bike itself.

2.3 Fairing Fabrication Process

Fairing Material Selection:

Early in January the deadline was approaching for creating a concept for how were going to cover the frame and the rider of the vehicle. Some of the ideas were as follows:

- Full, one-piece fiberglass fairing. Beautiful and fast, but also expensive and difficult to make
- Partial one piece fiberglass fairing. Simpler to make, but unforgiving if we want to modify designs, besides, we felt like we were capable of creating a full fairing
- Multiple piece fiberglass fairing. Modular and fast, but highly complex to design and make
- Full fairing, incorporating both, solid fiberglass components and a bulkhead/stringer assembly to support a fabric or similar skin. Simpler to build, forgiving in terms of modifications, but highly dependent of finding and using the right materials for all components

The bulkhead stringer assembly was chosen for a few reasons. It allowed a lot of modification to the bike even after much of it was assembled. It is a light and efficient concept. It is a proven concept; it has been proven in the field of aviation and land vehicles. Some of the potential problems with this concept are that even though we can do a lot of tinkering, it is going to take a lot of tinkering to get the shape right in the first place. The stability, rigidity and shape of the structure is highly dependent on using the right materials in the right places, this could make things complicated.

For this reason special care has been taken in the materials selection for the stringers, bulkheads and skin of the fairing. Stringers run along the vehicle and cross the bulkheads from front to back. They must be of a prescribed flexibility in order not to be too stiff or too flexible. They will form the framework for laying the skin over the bike. They must have enough stiffness to support the skin, but not so much that they cannot bend to the designed curves. Wood, carbon fiber rod and fiberglass rod were the two major options in this decision. Carbon fiber rod is very stiff, and glass rod, not as much so. Wood comes in a variety of properties and is easy to modify. A sample of glass rod was obtained and we felt that it would suit its purpose well, however, due to its extreme flexibility it was deemed a tad to flexible and the team decided to go with something that gives us more control over its properties, like wood.

Also in consideration was the skin of the fairing. The skin has to be something that is easy to work with, somewhat cheap and durable. It would have to be stiff enough to keep from flapping uncontrollably in the wind, but not so stiff as to be heavy. Sailcloth, Mylar, plastic, nylon, aircraft covering and foam were all considered. We decided on aircraft covering. It is used in the aircraft industry to cover the wings and fuselage of planes. It is a pliable material at first, and can be fitted to what shape you need. After the fitting is done, you heat shrink it and seal it, and it hardens to the shape that you formed it in. In our case, it will be formed over the stringers.

The fairing was constructed of wood in a bulkhead stringer arrangement. Two side panels were made that fit to either side of the rider, reaching from the nosecone, to the roll bar. Also, a single rear fairing, cantilevered off of the roll-bar was made. All of these were skinned in ceconite and painted blue like the rest of the bike.

Figure 2.12, below, shows one of the side fairing panels during construction. Note the use of plywood for the bulkheads and the use of T-shaped stringer to provide optimization between weight and stiffness.

