



An Introduction to Aerodynamics

James Smith

Andrew Noble

Wales Institute for Science & Art

BEng Motorsport Engineering with Foundation Year

Introduction

During the 60s when cars would race down the straights at Le Mans, they would be reaching up to 235MPH. At that speed, the lift they produce meant they could have taken off at any moment. The Mercedes CLR did just that during the 1999 Le Mans GP. That was 40 years after aerodynamic devices were first introduced. Even with the understanding of lift and drag the car was still unstable at high speeds. Developing and innovating new aerodynamic devices that ensure the car doesn't become a life-threatening piece of machinery is vital. That means understanding laminar and turbulent flow, Bernoulli's principle and the characteristics of air. CFD and other testing methods help make this a reality.

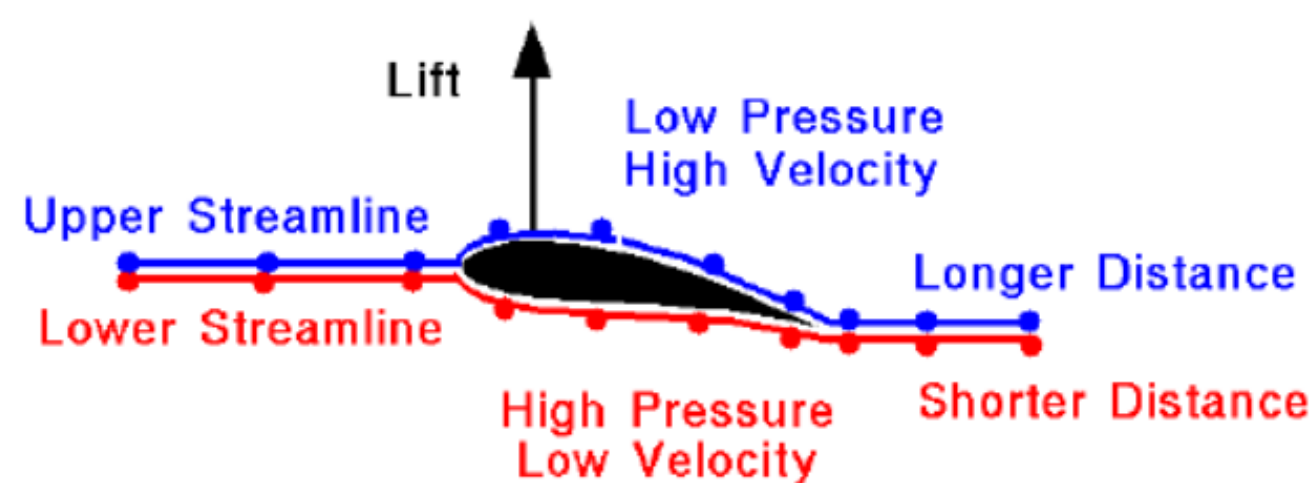


Figure 1 – “Incorrect Lift Theory”

Lift / Wing Theory

The low pressure on the roof of the vehicle creates lift. This is exaggerated at high speeds. In figure 1 is an airplane wing. “According to the incorrect lift theory, the air on the top surface must travel faster (to meet the molecules at the trailing edge) because the upper surface is longer than the bottom. (Benson, n.d.)”

Bernoulli's principle does state that when there is low pressure the speed must increase however, this is not because of the length of the upper surface. The molecules on the upper surface wouldn't meet the molecules at the trailing edge like the image suggests. On the trailing edge there will be turbulence meeting the laminar flow from the bottom surface. This is known as wake. A trail of disturbed air. After the laminar flow has separated from the upper surface a boundary layer is created that allows the laminar to keep flowing.

Bernoulli's Principle

“Bernoulli's principle says that the faster a fluid (air) flows the lower the pressure. (Johnson, 2022)” This is demonstrated in venturi tunnels that were used in f1 during the 70s & 80s. Pressure on a vehicle is at its highest around the front bumper. This is because the air has slowed down significantly. It then speeds up again over the top of the vehicle and creates low pressure

