Aerodynamics of Car Spoilers

Daniel Cho
Mechanical Engineering
Penn State Hazleton

Tariq Alnuaimi
Mechanical Engineering
Penn State Hazleton

Ranee Perricone
Mechanical Engineering
Penn State Hazleton

Advisor Dr. David Starling, Associate Professor of Physics Penn State Hazleton

Abstract

Aerodynamics is the study of the movement of air and other gases around an object. Areas where aerodynamics is typically applied is in the designing of aircrafts and other vehicles. Air drag is also a related study in aerodynamics. Air drag, or air resistance, is a force that opposes an object moving in a certain direction through an air medium. Spoilers, or rear wings attached to race cars, are designed to maintain a down force on the car at a high speed. The spoiler's down force is created by the difference of pressure above and under the spoiler as a result of the angle at which the spoiler is set. Bernoulli's principle states there is an inverse relationship between the pressure and the speed of the fluid--in this case, air—that the object is moving in. Therefore, as fluid gains speed, the internal pressure of the fluid decreases.

Introduction

An F1 car has specific sections of aerodynamics on the body that helps maintain a down force on the car at a high speed. These aerodynamic sections will help the car to stay on track.

These sections include

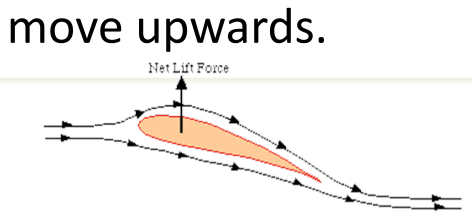
- Front: Spoilers or Canards
- Middle: Side skirts and side ducts
- Rear: Spoiler

Although there are many part that will help maintain the down force, the most important sections that relates to differential equations are the front and the rear spoilers.

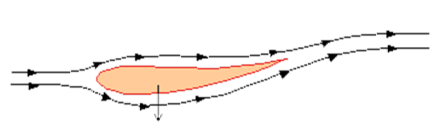
www.icars.sg/2009/4973/toyota-f1-selling-off-car-parts

Difference between lift and down force

Lift Force- In higher speeds, the air flow through a wing of an airplane will exert lower pressure at the top of the wing than to the bottom which will cause the wing to move upwards.



Down Force- The concept is similar to Lift Force but instead the air will have a greater flow underneath the spoiler instead of the top so this will cause the spoiler create a down force on the front and the rear of an F1 car.

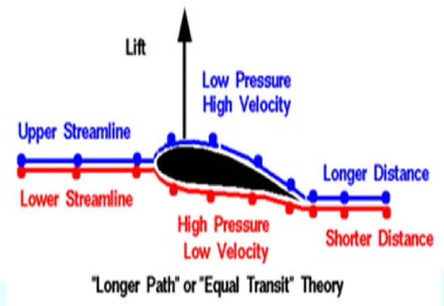


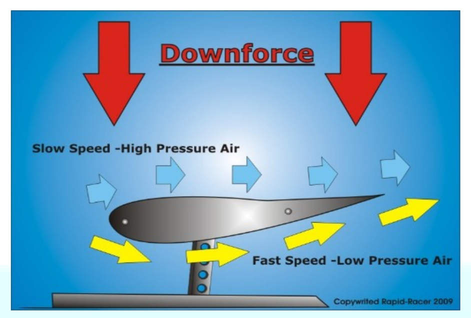
Airflow through the Spoilers

Difference between Airplane's wings and Car spoilers

- Airplanes are meant to fly so they need a lift force. The wings on the airplane are created so that it will project a force upwards
- Cars on the other hand need a force that will keep the car have as much grip as possible. In order for it to have grip, a car will have spoilers either on the front

www.rapid-racer.com/aerodynamics





Relation Between Bernoulli's and Aerodynamics

"Bernoulli's principle states that when an incompressible, smoothly flowing fluid gains speed, internal pressure in the fluid decreases, and vice versa. Ignoring changes in temperature and density, and energy dissipated by friction, Bernoulli's principle can be expressed in units of pressure" –Paul G. Hewitt (NSTA)

- 1/2 ρv^2 + ρgy + p = constant
- ρ - density of the fluid
- v - speed
- y - elevation
- p - internal pressure
- g – gravity

Application of Bernoulli's Equation

Bernoulli's equation applies to lift force but it also applies to down force as well.

