Automobile Aerodynamics

How it Applies to LFEV Project

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***Abstract*— This document will provide a brief overview about how automobile aerodynamics are applied. This paper will explain the basic terms and formulas that would affect the LFEV.**

Keywords*— *lift, thrust, drag, downforce, automobile, aerodynamics

I. Introduction

This document will address the purpose, factors, and modeling components of automobile aerodynamics. There are multiple economic, social, and performance related reasons that cause automobile aerodynamics to be important. These both apply to commercial and racing vehicles. With the range of benefits the study of automobile aerodynamics is an important field of study. These concepts will be applied to the Lafayette College Formula Electric Vehicle in the following years so it is import to have a strong base understanding regarding the design choices that will be made.

II. Purpose

A. Reduce Drag

The first and most prominent purpose in studying automobile aerodynamics is to reduce the overall drag on a vehicle. By reducing the drag you need to produce less thrust to overcome the drag. Since less thrust is needed to move the car then what was used prior this increases the fuel consumption of a car. This provides an economic benefit because the car will have to refuel (or recharge in the case of an electric vehicle) and will last longer on a single charge.

B. Reduce Noise

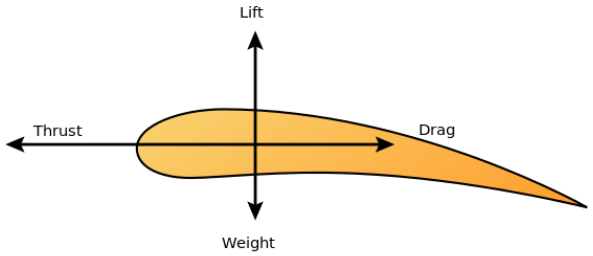
Another reason for the study of automobile aerodynamics is to reduce noise. In commercial vehicles the user comfort in the vehicle is paramount. There are certain comfort characteristics that a driver would look for in their car. One such characteristics is a very quiet car with little wind noise. To the consumer this is very luxurious and will add to the value of the car.

C. Prevent Aerodynamics Instability

The last characteristic that the paper that will be discusses has to do with automobile aerodynamics and its impact on aerodynamic instability and driving characteristics. This can be split into two different sections that relate towards each other. The first goal is to prevent lift in the car because we do not want the car to begin to be airborne the second is to create a downforce which will allow for tighter turns.

III. Basics of Aerodynamics

Aerodynamics is a branch of fluid dynamics that deals with how air interacts with objects. The first major push in the study of aerodynamics began around flight. By taking advantage of aerodynamics scientist hoped to achieve flight with materials that were heavier than air. This principle did not begin to be applied to automobiles until the 1920s. The four major forces in aerodynamics are as follows: thrust, lift, drag, and downforce (weight). The diagram shows a wing and how these four forces affect it.



These four forces will be described at greater length in the following sections. There are three Fundamental Concepts of Aerodynamics that will now be covered

A. Flow Classification

Depending on the classification of flow you are working in there are different considerations to be had with you equations you use to calculate the forces described above. There are four types of flow classification:

- Subsonic- Object in question is traveling at speeds much less than the speed of sound

- Transonic- Object in question is traveling at speeds both above and below the speed of sound
- Supersonic- Object in question is traveling at speeds higher than the speed of sound
- Hypersonic- Object in question is traveling at speeds much higher than the speed of sound

Our car and most cars fall into the subsonic flow classification. In this classification we can treat the flow as incompressible. This means we can treat the density of air constant for our purposes.

B. Continuum Assumption

The continuum assumption allows us to look at air in a macroscopic view. Instead of viewing the air as collisions of molecular particles we can view this as at a much larger scope. This allows us to treat the air as a continuous fluid. From this we can calculate density and flow velocity anywhere in the flow of air.

C. Laws of Conservation

The Laws of Conversation of mass, momentum, and energy are applied to the system we are testing. This allows us to solve the system. These laws ensure that mass, momentum and energy are not created nor destroyed within our system.

With these three fundamental concepts we can begin to analyze the difference elements of automobile aerodynamics.

