Michigan Hybrid Racing 2014

Design Report Aero Division 2014

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REPORT OVERVIEW

This report outlines the design approach the aero division of the Michigan Hybrid Racing team to build and design a car for the 2014 Formula Hybrid competition. It summarizes our design goals, rules constraints, concepts generated and relevant analysis. The report is divided into three main sections; the aerodynamic body, cooling system and human machine interface. Each section describes our final selected concept with justification for why it is the most efficient and feasible for our purpose.

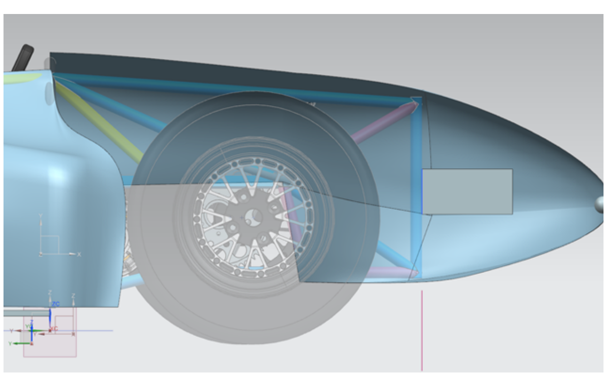
AERODYNAMIC BODY

Design goals

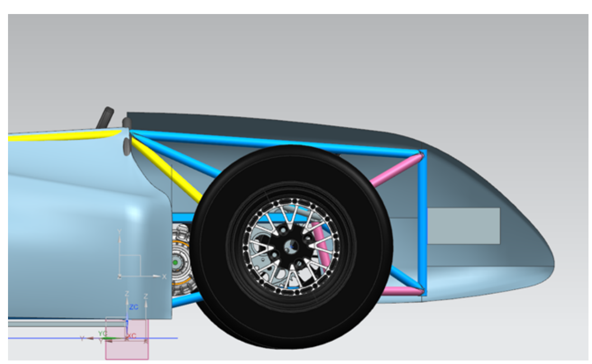
This year we plan to make many improvements from last years design. One of our biggest concerns this was weight reduction. For this years design we are expecting a weight reduction of at least 30% from last year. In addition, we would also like to incorporate some downforce into our body design. In previous years this was never a concern for the Aero team. However, this year we are expecting an increase in downforce by about 20%. We will accomplish this goal by designing and manufacturing the teams first undertray for the car which will provide the downforce we desire. Finally, we plan to have all of our components manufactured one month before the date of competition.

Nosecone

As with previous years we designed the front end of the car that covers the impact attenuator as its own separate entity or nosecone. When designing the nosecone we need to take into account the contour of the front end of the chassis the size of the impact attenuator. Also, the bottom of our design was refined to have an acceptance angle of around 15o to avoid any possible contact between the nose cone and the ground. In addition, the premise of our design is to produce a nosecone that is very aerodynamic with very little drag. This year we came up with two designs for the nose, each of which can be seen below in Figure 1.



(a)



(b)

Figure 1: (a) Nose Cone design 1: Higher angle of acceptance, (b) Nose Cone Design 2: Smaller nose radius and lower angle of acceptance

In order to choose which of our designs was most suitable we ran CFD analysis on both and compared the results. Figure 1.2 below depicts our CFD analysis on both designs 1 and 2. Design number 1 resulted with a coefficient of drag of 0.0914 and a coefficient of lift of 0.0674. Design number 2 produced a drag coefficient of 0.0963 and a lift coefficient of 0.0626. From this data we were able to deduce that design number 2 was the most suitable for our application. As compared to last years design which produced a drag coefficient of 0.334 and a lift coefficient of -0.144. From these results we concluded that both of our designs have drastically improved from that of previous years meeting the criteria set down in our design goals.