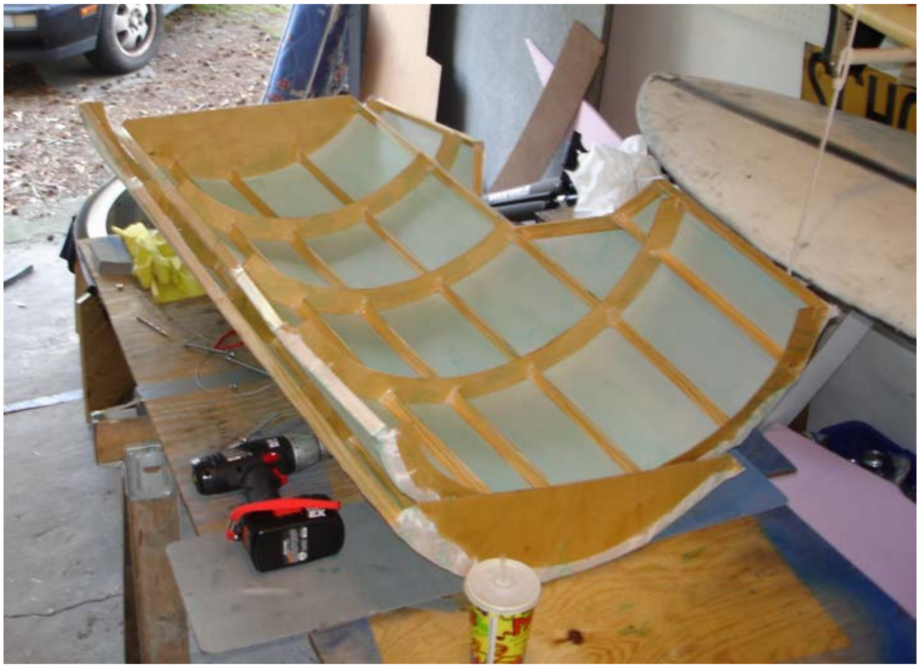


Figure 2.12 Side Fairing Panel during Construction

Fairing Testing:

Had we had time to get into the wind tunnel with the bike, we would have like to have tested a few aspects of it. An aerodynamic test would have been best performed at the Langley full scale wind tunnel. Among the criterion tested would have been the separation point of the attached flow along major surfaces. We want the flow to be attached for as long as possible along the surfaces of the fairing. Attached or laminar flow has less skin friction (drag) than turbulent or detached flow. Ideally we would like the flow to remain attached for the entire length of the fairing. If we can get close to this goal, drag should be reduced significantly.

Another testing criterion would have been testing to find the stagnation point on the front of the nose cone as well. This location is utilized for an air vent to vent fresh air into the cockpit of the bike. The stagnation point has the highest air pressure of any point on the fairing. We would have used the point of stagnation for two reasons. One reason is that the air vent will be fed more air, the higher the differential pressure between outside and inside the fairing. The second reason is that relieving some of this pressure would do positive things for our aerodynamic efficiency.

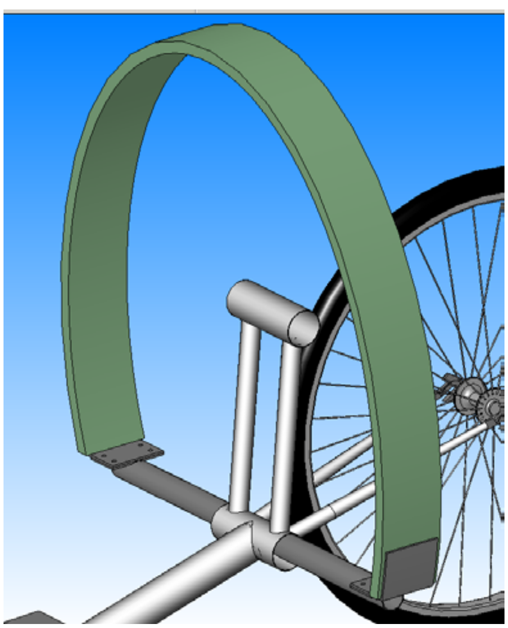
Our analysis plan would have involved using a smoke wand to visibly inspect the flow characteristics. A drag force analysis would have been beneficial, however that analysis would involve making specialized equipment, equipment that we may not have time to build and calibrate. Smoke analysis should be able to deliver a basic idea of how air is going to flow around the vehicle. As you use more advanced methods, one starts suffering from the law of diminishing returns.

3.0 Roll Bar Construction

3.1 Roll Bar Design

Competition design rules require that the vehicle have rollover protection. The team made the decision that the easiest means of accomplishing this would be with a roll bar. The material chosen for the roll bar was again fiberglass, for ease of manufacture, ready availability, light weight stiffness, etc. The design rules, however, require that the roll bar be "equivalent" to a roll bar constructed from 1.5"∅ x 0.050" thick 4130 steel tube. The equivalency was determined by calculating maximum tensile and bending loads that the steel tube could withstand and then applying those loads to the fiberglass beam shape. The shape was optimized until the calculates stresses from both tensile loading and bending were below that of the failure strength of the fiberglass material (estimated to be approximately 15,000 psi). The yield strength of the steel tube was very conservatively estimated to be 30 ksi. This conservatism adds some additional safety margin to help account for the sensitivity to processing conditions that are inherent in using composite materials. Details of these calculations are included as Appendix A.

