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Main Body Aerodynamics

Michael Al-Badini
Virginia Commonwealth University

Christopher Buettner
Virginia Commonwealth University

Wesley Russell
Virginia Commonwealth University

Steven Summerville
Virginia Commonwealth University

Marcus Wardlow
Virginia Commonwealth University

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Team Members: Michael AL-Badani
Christopher Buettner • Wesley Russell
Steven Summerville • Marcus Wardlow

Faculty Advisor: Dr. Robert M. Sexton

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MECHANICAL AND NUCLEAR

Main Body Aerodynamics

VCU Formula SAE® RACE TEAM

CAPSTONE DESIGN EXPO 2015

Introduction

Aerodynamic components are critical for the enhancement of the performance of and aesthetics of many vehicles. With the emergence of more accessible and intuitive computational fluid analysis software, Formula SAE® prototypes evolve aerodynamically each year.

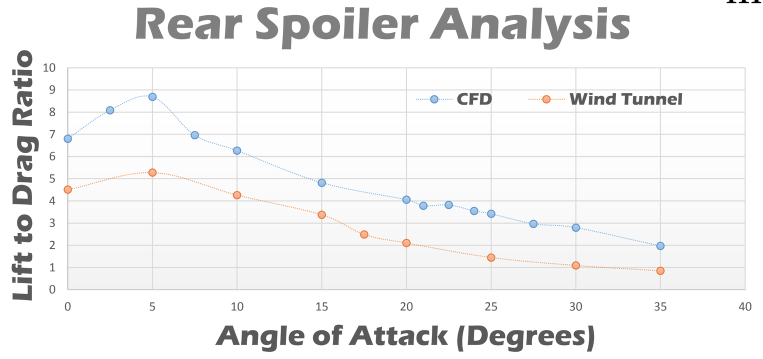
Objectives

- Induce downforce while reducing drag (obtaining a magnitude of lift to drag such that $\frac{L}{D} \geq 2$ for the entire car)
- Generate an optimized spoiler profile for front and rear of vehicle
- Manage airflow around body of car through use of a front spoiler and diffuser combination
- Build prototypes and retrofit wind tunnel for comparative testing results and for the benefit of future VCU FSAE teams

Conclusion

Overall, our design yielded a lift to drag ratio close to the desired value. We observed a strong correlation between the CFD and wind tunnel results for each component as well as collectively. However, the magnitude of lift to drag was proportionally lower in the wind tunnel experiment when compared to the computational results. This was due to factors only present in the physical experiment.

Rear Spoiler Analysis



Component	Magnitude of Lift to Drag
Main Body	0.0482
Rear Spoiler (18°)	3.079
Front Spoiler (15°)	2.463
Overall	1.863

Design

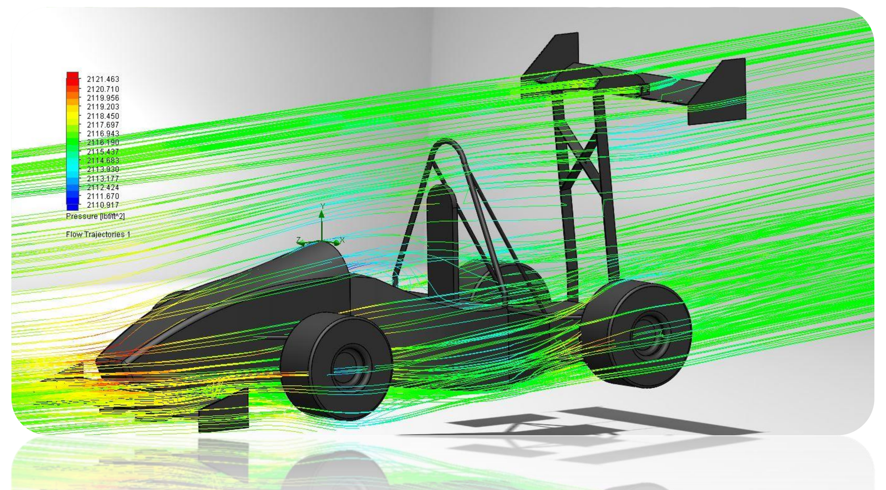
Mechanical Inputs

Parameter	Input Value
Wheelbase	64in
Front Bulkhead L x W x H	28.00 x 15.20 x 15.30in
Rear Bulkhead L x W x H	15.80 x 13.50 x 10in
Total Frame Length	95in
Overall Frame Width	37in
Overall Frame Height	48in
Suspension Spring Rate	1.119 lbf/in

Fluid Dynamics Inputs

Parameter	Input Value
Velocity Range	20 < V < 80mph
Spoiler Width	W ≤ 64in
Minimum Radii	R ≥ 0.060in
Properties of Air	
Temperature	68˚F
Pressure	14.696 lbf/in²
Density	3.612X10⁻⁵ lb/in³

In order to meet both SAE® regulations and prototype chassis restrictions the design incorporated 3 key components:



