Optimization of Aerodynamic Aids for Autocross Racing

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Introduction

Autocross is competitive, educational form of car racing. The emphasis is on driver skills and car design as participants navigate through a designated course. It is more of a race against the clock as drivers compete for the fastest time.

Cars can be designed for twp types of autocross racing: large track, high speed racing and short track navigation generally at lower speeds. Aerodynamic aids such as wings can help improve performance; providing better car control while maintaining speed around corners by increasing the downward force and reducing the drag on the car.

Project Description

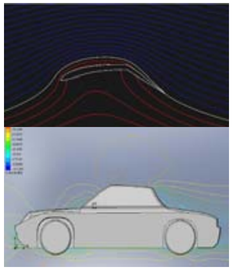
This project focuses on aerodynamic aids for Chris Cassidy's Porsche 914, emphasizing on the use a large rear wing design. In addition, the air flow characteristics in the engine compartment of the Porsche 914 is investigated for different configurations.

Project Objectives

- Research and model rear wings for a Porsche 914 for large and small track racing
- Determine optimal wing design for Chris Cassidy's Porsche
- Perform flow analysis on other Porsche 914 owners cars w/ wings
- Determine airflow characteristics through engine compartment for different configurations
- Verify models with experimental test on 18:1 model Porsche

Testing Methods

- **VisualFoil:** Determine angle of attack, drag and lift coefficients for different airfoil designs
- **SolidWorks**: Model Porsche 914 and with different wing designs
- **Cosmos FloWorks:** Air flow analysis on model cars and engine compartment
- **Water Channel:** Flow visualization test and comparing normal and drag coefficients



Wing Design Theory

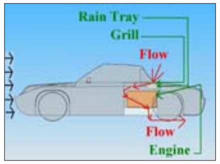
Wing design and efficiency is dependent on many variables. The aspect ratio (AR), defined as the span of the airfoil divided by chord length, is an important factor. A larger aspect ratio yields higher wing efficiency. The angle of attack (AOA) also affects wing design; a larger angle generates more downforce, providing better car control. However there is a trade-off as a larger angle also produces more drag.

$$D = \tfrac{1}{2} \times WS \times H \times AoA \times F \times \rho \times V^2$$

Where D is the downforce, WS is the wingspan, H is the height of the wing, F is the drag coefficient, ρ is the density of air, and V is the velocity of the car.

Engine Compartment Theory

Porsche 914 is powered by an air cooled engine. The engine sits behind the passenger seat and is cooled by a fan. This fan sucks the air from the engine bay and sends it out the bottom of the car



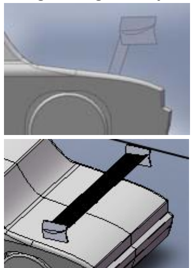
Theoretical airflow through engine bay

The air pressure along the car is different along its contour. Finding the coefficient of pressure (Cp) can assist in determining the airflow through the engine. A positive coefficient pertains to high pressure, a negative one corresponds to low pressure.

Modeling the Wings

The team obtained pictures and dimensions of wing designs from other Porsche 914 owners for analysis. Using this information the wings were modeled on SolidWorks and put on a standard model Porsche 914 model. The car with the wing design was then put through a FloWorks analysis.

Wing Designed by the Team



- E423 Airfoil Selected
  - C_L = 2.268
  - C_D = 0.029
- Chord length: 10"
- Wingspan: 70"
- Angle of Attack = 13°
- Angled end flaps

FloWorks Results

Wing Design 1

Speed	Drag Force (lbf)	Normal Force (lbf)	C_D	C_N
40	27.708	26.950	0.340	0.340
50	44.217	42.802	0.347	0.336
60	63.951	61.699	0.349	0.337
70	87.702	84.396	0.352	0.338
80	115.325	110.824	0.354	0.340

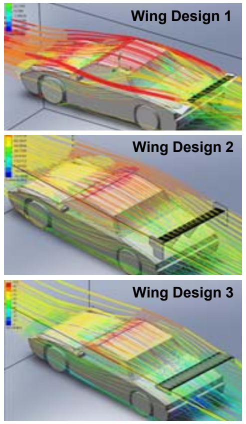
Wing Design 2

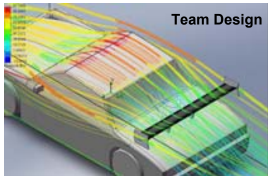
Speed	Drag Force (lbf)	Normal Force (lbf)	C_D	C_N
40	23.868	23.272	0.293	0.286
50	39.702	38.929	0.312	0.306
60	58.353	55.545	0.318	0.303
70	82.203	77.081	0.330	0.309
80	107.386	102.623	0.330	0.315

Wing Design 3

Speed	Drag Force (lbf)	Normal Force (lbf)	C_D	C_N
40	27.143	29.368	0.333	0.361
50	43.685	46.289	0.343	0.364
60	65.896	65.335	0.36	0.357
70	89.826	89.510	0.360	0.359
80	117.945	117.239	0.362	0.360

Comparison With Custom Wing at 50 mph





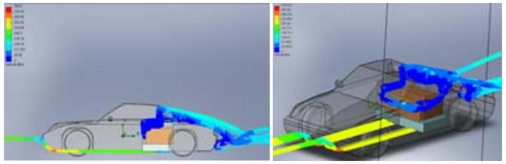
Common Observations

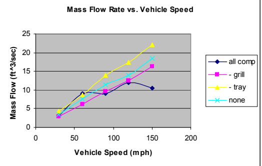
- Laminar flow before and after it passes car
- Vortex forms between roof and wing
- More red lines = more turbulence

Configurations	Drag Force (lbf)	Downforce (lbf)	C_D	C_N
No Rear Wing	35.272	35.722	0.277	0.281
1st Team Design	38.086	37.060	0.299	0.291
2nd Team Design	41.532	40.313	0.326	0.317
Final Design	44.043	56.425	0.346	0.443
Wing Design 1	39.702	38.929	0.312	0.306
Wing Design 2	43.685	46.289	0.343	0.364
Wing Design 3	44.217	42.802	0.347	0.336

Engine Analysis

Air flows up in Porsche 914 regardless of configuration



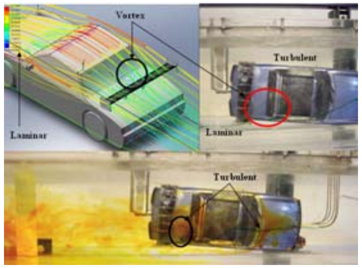


Four configurations were tested for engine:

1. All components
2. No rain tray
3. No Grill
4. No components

Experimental Results

Flow visualization and water channel experiments mostly consistent with FloWorks models.



Configuration	C_D	C_N	δC_D	δC_N
Water channel	0.434	0.358	0.000	0.000
FloWorks	0.331	0.321	0.103	0.037

Discussion of Results

The experimental data taken and documented confirmed the FloWorks models for the most part. The team also designed an effective wing, but it did not generate the most downforce, even when placed in the same locations as a couple of the designs. It was determined that the optimal location for the wing is the far back of car, at a height level to the roof. The flow is the most laminar at that position for any design.

The results of the engine compartment were consistent with the expected result. Air flowed up through the compartment for all configurations. However, the amount of air flow was reduced for configurations that had the rain tray.