The profile for the roll bar was created from the same traces that were used to generate the nose cone shape. Figure 3.1, below , shows the geometry of the roll bar (the seat is hidden for clarity).



Figures 3.1: Roll Bar design

The roll bar is attached to the frame of the vehicle under the rider to provide maximum protection for the riders vital parts. The means of attachment is 1.5"∅ x 0.050" thick 4130 steel tube with a flange weld to it. The flange bolts to another flange that is glassed into the roll bar. This allows for removal of the roll bar for maintenance and/or replacement.

3.2 Roll Bar Fabrication Process:

We needed our roll bar to be in a shape that would coincide with the fairing profile because our roll bar is incorporated into our fairing attachment design. We did not have to worry about bending our roll bar material because fiberglass provided us with a medium that allowed us to easily create whatever shape we needed.

Once the material selection process was completed, it was time for us to start the roll bar fabrication. The first step involved was for us to create a core to lay the glass up on. We cut out our desired shape from a matted reinforced fiberglass coring foam. This will add extra strength at a minimal weight. Four iterations of this shape were cut out and glued on top of each other to get the proper core width for our roll bar. This is shown in Figure 3.2.

The next step in the process was to lay up several layers of fiberglass around the core. In order to ensure the maximum strength possible, we did each layer in a different direction. Most of the strength acquired from the fiberglass was from the layers that were wrapped at 45-degree angles around the entire roll bar cross section from one lower attachment point to the other. After each layer was glassed in, the entire bar was clamped into a form so that the correct shape would be maintained, as shown in Figure 3.3. Any bubbles in the fiberglass reduce the roll bar's final strength.


Figures 3.2 & 3.3 Roll bar core & Roll bar clamped in the form

After the roll bar construction was completed, we needed an attachment method that would allow the roll bar to be removed easily if need be. In order for this to be possible, we glassed "L" shaped steel brackets, with bolt holes drilled into them, to the two bottom portions of the roll bar (Figure 3.4).

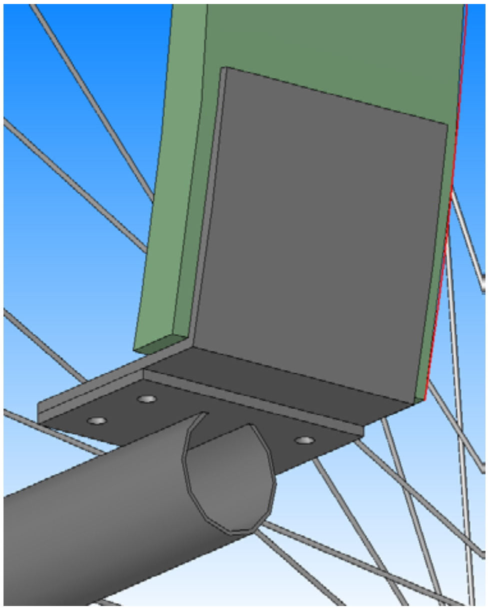


Figure 3.4 Roll bar attachment method

A lot of time was spent making the roll bar visually pleasing because it will be visible at all times during riding. We did not want to fair out the surface of the roll bar because this would take away from its overall strength. The imperfections in the fiberglass were filled in with West Systems epoxy and micro-filler. This was a simple and lightweight way to smoothen the roll bar surface. We then painted the bar blue with "ODU" and the vehicle number "3" painted in silver. Figure 3.5 shows the roll bar attached to the bike.

Figure 3.5 Final roll bar

Overall, this roll bar serves many purposes other than just rider protection. A lot of time and effort went into the design and construction of the roll bar, and it proved to be worth every bit of it. Not only did it give us good attachment points for the fairing, but also provided us with a nice place to display the required information for the competition, and also provided us with a way to stabilize the bike while riders get in and out.

