



Evolution of Aerodynamic Principles

Joshua Billings-Evans

Tim Tudor

Wales Institute for Science & Art

BEng Automotive Engineering

Introduction

Aerodynamics is a topic of interest due to its constant and very fast development throughout the lifecycle of cars. Most prominent in the highly competitive field of disciplines such as F1 and other various open and closed wheel racing. There is then also a crossover to where it is applicable to road vehicles, often stemming from the R&D done in these high stress racing vehicles. Manufacturers such as BMW, Mercedes and so forth use the data and experience from these to then filter down into their road cars, whether it be for better performance for the sports or super car models but also for the efficiency benefits on the broader spectrum.

Development Path

There's the basic understanding of what forces effect a car under motion from an aerodynamic perspective:

- Lift generated by Aero
- Drag generated by Aero

The Term lift is a little misleading as the Aero, typically either a front wing or Rear wing, generates downforce which in essence is negative lift, pushing the vehicle into the ground.

The same surfaces forcing the car into the ground are the same acting as a large air trap pulling the car back.

As Racing became a larger spectacle, The competitive nature of the sport drove the early development of Large wings and even ground effects later to gain the advantage in cornering as they were able to achieve higher levels of grip. (figure – 1)

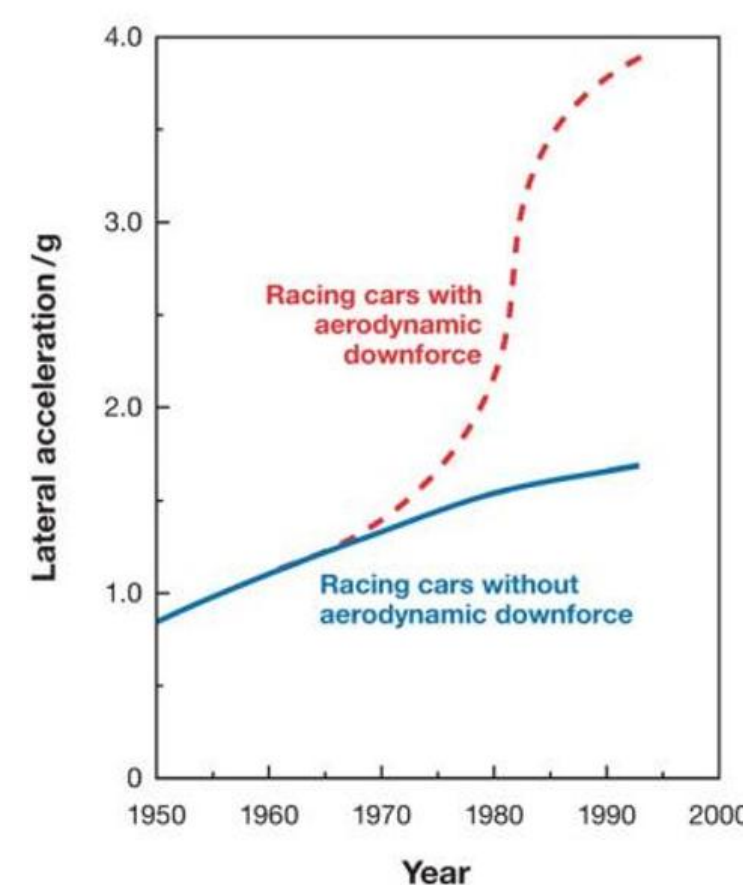


Figure 1 – Gains in grip over the passing Years as cars evolve (Tim Tudor, 2020)