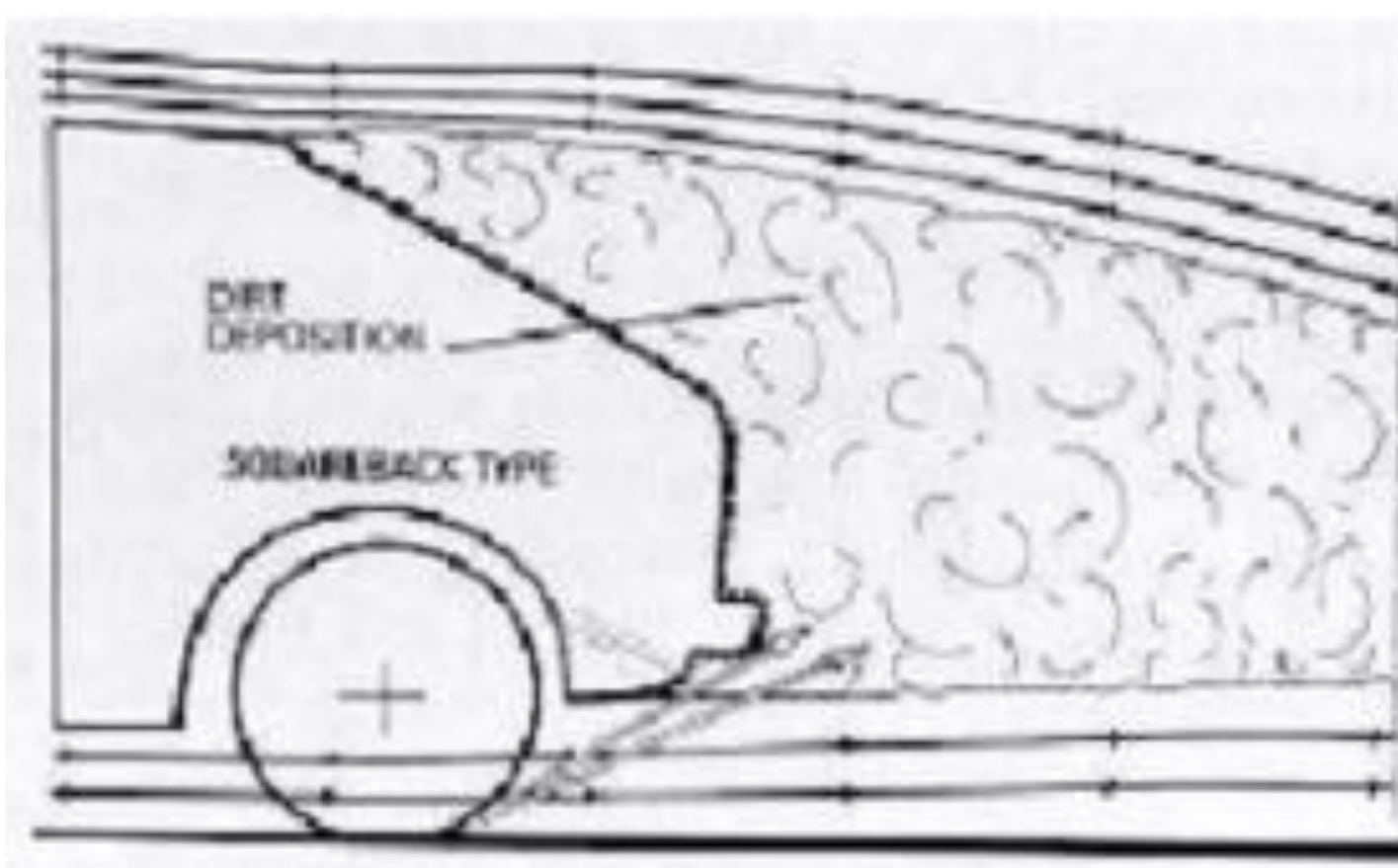


Figure 2 – “separation”

Characteristics of Air

When the geometry change is to steep the air will separate from the object it is following. Turbulent air now occupies the space that the laminar flow has left. A boundary layer is formed between the turbulent flow and the laminar flow. This area of turbulent air increase drag. It is important to note that the characteristics of air can be divided into two categories. Turbulent and laminar. Turbulent flow is unpredictable and constantly changing. Laminar flow is smooth, predictable and streamlined. Both have advantages and disadvantages. Then there are vortices. “A swirling mass of fluid or air that revolves around an axis (“VORTEX | English meaning - Cambridge Dictionary,” n.d.)”.

