Main Body Aerodynamics

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Introduction

Aerodynamic components are critical for the enhancement of the performance 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.

Mechanical Inputs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Input Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheelbase</td>
<td>48 in</td>
</tr>
<tr>
<td>Front Bulkhead L x W x H</td>
<td>28.0 x 15.20 x 15.30in</td>
</tr>
<tr>
<td>Rear Bulkhead L x W x H</td>
<td>15.0 x 13.50 x 10in</td>
</tr>
<tr>
<td>Total Frame Length</td>
<td>95in</td>
</tr>
<tr>
<td>Overall Frame Width</td>
<td>2ft</td>
</tr>
<tr>
<td>Overall Frame Height</td>
<td>48in</td>
</tr>
<tr>
<td>Suspension Spring Rate</td>
<td>1.119 M/in</td>
</tr>
</tbody>
</table>

Fluid Dynamics Inputs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Input Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity Range</td>
<td>20 to 125mph</td>
</tr>
<tr>
<td>Spoiler Volume</td>
<td>17 ft³</td>
</tr>
<tr>
<td>Minimum Radius</td>
<td>3.00 in</td>
</tr>
<tr>
<td>Minimum Radius</td>
<td>2.50 in</td>
</tr>
<tr>
<td>Temperature</td>
<td>60°F</td>
</tr>
<tr>
<td>Pressure</td>
<td>14.976 lb/in²</td>
</tr>
<tr>
<td>Density</td>
<td>0.052 lb/in³</td>
</tr>
</tbody>
</table>

Design

In order to meet both SAEe 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.

Prototyping & Testing

An optimized aerodynamic model was established utilizing a three pronged guide

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.

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)

Conclusion

In order to provide an experimental comparison to our computational results, 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.