CFD Modeling of Formula 600 Race Car

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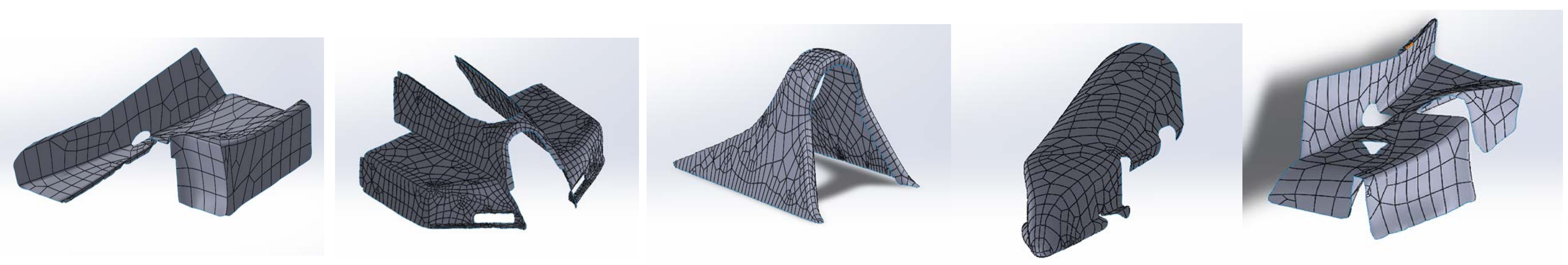
ABSTRACT

Auto racing is a competitive venture that has teams fighting to improve vehicle performance, allowing lap times to be decreased by fractions of a second. Red Pony Motorsports has asked for Wright State engineering students to help with the improvement of their Sports Car Club of America (SCCA) Formula 600 Car. The design team assigned to the task will work to create and test a new body kit for the vehicle with the goal of decreasing drag and increasing downforce. Improvement of these aerodynamic factors will help to improve lap times and increase the competitiveness of the vehicle.

BACKGROUND

The team was provided a chassis by Rich Jones from Red Pony Motorsports. The cars body was behind the times and required enhancements for better aerodynamics. The team was provided a Creality 3D scanner for which was used to scan the body panels but it came with a lot of challenges. Trying to get a 3D scan on the large panels took many tries to get working. Formula 600 is a specific class of open-wheel racing that falls under the Sports Car Club of America's Umbrella. They impose regulations such as the chassis design, engine specifications, and safety requirements, to ensure fair competition and safety standards.



DESIGN CONSIDERATIONS

- Body kit - front and side splitters, rear diffuser, and spoiler
- Decrease Drag
- Decrease Lift
- Improve Handling
- Aerodynamic Balancing
- Designed per SCCA Regulations
  - Minimum weight requirement of 900lbs
  - Hoosier Road Race Tires (18"x6.5")
  - Dimension range on each body panel
  - Open-wheel racing, nothing above the tires

ESTABLISHING A BASELINE

Using the Creality CR-Scan 3D scanner, an initial test model was created to run the first simulations. Initially, the entire car was scanned and attempted to import into both Solidworks and Autodesk Fusion 360. This proved to be difficult as the material hindered on the ability to properly scan the entire car. Thus, the body panels were scanned into Fusion 360 to create the initial body kit pieces. Both the model and the scanned body kit were then merged together, and constant were made to improve the accuracy. Once the body kit was fitted properly simulation started.

GOVERNING EQUATIONS

Conservation of Mass

- $\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u)}{\partial x} + \frac{\partial(\rho v)}{d\partial} + \frac{\partial(\rho w)}{\partial z} = 0$

Conservation of Momentum

- $\frac{\partial(\rho u)}{\partial t} + \frac{\partial(\rho u^2)}{\partial x} + \frac{\partial(\rho uv)}{\partial y} + \frac{\partial(\rho uw)}{\partial z} = -\frac{\partial p}{\partial x} + \frac{1}{Re_r}\left(\frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{xy}}{\partial y} + \frac{\partial \tau_{xz}}{\partial z}\right)$
- $\frac{\partial(\rho v)}{\partial t} + \frac{\partial(\rho uv)}{\partial x} + \frac{\partial(\rho v^2)}{\partial y} + \frac{\partial(\rho vw)}{\partial z} = -\frac{\partial p}{\partial y} + \frac{1}{Re_r}\left(\frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{yz}}{\partial z}\right)$
- $\frac{\partial(\rho w)}{\partial t} + \frac{\partial(\rho uw)}{\partial x} + \frac{\partial(\rho vw)}{\partial y} + \frac{\partial(\rho w^2)}{\partial z} = -\frac{\partial p}{\partial z} + \frac{1}{Re_r}\left(\frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \tau_{zz}}{\partial z}\right)$