4.0 Other Design Challenges

4.1 Seat Design:

Several design changes were made to the bike to enhance its performance. The main one deals with the seat and its mounting components. The original seat was uncomfortable, unstable, and not adjustable. We took on the challenge of correcting these design flaws.

The first thing we did was design a new seat that better conformed to the rider's body. This new design helps distribute the rider's body weight throughout the seat so that the force of his/her weight is not concentrated to one part of the body. The new seat is also angled to give the rider a rigid body to push against during each stroke.

The second design modification to the seat was the attachment mechanism. The original seat wais attached to the frame at the front of the seat, and by two angled rods coming off the back. This attachment method did not adequately prevent a side-to-side motion in the seat during riding. Any slight movement in the seat causes balance problems. Our new design still uses the angled rods off the back, but also incorporates steel tube supports that go straight down from the seat. These supports form a triangle with the frame, and better stabilize the seat.

4.2 Rear Brake Design:

Initially, the bike was safely functioning with only a front brake. The competition rules do not require a front and rear brake, as long as the bike is able to stop with in 20 feet while going 15 miles per hour. Since 80 percent of the vehicles stopping force comes from the front brake, we technically did not have to add a rear brake. We chose to do so just for extra safety. We needed to make sure the brake did not interfere with the ability to remove the rear wheel because the wheel needs to slide forward upon removal. Using our new seat design, we were able to easily weld a rear brake mount. Figure 4.1 shows the rear brake mount as well as the seat mount behind it.

Figure 4.1 Rear brake and seat mount

4.3 Drive Train Design:

Modifications to the drive train were needed to make the bike more efficient. The chain that drives the back wheel is very long and winds along the frame of the bike on idler wheels (Figure 4.2 & 4.3). Because of this, the chain occasionally gets derailed.

We discussed heavily the possibility of using a jackshaft in place of one of the idler wheels. We decided against it because it would change our gear ratios, force us to use two chains, and be expensive. The idlers were enhanced to prevent the chain from falling off. This was done by welding in a larger axle for the gears and idler wheels to spin on. This helped to keep the chain in line and drastically reduced the motion that caused the chain to become derailed. Also, as a safety feature, a metal guard was welded to the frame in order to protect the rider's leg from interfering with the chain. This was only a problem for the riders who ride with the seat in the forward most position.

Figure 4.2 & 4.3 Idler wheel supporting chain along the frame of bike

4.2 Steering Design:

Another problem we had with the bike was the steering. The bike's steering system is very sensitive towards any movement. It is also long and awkward. Due to the height of the steering, there are also some visibility issues.

We planned to fix these problems with a remote steering design. Remote steering is a proven method for a recumbent bike with a fairing. The use of remote steering would allow us to move the handlebars to a lower location on the bike. It would also cut down on the amount of motion needed to steer the bike, therefore helping with stability.

Our new handlebars would have been fastened to a steel tube riser mounted onto the bike frame (Figure 4.1, next page). These handlebars would drive the steering rod attached to the headset with a pivot bolt. This design would change the sensitivity of the steering system by changing the distance between the rod's two attachment points (Figure 4.2, next page). This design change would also have reduced visibility problems the steering assembly would be mounted at a lower position on the bike.

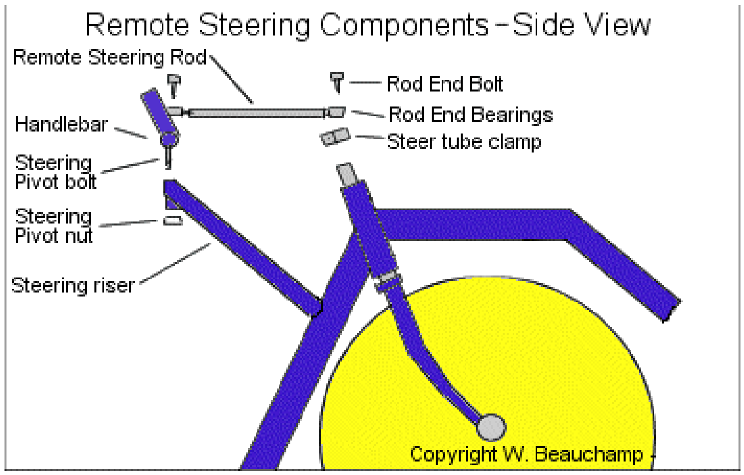


Figure 4.1 Steering riser mounted to bike frame to support the remote steering components