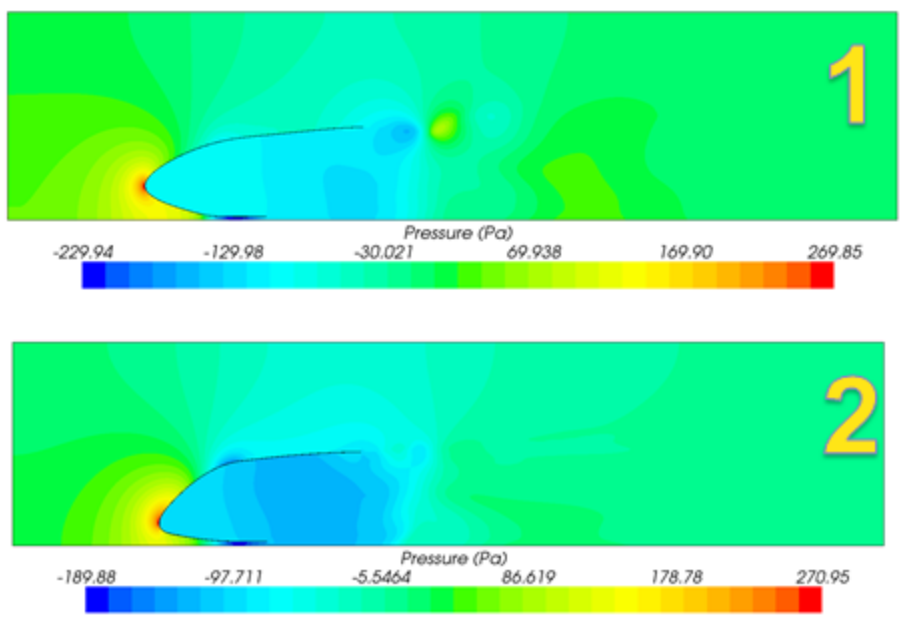
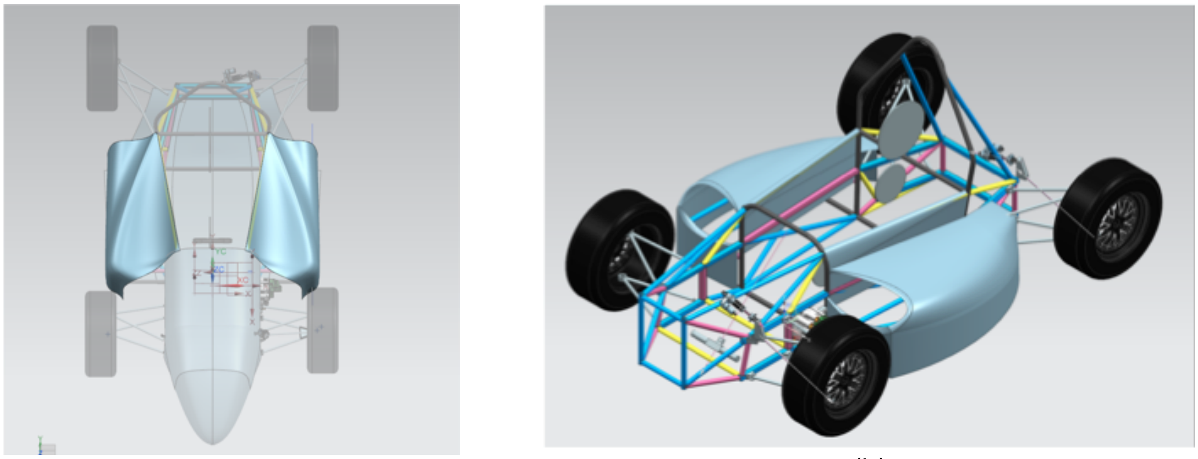


Figure 2: CFD Analysis of nosecone

Side pods

In previous years the sidepods were only used to cover the battery packs of the car. This year in addition to protecting the battery packs they were designed to redirect flow to the radiators for the cooling system and reduce overall drag of the car. Two designs were generated and later evaluated through CFD analysis, figure 3 show both designs.



(a) (b)

Figure 3: sidepods concepts

Both designs were designed within the constraints of the Formula Hybrid Competition Rules. The rules to consider for sidepods design are rules T2.1.1 through T2.5 from the Formula Hybrid Competition rules manual. Figure 4 indicated how the they pass the “keep-out-zone” (rule T2.1.2). Design 1 is based on last year design where it wrapped around the cage of the battery pack. It is designed to be mounted using side snap latches to provide fast access to the electrical components. Design 2 is more elaborate, it has a curving shape as seen from above, and it has an opening specifically designed to conduct air to the radiators. It also fastens by wrapping around the chassis bars and uses not fasteners. This concept has been proven to work by other Formula Hybrid teams in the past. Also, the sidepods are sized so that the radiators inside them so that there is a better flow through them.