- Nose Cone and Side Panels
  - Air redirection around chassis
  - Drag reduction
- Rear Spoiler
  - Induce downforce to driving wheels
  - Mitigate effects of crosswinds/turbulence
- Front Spoiler
  - air redirection for Lower body
  - Balance forces induced by rear spoiler

Swan-Neck Mounting Mechanism

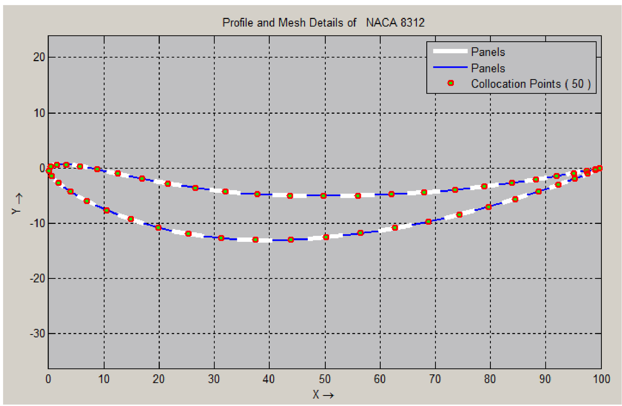
- As a recent development in automotive aerodynamic design, the "swan neck" style of spoiler mount helps to reduce both drag and flow separation at the points of attachment to the spoiler planform, when compared to traditional mounting methods.

Sources of Error

- Geometric deformation to spoilers in wind tunnel testing due to vibrations
- Achieving precise angle of attack on scaled model
- Distribution of incoming flow on computational model
- Simplified recreation of boundary conditions (e.g. rolling floor)

Prototyping & Testing

An optimized aerodynamic model was established utilizing a three pronged guide



Analytical Fluid Dynamics

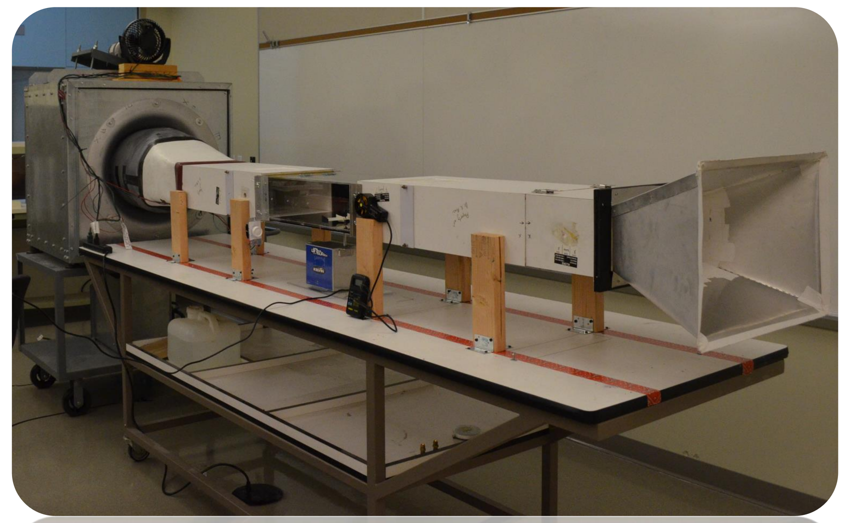
- Implemented more directly within the spoiler design process, the paneling method analytically determined a theoretically optimized, 2-D spoiler profile based on the desired lift to drag ratio. The nose cone and side panels were shaped initially by the physical restraints (attenuator and bulkhead) as well as the FSAE regulations.

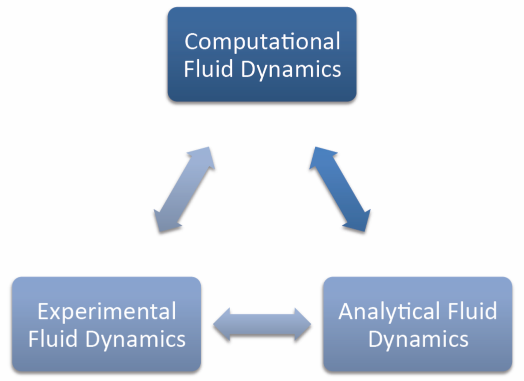
Computational Fluid Dynamics (CFD)

- With the ability to quickly alter geometries and obtain rapid analysis results, CFD allowed for numerous calculations of the lift forces and drag forces on the spoilers at different angles of attack and test their results prospectively.

Experimental Fluid Dynamics

- In order to provide an experimental comparison to our computationally generated designs, we performed a physical wind tunnel experiment. This utilized the Buckingham Pi Theorem by taking advantage of similarity conditions satisfied by the dimensionless coefficients of lift and drag.





$$\frac{C_{L,P}}{C_{L,M}} = 1 = \frac{\left(\frac{F_L}{\frac{1}{2}\rho v^2 A_s}\right)_P}{\left(\frac{F_L}{\frac{1}{2}\rho v^2 A_s}\right)_M}$$

In order to apply this theory, we implemented a scaling application of dimensionless analysis by performing our experiment at a 1/8 scale. Once a representative model was constructed, the wind tunnel was coupled with a sensor operating with a series of orthogonal strain rosettes to obtain experimental lift and drag forces.