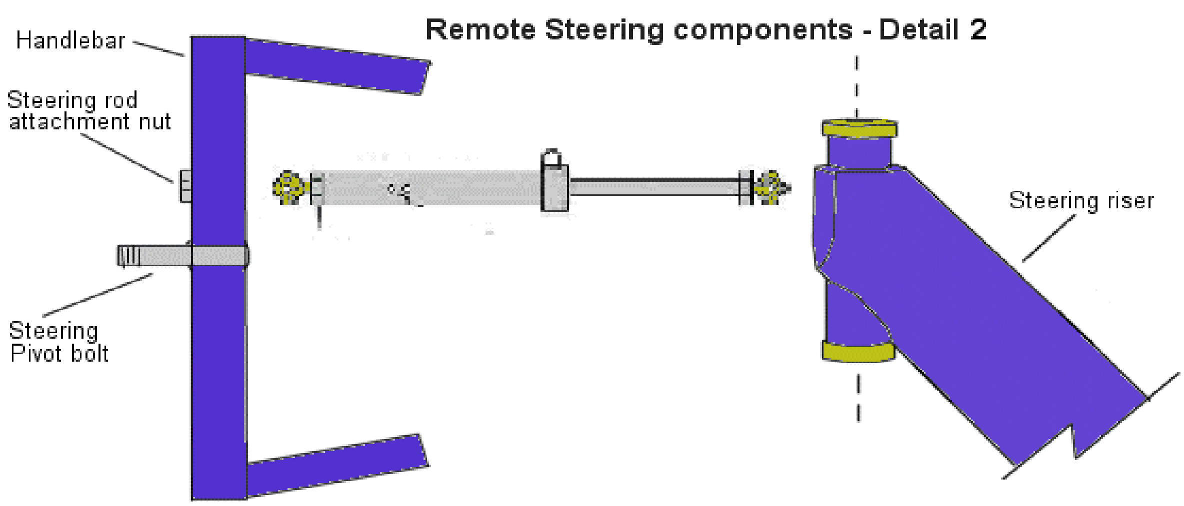


Figure 4.2 Remote Steering components

Ultimately the design for the remote steering assembly was not implemented due to time constraints and some design issues that could not be resolved. The issue of visibility was improved somewhat with the lowering of the nose cone and removal of some portions of the side fairing panels.

5.0 Cost

We have finished buying materials for the construction of the bike. We have some money left over in the account but with Dr. Bawab's permission we are going to use that amount to help with our travel expenses. Specifically, the left over amount will go to pay for our vehicle rental fee. The team has managed to save money in various ways, even though we lack additional sponsorship. Through the donations of friends and Dr. Landman we have been able to cut the costs of fiberglass mat and resin. We have talked to the owner of Eastern Burlap and Trading Company, and he has agreed to sell us materials at wholesale cost. These were two of our larger expected costs in the planning stage. The money saved has been used to buy little things for the actual fiberglass application that was not budgeted for. These are things such as brushes, gloves, kerosene, and plastic tarp. We have approached East Coast Bicycles, Cycle Classics, AirBomb.com, Burley Design Cooperative, OnlineMetals.com, Eastern Burlap, and Cary Machine Shop about financially sponsoring our team but all groups declined. But they did give us discounts and some free parts.

None of us had ever fiber glassed before so we did not know to include these items in the initial planning costs. We use so many brushes because when you're done painting the resin onto the fiberglass, the extra will harden in the brush and there is no way to remove it and make the brush reusable. Also, gloves are a necessity because the resin is toxic and very sticky, and it is not good to touch fiberglass with bare skin. Because it is winter and fiberglass needs warm air to cure, we have been using a kerosene heater to keep the temperature warm enough to make the fiberglass set up. For cleanliness, we have been working over top of a plastic tarp to protect the working surfaces, and to stop dust and dirt from getting in our glass.