IV. DRAG

Drag (also known as air resistance) is the force opposing the thrust of our vehicle. Drag is due to the air passing over the body of our object. The equation of the Drag Force on an object is equal to:

$$F_D = \frac{1}{2}\rho v^2 C_D A$$

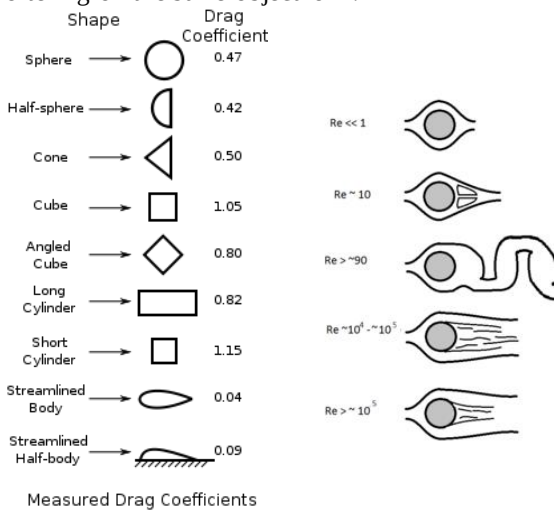
Where Fd is the drag force, rho is the air density, v is velocity of the object with respect to the air. Cd is the drag coefficient and A is the cross-sectional area of the object going into the wind. There are three types of drag that will influence drag and the above equation. They are as follows:

A. Parasitic

Parasitic drag is the type of drag most commonly thought about in layman's terms. It deals with the shape and body of the object and how it affects the overall drag. There are three influencing factor towards parasitic drag:

- Form- This deals with the overall shape of the body that is in question. To reduce form drag you want to keep you object sleek and streamlined. Having a smaller cross-sectional area will help to achieve this. The object should have a smooth longitudinal section which will prevent vortexing. This will avoid separation of the boundary layer
- Interference- When airflow from two sections of the body intersect in one area they must both speed up so as to not occupy the same space at the same time. Due to this the air will speed up and cause more drag on the areas intersecting.
- Skin-Friction- The material that is used for the object will have an effect on the objects drag. The friction from the air and the surface of the object will increase as the friction increases. The skin-friction will also increase as the amount of surface area of the object increases.

Using the form and interference drag along with the skin-friction we can uses these to calculate the drag coefficient of an object. Below shows two pictures. The first relates shape to the calculated drag coefficient (with constant skin-friction). The second shows how increasing the skin friction can cause vortexing on the same object form.



Measured Drag Coefficients

B. Wave

Wave drag is the drag generated by breaking the barrier of sound. Since our vehicle is subsonic we need not worry about Wave drag.

C. Lift-Induced

Lift-Induced drag comes from extra drag created by lifting the body up into flight. Since cars are not meant to fly this is not an important factor in our drag calculations.

From this a person should understand the basics of drag. We can then apply these basics to the vehicle that will be made for LFEV. By choosing material carefully and designing an aerodynamic vehicle we will be able to reduce the thrust needed to overcome the air drag.

V. LIFT AND DOWNFORCE

In addition to reducing drag on our vehicle we also want to reduce the lift, to prevent takeoff, and increase downforce, to provide better handling of the vehicle. Lift is caused when the object exerts a downward force on the air the air interns exterts

and upward force on the object. The lift force can be characterized by the equation:

$$L = \frac{1}{2}\rho v^2 C_L A$$

Where L is the lift force, rho is the air density, v is velocity of the object with respect to the air. Cl is the lift coefficient and A is the cross-sectional area of the object going into the wind. From the design of the car we want to reduce the lift force acting on the car.

In addition to this we care about the downforce exerted on the vehicle. Downforce is characterized by the following equation:

$$D = \frac{1}{2}\rho v^2 (WS) H F \alpha$$

Where D is the downforce on the car. Rho is the air density, v is velocity of the object with respect to the air. WS is the wingspan, H is the height, F is the lift coefficient and alpha is the angle of attack in the vehicle. To increase the downforce we can alter the shape of our car and add airfoils at various heights in order to increase the downforce.

VI. Moving Forward

These concepts will be important to the design of the LFEV in the upcoming years. With this paper students should be able to understand the basics of automobile aerodynamics and will be able to relate this to why vehicle design choices are made.

References

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