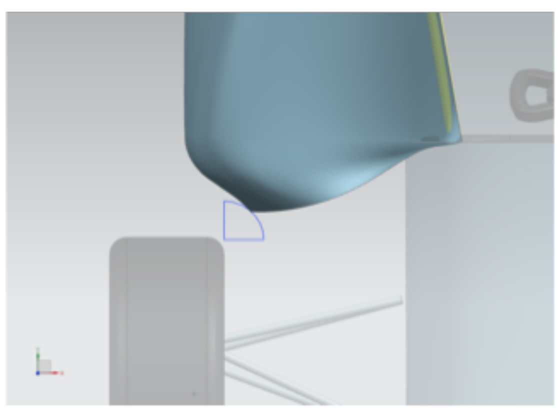


Figure 4: Passing rule T2.1.2

Design 2 was chosen because of its simpler mounting mechanism and compatibility with the cooling system. CFD analysis was performed on the sidepods with the nose cone in place, (see Appendix B). Figure 5 show the velocity field over the body. As expected the velocity at the front of the sidepods is zero but increases as it moves through them. This increase in airspeed will ensure appropriate airflow for the radiators. Further, the Coefficient of lift was estimated to be 0.179. This is almost half the value obtained last year of 0.33. This design also minimized the lift coefficient that was estimated to be 0.00628.

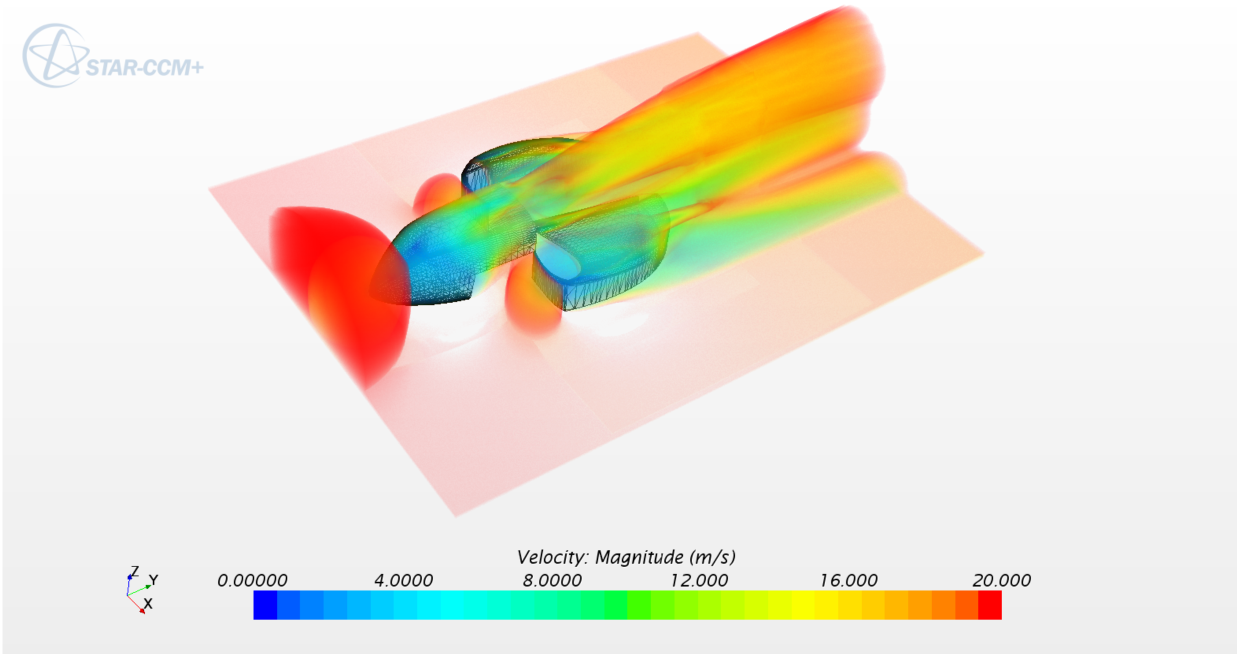


Figure 5: CFD analysis result, velocity field over nosecone and sidepods

Undertray

This year the aero division added an undertray to the aerodynamic elements of the car. The purpose of the undertray is to increase the downforce that pushes that car down so that the traction of the tires increases. This improves acceleration, braking and control of cars in turns.