For the skin of the fairing we decided to use ceconite. We spent $80 on the fabric alone and another $94 on the chemicals needed to shrink it. This saved us some money because originally we planned on using nylon as the skin. And we had budgeted that out to be $200 for the fabric alone and then we would have needed someone to sew the pieces together. You can see a breakdown of our expenditures in Appendix B.

According to Map Quest the estimated time for one way is almost 13 hours. The distance each way is 769.33 miles, that's 1538.66 miles roundtrip minus driving from the hotel to the competition site. We are using the college's van to pull the ASME formula team's trailer. The general gas mileage for a van pulling a trailer is 15 miles to the gallon. So it will take 102.58 gallons of gas. And at $2.10 a gallon for regular that comes to $215.41 to cover our costs for gas. Hotel reservations have already been made at the Jameson Inn of Tuscaloosa. We were given a special discount rate for the two rooms because we are students. The total for the hotel is $398.04. That covers 2 bedrooms with 2 double beds for 3 nights. The competition will end Sunday April 24 afternoon at which time we will leave. We can cut costs by getting the Aerospace Engineering Department to pay for Dr. Landman to fly to the competition and pay for his lodging if there are not sufficient funds. The only other cost is food. We will only have to eat 9 meals on the road for 8 people. The competition is providing us with 2 meals. At $10 a meal, that comes out to

$90 dollars in food costs. We will also need $240 for the vehicle rental cost. A break down of these costs can be seen in Appendix C.

6.0 Conclusion

All of the major tasks that we laid out at the beginning of the task were addressed during the semester, in form or another. With the exception of the improved method of steering, all of these designs were realized in the form of finished components.

The vehicle will compete in the ASME competition at the University of Alabama during the weekend of the April 22-24, 2005.

There were several lessons learned by the group during the completion of this task. They are as follows:

- The human form is inherently difficult to design around. The team did not have any members with experience in ergonomic design. This proved to be a problem when designing a vehicle for not one rider, but several riders of different shapes and sizes.

- Engineering tasks require a high level of planning and coordination. Time was a major factor in many of the design decisions that were made during the course of the task. In many cases, construction of components ran concurrently with the design. This required a great deal of flexibility when designing components.

- Systems integration is perhaps the most important element of any engineering task. During this task we had to integrate newly designed components with existing hardware as well as integrate newly designed components with other newly designed components. The team did not designate integration as a major area of responsibility and it proved to be a limitation.

- Coordination of all of the individuals involved in the task (current team members, former team members and outside team members) did not go as smoothly as planned. Many times during the task there were small sub-groups working individually without any knowledge of the other sub-groups' activities.

Overall, the team is pleased with the results of the project. The vehicle is ready to compete and favorably represent the team, the Department and the University.

Completed Vehicle (Rear fairing panels not shown)

Appendix A: Roll bar equivalency calculations

steel tube

$do := 1.5 \quad tt := 0.049$

$di := do - 2 \cdot tt \qquad c1 := \frac{do}{2}$

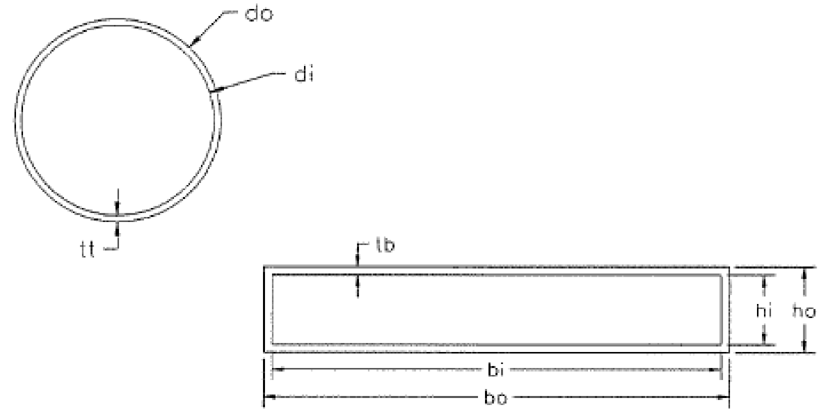
$Ai := \frac{\pi}{4} \cdot \left(do^2 - di^2\right) \qquad Ii := \frac{\pi}{64} \cdot \left(do^4 - di^4\right)$

