SURG Proposal:
Investigating the Use of Aerodynamics to Improve Fuel Efficiency and Optimize Drag Coefficient on Formula SAE Racecars

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Abstract

Use of sophisticated aerodynamic systems in half-size Formula racecars to improve fuel economy and enhance performance has always been a characteristic among top tier Formula SAE teams, and this year Carnegie Mellon Racing will be introducing aerodynamics into their latest vehicle design. FSAE groups around the world are now aiming less for raw power in their design, and more for a light, aerodynamically efficient model which uses fluid dynamics to increase down force on the vehicle and thereby increase velocity without altering the motor. The Aerodynamics Division of CMU Racing wishes to increase efficient energy consumption of their latest vehicle design by a system of diffusers on the undertrain of the car. The aim of this study is to identify the effect of adding a diffuser and wings to a half-size formula racecar with respect to down force generated and increased fuel efficiency. Using Computational Fluid Dynamics (CFD) simulations, different compound materials will be tested to create an optimal aerodynamic system for CMU Racing's latest racecar design.

Research Question and Significance

Understanding air flow is essential for increasing performance in vehicles and helping us to improve their energy consumption. By manipulating airflow, fuel consumption and drag coefficients can be lowered. Our goal is to give our existing racecar design the ability to travel significantly faster and simultaneously use less fuel. We will perform multiple Computational Fluid Dynamics (CFD) simulations upon our Formula SAE racecar in order to investigate the effect of incorporating front and back wings, and a diffuser on fuel consumption, drag coefficients, and down force at a given velocity.

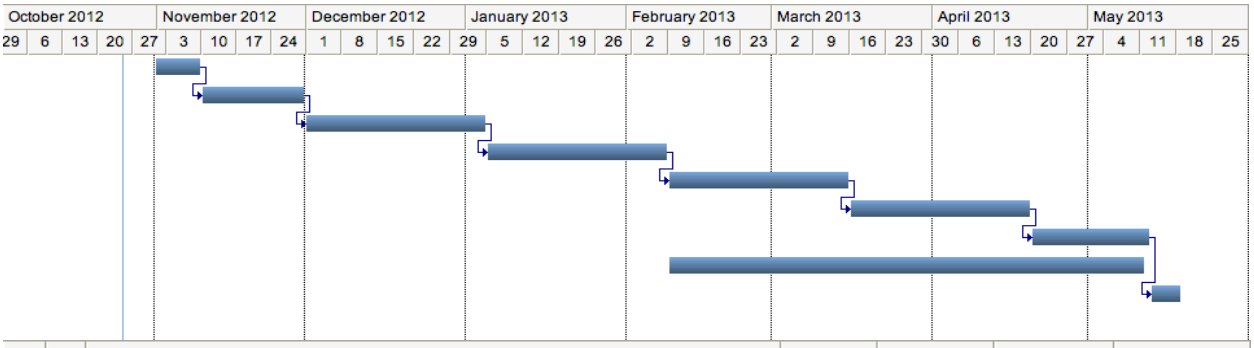
Based upon these simulations, a scale model of the diffuser and wings we are planning to fabricate will be created. The final manufacturing of the actual diffuser will involve testing with composite material manufacturing. A composite of Kevlar, Carbon Fiber, and Fiberglass will be used to fabricate a flexible undertrain for our open wheel racecar. Combined with a smaller and lighter racecar design, our diffuser will effectively generate down force and dramatically improve fuel economy at similar velocities.

Project Design and Feasibility

The component of aerodynamic equipment which will be incorporated in Carnegie Mellon Racing's newest racecar is the diffuser. The diffuser acts as an insulating tray on the undertrain of the car which directs airflow in uniform currents beneath the car and releases them behind the rear creating down force.

The initial step in this project involves digitally designing the diffuser digitally using SolidWorks. The design will consist of an air intake directly below the nose of the car, a channel below the driver, and a rear Simple Diffuser underneath the engine. Once the three-dimensional digital model has been created, airflow testing can be conducted. Using Computational Fluid Dynamics (CFD) a virtual wind tunnel will be used to analyze the effect of the added diffuser upon down force generated, and air flow with respect to the enhanced streamlined geometry of the racecar. CFD Analysis will also be used to investigate the degree to which an added back and front wing would generate down force working with the diffuser.