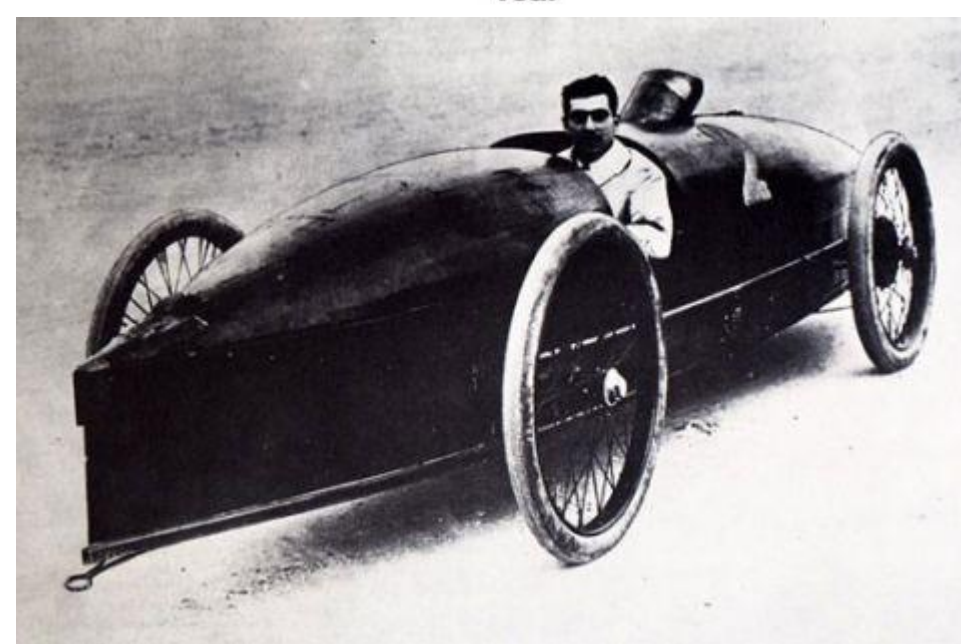
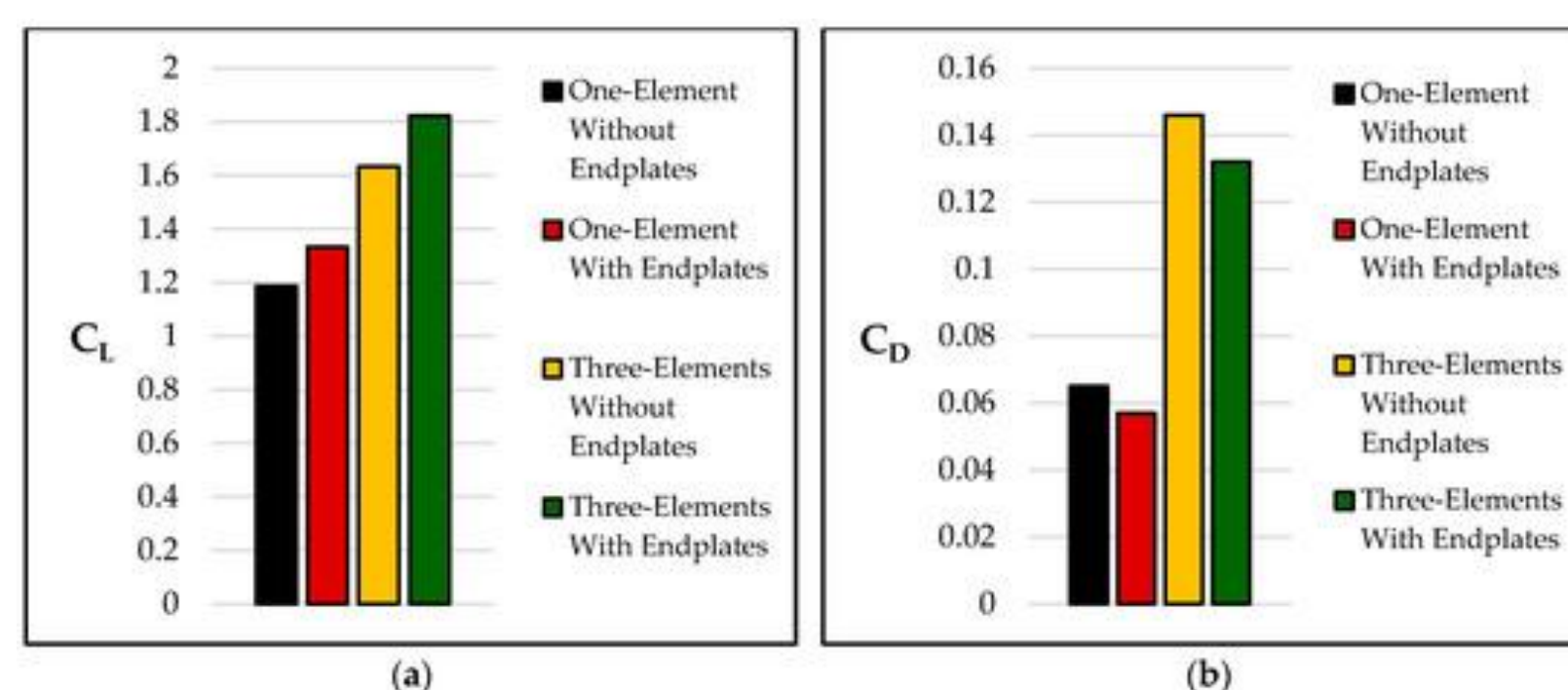


Figure 2 – (Niedermeyer, n.d.) Above is an early design of a race car. As you can see the understanding of Aerodynamics at this point in racing was to make the vehicle as 'slippery' through the air as possible to attain high speeds.



Figure 3 – [image source: formula1.com] Modern example of recent F1 Aerodynamics. A noticeable difference as there is more of an emphasise on maintaining corner speeds whilst also increasing stability at higher speeds.