Downforce is generated through the pressure difference between the top and bottom of the car. Lower pressure under the car will cause the airflow at higher pressure over the car to move towards the lower pressure section exerting a force on the car. To lower the pressure under the car we designed the undertray following Bernoulli's principle that states that an increase in the speed of a fluid occurs simultaneously with a decrease in pressure [1].

Similar, to airplane wings by having the length from the nosecone tip to the end of the car in the bottom be longer than at the top, by conservation of mass the flow under the car must accelerate to reach the back of the car the same time than the flow over the car. To increase the length under the car we used diffusers, to replicate the airfoil of an airplane wing. Channels in the undertray were created to direct the flow through the diffusers effectively. The channels constrict in the middle so that the by the venturi effect [2] the flow will further accelerate.

Using STAR-CCM+ software CFD analysis was conducted on the CAD model of the part. A 8 million cell mesh was used to obtain accurate estimations. Figure 6 depicts stream tracers of the flow under the car and clear shows pressure is up to 600 Pascal below ambient pressure as desired. Setting the inlet boundary conditions to 45 miles/hour we calculated a coefficient of lift, $C_l = -0.228$. Then using equation (1) we calculate the down force to be -109.8N which is approximately 25 lbf.

$$F_{down} = 0.5*A*C_l*\rho*v^2 \quad (1)$$

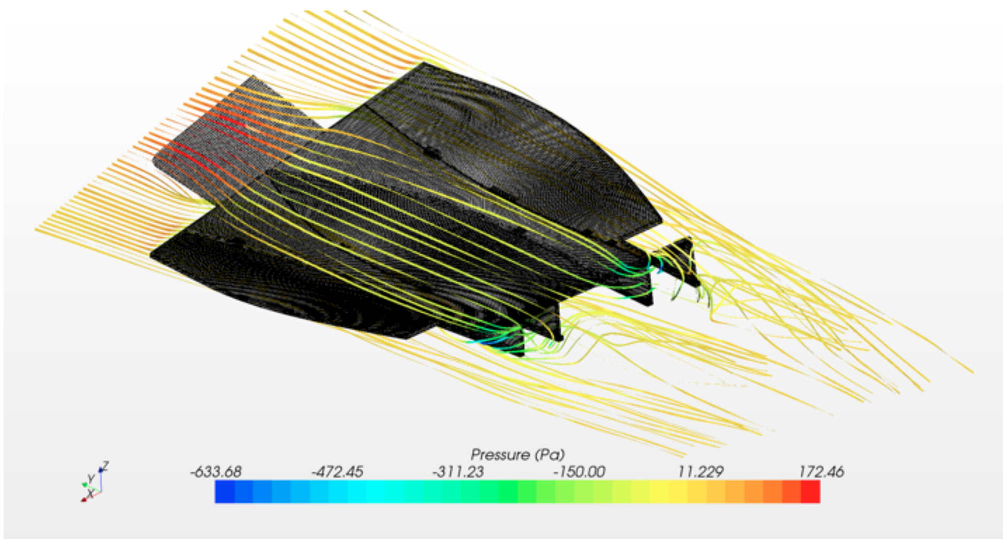


Figure 6: CFD analysis result, stream tracers through undertray

COOLING SYSTEM

In order to ensure that the components essential to the propulsion of the vehicle stay within operating temperatures, even during long endurance races, a cooling system has been implemented for these components. Individual cooling systems have been put in place for the combustion engine, batteries, and electric motors, all to ensure that their respective component remains within its operating specifications and does not overheat.

Batteries, engine, electric motors

The cooling subsystems for each of these components, the batteries, engine, and electric motors are different and accommodate the needs for that particular subsystem.

For the battery components, the cooling system is fairly straightforward. The batteries are contained within the side pods on the car, with generous amounts of airflow around them. This airflow is what is used to cool the batteries, with the side pods designed to allow for large amounts of airflow to keep the batteries cool and within their operating parameters.