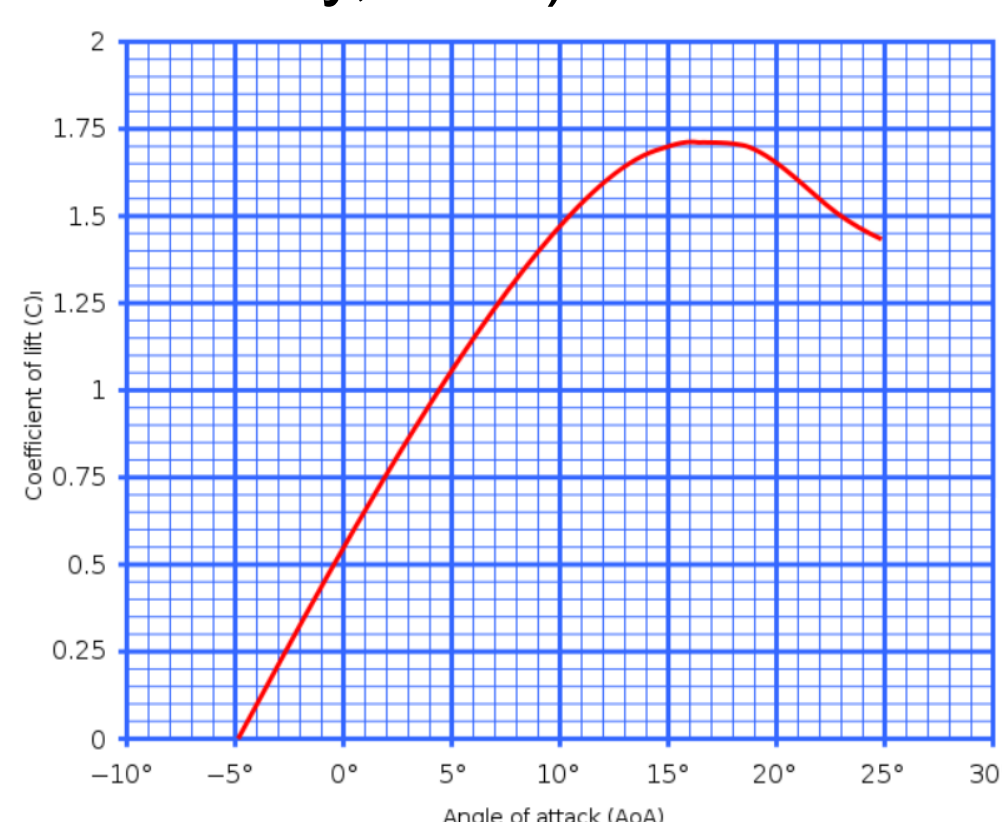


Figure 3 – “Angle of attack”

This graph shows the angle of attack possible before the wing stalls. (Alicja, 2013)

Aerodynamic devices

To prevent unwanted lift at high speeds engineers have developed aerodynamic devices. Wings work to create low pressure on the top of an object, like how a vehicle creates lift at high speed. This design is then flipped upside down to create a downward force. Ground effect (venturi tunnels) creates this downwards force by squeezing the air as it passes under the vehicle. The air speeds up and creates low pressure that sucks the vehicle to the ground. Vortices are now more commonly used instead of skirts to seal the floor of the vehicle. These vortices run along the side the edge of the floor, utilizing turbulent and laminar flow.



Figure 4 – “Skirting The Issue”

In NASCAR teams would bend the side skirts near the rear tiers to create a small triangular shaped flare. They only did this on the right because it helps with cornering. Since NASCAR race on ovals, there is no need to increase the downforce on the left side.. It was eventually banned.

References

- Johnson, L., 2022. Bernoulli's Principle: Definition, Equation, Examples [WWW Document]. Sciencing. URL <https://www.sciencing.com/bernoullis-principle-definition-equation-examples-13723388/> (accessed 4.23.25).
- Benson, T., n.d. Incorrect Lift Theory [WWW Document]. URL <https://www.grc.nasa.gov/WWW/k-12/VirtualAero/BottleRocket/airplane/wrong1.html> (accessed 4.24.25).
- VORTEX | English meaning - Cambridge Dictionary [WWW Document], n.d. URL https://dictionary.cambridge.org/dictionary/english/vortex#google_vignette (accessed 4.26.25).
- Alicja, 2013. Stalls and angle of attack: a very important relationship - FlyTime.ca [WWW Document]. URL <https://www.flytime.ca/stalls-angle-of-attack-important-relationship> (accessed 4.27.25).