$Ai = 0.223 \qquad Ii = 0.059$

$\sigma ysteel := 30000$

$Fmax := \sigma ysteel \cdot Ai \qquad Mmax := \sigma ysteel \cdot \frac{Ii}{c1}$

$Fmax = 6.701 \times 10^3 \qquad Mmax = 2.354 \times 10^3$



fiberglass beam

$bo := 4 \quad ho := 0.75 \quad tb := .07$

$c2 := \frac{ho}{2}$

$bi := bo - 2 \cdot tb \qquad hi := ho - 2 \cdot tb$

$bi = 3.86 \qquad hi = 0.61$

$Ax := bo \cdot ho - bi \cdot hi \qquad Ix := \frac{1}{12} \cdot \left(bo \cdot ho^3 - bi \cdot hi^3\right)$

$Ax = 0.645 \qquad Ix = 0.068$

$\sigma ysfiber := 15000$

$\sigma tensile := \frac{Fmax}{Ax} \qquad \sigma bending := Mmax \cdot \frac{c2}{Ix}$

$\sigma tensile = 1.038 \times 10^4 \qquad \sigma bending = 1.306 \times 10^4$

Appendix B: Table of project budget and cost

Costs

Material	Expected Cost	Actual Cost
Helmet	$10	
Safety Harness	$50	
Form Materials	$150	
Bondo	$18	$16.99
Aluminum	$82	
Wood Core/Structural Foam	$20	
Carbon Rods	$280	
Fiberglass Mat	$100	$54.86
Nylon	$200	
Epoxy Resin	$100	$34.18
Preliminary Entry Fee	$50	$50.00
brushes		$15.11
bulk iron		$5.00
1/8" steel		$35.00
Sandpaper		$4.99
Spreader		$1.99
trim roller		$7.10
latex gloves		$12.00
Jigsaw Blade		$13.93
Insulation		$33.92
Liquid Nails		$2.74
Entry Fee		$137.00
jigsaw blades		4.18
jigsaw blades		4.18
dib spray primer plastic		3.79
spray ocean blue		6.58
spray primer gray		4.79
spray clear		4.29
tape masking		1.99
west system fairing filler		6.63
west system epoxy resin		16.14
west system slow hardner		7.71
4" plastic squeese		0.68
quart painter pails		0.45
2" whtbrsbrsh		5.82
plastbaggds		2.55
2" whtbrsbrsh		2.91
roller kit		1.98
spray paint		2.79

mult 220hp		1.99
1.5" crnrbr		1.99
plastbaggds		3.4
2" whtbrsbrsh		2.91
sandpaper		2.57
trimrollrref		1.27
roller kit		1.98
11/21 pchlsaw		6.49
fiber wheel		7.49
disppnttray		1.96
AAA cutwshr .25		1.12
ALD .25*31/2 hblt		1.44
plastbaggds		0.85
ABA .25 flctwshgl		0.64
ADA cargblt .25		0.36
grt stf min fm 12		3.49
disc 5" sand 40		2.19
2m3 container mixing 1qt		1.58
chip brush 2"		5.94
bulk nuts, bolts, screws		1.68
bulk nuts, bolts, screws		0.4
bulk nuts, bolts, screws		2.88
iron crn11 2*5/8		3.98
2oz tube mfkp		2.56
Total	$1060	778.20

Appendix C Table of expect travel expenses

Item	Expected Cost
Suburban	$240
Gas	$215.41
Hotel	$398.04
Food	$90
Total	$943.45