For the combustion engine, cooling is more straightforward to what is found on a traditional vehicle. The combustion engine contains its own internal cooling pump, so all that is needed to cool it is a series of radiators, a coolant reservoir, and tubing connecting all cooling components. For the combustion engine, two separate small radiators on opposite sides of the car mounted near the side pods are utilized to ensure that the engine received enough cooling to keep it operational, even during endurance events.

For the electrical motors, the cooling system is similar to the combustion engine. It also makes use of a radiator, reservoir, and tubing to connect all components, but for this system, only one radiator is needed as the electrical motors generate less heat than the combustion engine. This system also makes use of a separate pump, as the electric motors do not include their own integrated pumps. However, these motors do have an integrated water jacket, with all water used for cooling directed through them to keep these electrical motors cool.

Radiators

Besides the cooling system for the batteries, which only incorporates airflow, the other cooling systems on the car utilize one or more radiators. These radiators allow for the heat contained within the coolant in the system to be quickly dissipated, keeping the system efficient and preventing the heat from merely being spread around, rather than dissipated.

With respect to the types of radiators, the combustion engine cooling system incorporates two separate Honda crf250r radiators that are located on opposite sides of the car, mounted near the side pods. This dual radiator design will provide plenty of cooling for the combustion motor, and keep it well within its operating temperatures. The electrical motor cooling system incorporates only one radiator, which is also located at the same position of one of the combustion engine radiators, except only on one side. This type of radiator is the same as those found on the combustion engine cooling subsystem, and is mounted directly behind one of the radiators for the combustion engine (see image) and will provide plenty of cooling for the electrical motor system to keep it within its operational range.

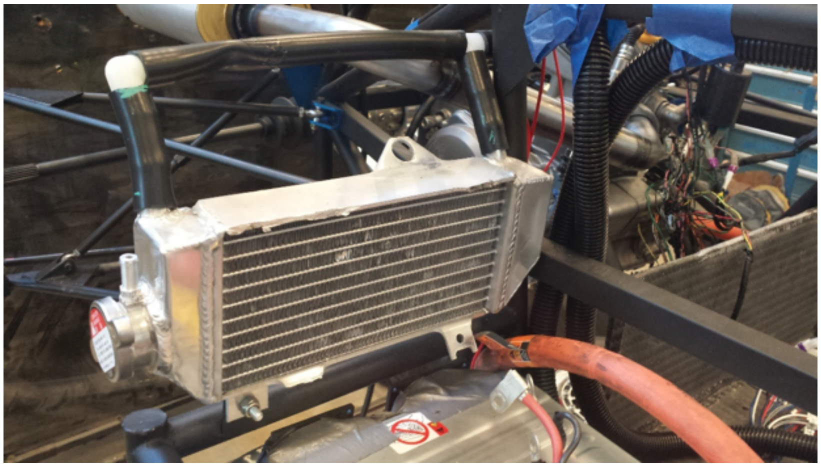


Figure 7: Right hand side radiator configuration (combustion engine only)

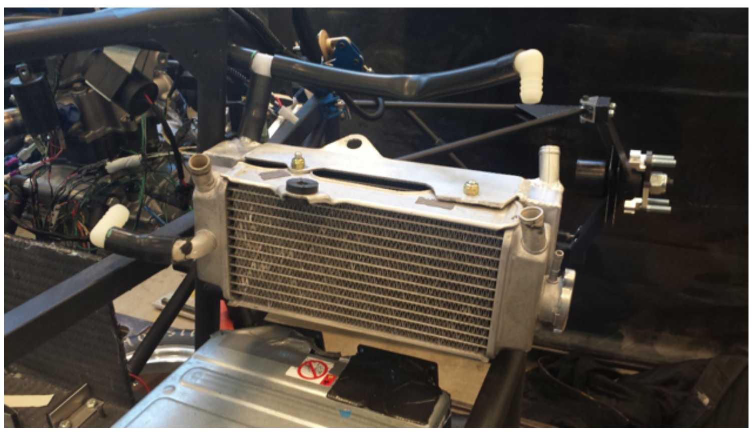


Figure 8: Left hand side radiator configuration (combustion engine and electrical motor)

Pump

Of the three cooling subsystems, only the electrical motor cooling subsystem requires an external pump. The batteries are air cooled, and do not require any pumps, and the combustion engine has an internal pump, so no extra external pumps are required for that subsystem.