Conservation of Energy

- $\frac{\partial(uE_T)}{\partial x} + \frac{\partial(vE_T)}{\partial y} + \frac{\partial(wE_T)}{\partial z} = -\frac{\partial(up)}{\partial x} - \frac{\partial(vp)}{\partial y} - \frac{\partial(wp)}{\partial z} + \frac{1}{Re_r}\left[\frac{\partial}{\partial x}(u\tau_{xx} + v\tau_{xy} + w\tau_{xz}) + \frac{\partial}{\partial y}(u\tau_{xy} + v\tau_{yy} + w\tau_{yz}) + \frac{\partial}{\partial z}(u\tau_{xz} + v\tau_{yz} + w\tau_{zz})\right]$

Coefficient of Lift

- $C_L = \frac{L}{\frac{1}{2}\rho u^2 S}$

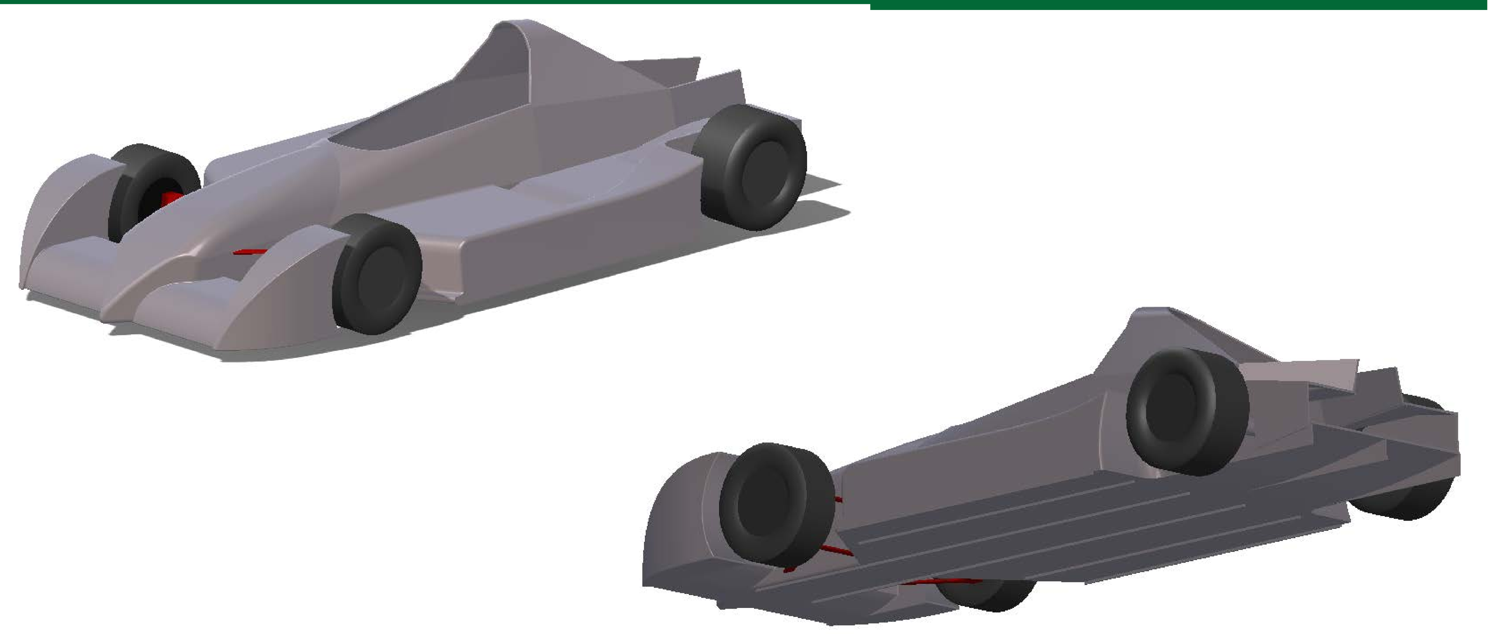
Coefficient of Drag

- $C_D = \frac{D}{\frac{1}{2}\rho u^2 S}$

Reynolds Number

- $Re = \frac{\rho V L}{\mu}$

IMPLEMENTED DESIGNS



Redesigned the nose and side panels for smoother air flow. The new front splitter now covers the front tires in hopes to minimize the drag generated by the exposed tire surface as well as redirecting the airflow around the vehicle to direct the airflow in a more controlled manner to reduce turbulence. By maintaining a sleek and streamlined profile with the side panels, the car can move more efficiently allowing for higher speeds without excessive power. The purpose of adding a rear diffuser is that it can generate greater down force on the rear, which enhances traction, cornering capability, and stability. The diffuser also further decreases the overall drag of the car.

ANALYSIS

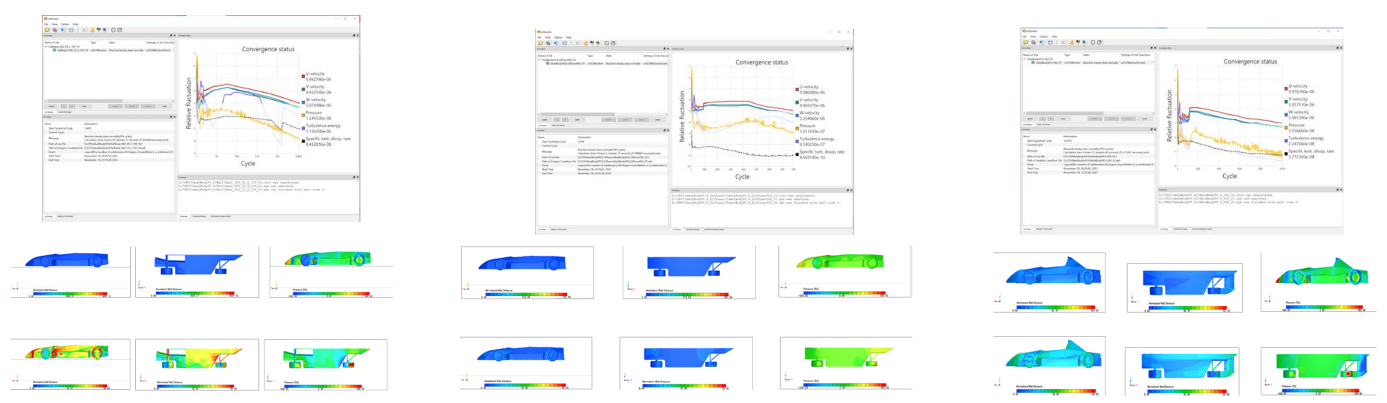
Analysis was conducted using the Cradle scFLOW software with the SST k-omega model. The SST k-omega model has been shown to provide accurate predictions for a wide range of turbulent flows, including boundary layers, free shear layers, and separated flows.