$$m\frac{dv}{dt} = F$$

$$\rho A dx\frac{dv}{dt} = -A dp$$

$$\rho\frac{dv}{dt} = -\frac{dp}{dx}$$

$$\frac{dv}{dt} = \frac{dv}{dx}\frac{dx}{dt} = \frac{dv}{dx}v = \frac{d}{dx}\left(\frac{v^2}{2}\right)$$

$$\frac{d}{dx}\left(\rho\frac{v^2}{2} + p\right) = 0$$

$$\frac{v^2}{2} + \frac{p}{\rho} = C$$

Air Drag

This diagram represents the basic forces on a car spoiler. The force of gravity and the normal force cancel out so the force of the engine pulling against the air is important.

Solving the Differential Equation

$$ma_x = m\frac{dv}{dt} = F_E - F_{drag}$$

$$mdv = (F_E - F_{drag})dt$$

$$\frac{mdv}{F_E - F_{drag}} = dt$$

$$\frac{mdv}{F_E - kv} = dt$$

$$\int_{v_i}^{v_f}\frac{mdv}{F_E - kv} = \int_{t_i}^{t_f}dt \quad \begin{pmatrix} u = F_E - kv \\ du = -kdv \end{pmatrix}$$

$$-\frac{m}{k}\int_{u_i}^{u_f}\frac{du}{u} = \int_{t_i}^{t_f}dt$$

$$-\frac{m}{k}ln(F_E - kv_f) - \ln(F_E - kv_i) = (t_f - t_i)$$

$$-\frac{m}{k}\ln\left(\frac{F_E - kv_f}{F_E - kv_i}\right) = (t_f - t_i)$$

$$\frac{F_E - kv_f}{F_E - kv_i} = e^{-\frac{k}{m}(t_f - t_i)}$$

$$F_E - kv_f = \frac{e^{-\frac{k}{m}(t_f - t_i)}}{F_E - kv_i}$$

$$kv_f = -\frac{e^{-\frac{k}{m}(t_f - t_i)}}{F_E - kv_i} + F_E$$

$$v_f = -\frac{e^{-\frac{k}{m}(t_f - t_i)}}{k(F_E - kv_i)} + F_E$$

When $v_i = 0$

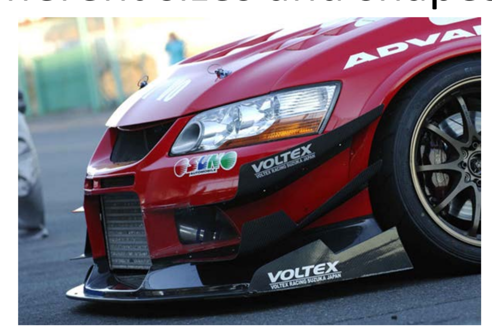
$$v_f = -\frac{e^{-\frac{k}{m}(t_f - t_i)} + kF_E^2}{kF_E}$$

Solution

$$v = -\frac{e^{-\frac{kt}{m}} + kF_E^2}{kF_E}$$

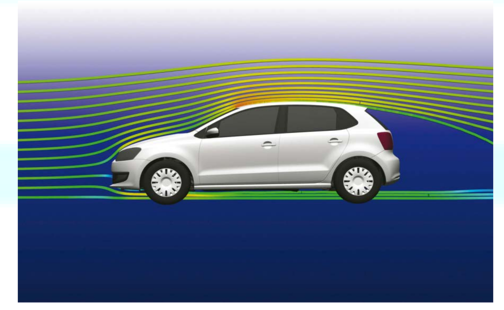
Application to Racing cars

Everything that's been said on the F1 car also applies to racing cars. However, they cannot have front spoilers like a F1 car they have front canards to take it's place. The spoilers attached to the rear of cars come in different sizes and shapes.



Everyday applications

Car Spoilers don't just apply to racing. Smaller spoilers, ones that you may not even notice. These help with the aerodynamics of any vehicle and save you money by giving your vehicle better fuel efficiency.



Conclusion

Spoilers are attached to most vehicles and help with traction in corners and keeping the vehicles from rolling or going out of control in some way at high speeds. The down force that spoilers create is opposite of the lift force that wings on planes create. Less noticeable spoilers save everyone money on gas. Spoilers are not just for show.

Resources

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