For the cooling subsystem for the electrical motors, an external, dedicated pump is required to circulate the coolant throughout the system, as both electrical motors lack any type of coolant pump. In order to provide adequate circulation for this system without requiring large amounts of power from the electrical system, this system employs a small inline electric water pump. This pump was tested with a mock tubing system, and will provide sufficient flow to keep both electrical motors cool and within their operating range

Figure 9: Coolant pump used for electrical motor cooling subsystem

Routing
For both cooling subsystems that require tubing, all tubing is routed in a manner as to keep intrusions into other car systems at a minimum.

For the combustion engine cooling tubing, all tubing is contained towards the rear of the car and is relatively limited in length, as all components for that system, the engine, radiators, and the reservoir, are located very close to one another in the rear of the car.

The electrical motor cooling subsystem, however, requires much more complicated routing, as its components are spread across the entire car. The electric motors themselves are located at the front of the car on either side, and all other cooling components are located to the rear of the car. This means that tubing must be routed across the entire length of the car, and also on each side. To accomplish this, the tubing for this system is routed along both sides of the car along mainframe supports, and connected to each electric motor on its respective side. The tubing is then routed back to the rear of the car, where the pump, reservoir, and radiator are located. Because this system only utilizes one pump, reservoir and radiator, for two separate motors, the tubing also incorporates a t-splitter fixture near the rear of the car to split the coolant between the two circuits, one for each motor. This splitting ensure that both motors receive the same amount of cooling from the system, rather than cooling being routed in series through one motor and directly to the next, which would leave one motor constantly warmer and less efficient than the other.

HUMAN MACHINE INTERFACE

Steering Wheel
In October the team started prototyping many of the interior features of the car including the steering wheel, nosecone and the seat. The first project was to design the steering wheel. We were trying to create something different than last years' wheel.

Last year's wheel had a very oval shape, which was hard to manufacture and was 7 inches wide and 10 inches long. It also had 5 inches between the handles and the centerpiece of the wheel.

For one, we wanted to make a wheel with a smaller radius so that the driver can have more control over the wheel and thus the car. Using CAD, the first prototype was 5 inches in width and 12 inches long and had a large space/distance between the outside perimeter of the handles of the wheel and the main square piece.

My second design was similar to the first but the space was greatly reduced. We then thought it would be a good idea to make the main design a square shape. We had to adjust due to the new rule: “T6.5.5 The steering wheel must have a continuous perimeter that is near circular or near oval. The outer perimeter profile can have some straight sections, but no concave sections”

The final design of the steering wheel was 10 inches wide and 5 inches long. Another main reason why we had changes was to make sure that the model was easy to manufacture. The new CAD wheel design is shown in figure 10 and last years wheel is shown in figure 11.

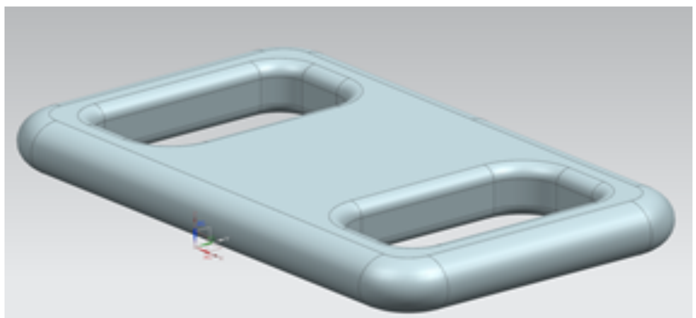


Figure 10: Steering wheel CAD model

Figure 11: 2013 steering wheel

Seat

We also created a CAD model for the seat, which was constructed from carbon fiber with foam core. We had to make sure our design allowed enough space for the autobox (max space autobox can occupy).

We also had to make sure our design aligned with rule T4.3.1. T4.3.1. stated that the “Lowest point of seat can be no lower than the bottom of the lower frame rails.”