A control volume measuring 5m in width 5m in height and 20m long was used. A half model of the vehicle was placed 5m from the inlet of the control volume with the centerline against the symmetric edge of the volume. Octrees for each model were generated using a 0.002 mm size and an influence range of 2 along the vehicles surface and road. 10 prism layers were inserted at an expansion rate of 1.05 to better capture boundary layer conditions.

A speed of 80 mph (35.76 m/s) was chosen as the test velocity.

RESULTS

Below are the convergences of each vehicle design simulation. The y+ contour is shown for each along with the pressure gradient for the surface of each vehicle. Y+ values were found to be within acceptable limits for the SST k-omega turbulence model that was used.



Baseline from Scans — Baseline with Diffuser — Full Aero Kit Design

Model	Drag Reduction	Downforce Increase
Baseline with Diffuser	18.61%	21.43%
Full Aero Kit	20.97%	71.70%

CONCLUSION

The modeling of the Formula 600 race car successfully met all the design requirements regulated by the SCCA. Improvements on the baseline with the diffuser were by 18.61% for drag and 21.43% for downforce. With a full aero kit, the drag improved by 20.97% and the downforce by 71.70%. Improving the lift and drag coefficients will lead to better fuel efficiency, higher top speeds, stability and control, and less tire wear. All of these factors will give the driver a competitive advantage, where even small advantages can make a big impact.