Next, a physical model of the diffuser will be manufactured on a 1:4 scale in order to investigate how the diffuser will be fastened to the chassis of the racecar, in order to integrate the diffuser effectively with the suspension system to keep the undertrain of the car as closely as safely possible to the ground for maximum generation of down force. The actual diffuser will be fabricated by milling a full scale foam body for the composite layup process. The full scale foam body will be gel coated for the mold layup, in which the fiberglass mold will be created. The final layup of carbon fiber for the diffuser will be made inside the fiberglass mold. The surface of the diffuser will be coated with Kevlar and fiberglass to allow for maximum ease in airflow. A timeline how when these goals will be accomplished is shown below:



		Name	Duration	Start	Finish	Predecessors
1		Study Previous Designs & Develop Designs	7d	10/29/2012	11/06/2012	
2		Model Design Using Old and New Chassis & CFD Data Testing	14d	11/07/2012	11/26/2012	1
3		3D Print 1:4 Scale Models and Testing Using Compressed Air	25d	11/27/2012	12/31/2012	2
4		Manufacture the Optimal Design using Balsa Wood, and Composite Coats	25d	01/01/2013	02/04/2013	3
5		Finish Manufacturing and Mount on the Car	25d	02/05/2013	03/11/2013	4
6		Integrate the Diffuser with Other Part Systems and Begin Testing	25d	03/12/2013	04/15/2013	5
7		Process Testing Data and Make Modifications	17d	04/16/2013	05/08/2013	6
8		Additional Design Review and Alternative Testing	66d	02/05/2013	05/07/2013	
9		Formula SAE Competition in Michigan	4d	05/09/2013	05/14/2013	7

Background

The idea to incorporate aerodynamics into Carnegie Mellon Racing's latest car stemmed from a trend observed in sophisticated Formula SAE racecars where increased usage of aerodynamics has been noted as a key performance enhancer. We have the experience of participating in past FSAE competitions, and discussing aerodynamic system designs with other Formula racing groups. Previous research performed by these groups has helped us understand that using a Simple Diffuser as a foundation for our aerodynamic system is the first step to developing state of the art, streamlined design. Below, Carnegie Mellon's previous design (on the left) is compared to Missouri University of Science and Technology's fully aerodynamic design (right).





The 4 main students involved in the aerodynamics project have professional experience regarding Computational Fluid Dynamics (CFD) and Computer Aided Design (CAD). All the students are mechanical engineering majors with a combined 5 years of experience designing and developing the Carnegie Mellon Formula SAE racecar. The group additionally has access to Formula SAE team alumni for guidance regarding incorporating aerodynamics competently into the car's other systems, as well as the experience of Mechanical Engineering Professor Ozdoganlar.

Feedback and Evaluation

Feedback regarding the development of the diffuser system will be provided by members of Carnegie Mellon Racing on a weekly basis at design reviews. This will involve presenting to our faculty advisor, Professor Ozdoganlar, who will be able to directly evaluate progress made with creating the diffuser, and provide feedback to the Undergraduate Research Office. The sophistication of our final product will be judged by design engineers at the 2013 Formula SAE Competition, and used to contribute to the overall ranking of Carnegie Mellon's FSAE team relative to other school's designs.

Dissemination of Knowledge

Feedback regarding the results of our aerodynamics study will be presented to the Carnegie Mellon community in a number of venues. The aerodynamics system on the CMU Racing's latest racecar will be evaluated by a panel of engineers at the 2013 Formula SAE competition. The judges' assessment will be processed and presented as a document, poster, and video to members of the Carnegie Mellon community at the 2013 Meeting of the Minds here at Carnegie Mellon. The write up of results of this project will be later submitted for consideration to an SAE journal, for the greater automotive engineering community.

Proposed Budget

The following materials are necessary for the fabrication of a diffuser. Any leftover materials will remain with the Carnegie Mellon Racing team and will be used in the production of the new car to compete in the 2013 competition. This and all other cars Carnegie Mellon Racing has built remain at the school in Carnegie Mellon Racing's garage to be used for testing new developments and educating new members. Any funding will be obtained from external sources.

Item	Description	Vendor	Part #	Unit Price	Quantity	Price
Carbon Fiber Fabric	5.7 ounce Twill Carbon Fiber Fabric	US Composites	FG-CFT5750	$31.50	15	$472.50
Epoxy Resin	635 Thin Epoxy System	US Composites	EPOX-635416	$275.00	1	$275.00
Fiberglass	50" Width 1.5oz Chopped Strand Fiberglass Mat	US Composites	FG-10550	$3.20	15	$48.00
Gelcoat	Orange Tooling Gelcoat	US Composites	GEL-OR100	$56.00	1	$56.00
Liquid Mold Release	PVA #10 Moldrelease	US Composites	REX-PVA105	$16.75	1	$16.75
Mold Release Wax	Partall #2 Paste Wax	US Composites	REX-270	$27.95	1	$27.95
Polyester Resin	Tooling Polyester Resin	US Composites	SM-404500	$153.00	1	$153.00
Kevlar	2x2 Twill weave 50" width	US Composites	FG-CK99050	$34.40/Yard	1	$34.40

Expected Total: $1083.60

Budget Request: $1000.00