Graph 1 - (Castro and Rana, 2020) The above Graphs show the effect on both the lift and drag coefficients.

Bernoulli's Principle

The discovery of Bernoulli's Principle:

$$\frac{1}{2}\rho V^2 + P + \rho gz = \text{constant}$$

Equation 1 - (Sciencedirect.com, 2018)

Allowed us to understand how to maximise the efficiency of the aerodynamics packages being introduced and tested on vehicles.

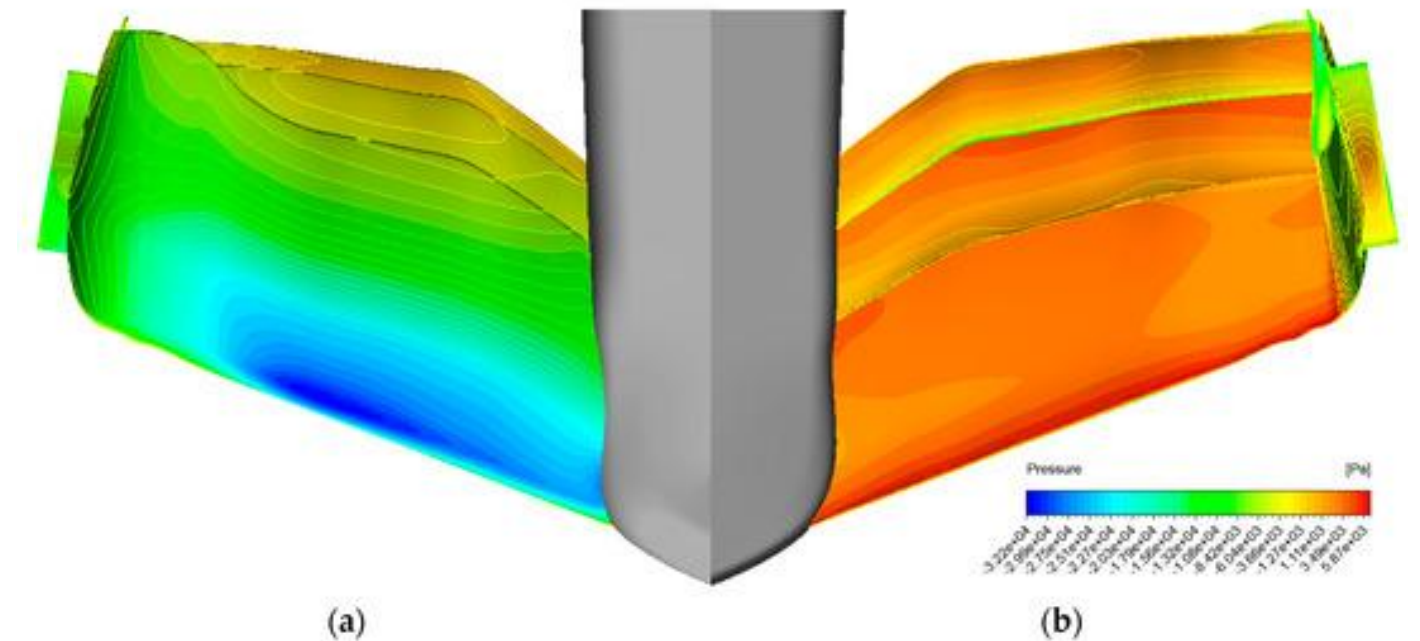


Figure 4 - (Castro and Rana, 2020) Pressure affecting the front wing of a formula car.

Effect of Lift

As the vehicles speed increase the pressure values change thus affecting the lift generated.

The concept of slapping a large foil on the back in the form of a wing seems counterproductive, however inverting it so that the shape causes the air above the wing slow whilst increasing the speed of the air below creates a pressure imbalance. This imbalance causes the effect of a venturi tunnel, which sucks the face toward the area of low pressure.

The same principle is in effect when talking about ground effect. The air is squeezed, thus its velocity increases causing a very low pressure under the car once again by design pulling it to the floor to increase grip.

Acknowledgements

I would like to Thank Tim Tudor for his technical insight and also the resources provided. As well as thank Andrew Harrison for supervising this work.

References

- Niedermeyer, P. (n.d.). *Automotive History: An Illustrated History Of Automotive Aerodynamics – Part 1 (1899 – 1939)*.
- Castro, X. and Rana, Z.A. (2020). Aerodynamic and Structural Design of a 2022 Formula One Front Wing Assembly. *Fluids*, [online] 5(4), p.237.
- Sciencedirect.com. (2018). *Bernoulli Equation - an overview | ScienceDirect Topics*. [online] Available at: <https://www.sciencedirect.com/topics/engineering/bernoulli-equation>.