



An Introduction to Vehicle Aerodynamics

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What is Aerodynamics?

Aerodynamics is how air interacts with an object and how it flows when moving at varying speeds effecting the motion of a vehicle.

To control the vehicle effectively you need to control the airs velocity and pressure which always acts perpendicular to the surface on which it acts.

The Majority of the time 6 forces are always acting on a moving vehicle:

- Reaction Force
- Drag Force
- Rolling Resistance
- Aerodynamic Lift
- Thrust
- Force gravity

Bernoulli’s Theorem

Bernoulli’s theorem is the relation among the pressure velocity and elevation in a moving fluid (liquid or gas), the compressibility and viscosity resulting in a lower pressure the higher the speed (Britannica Editors, 2026).

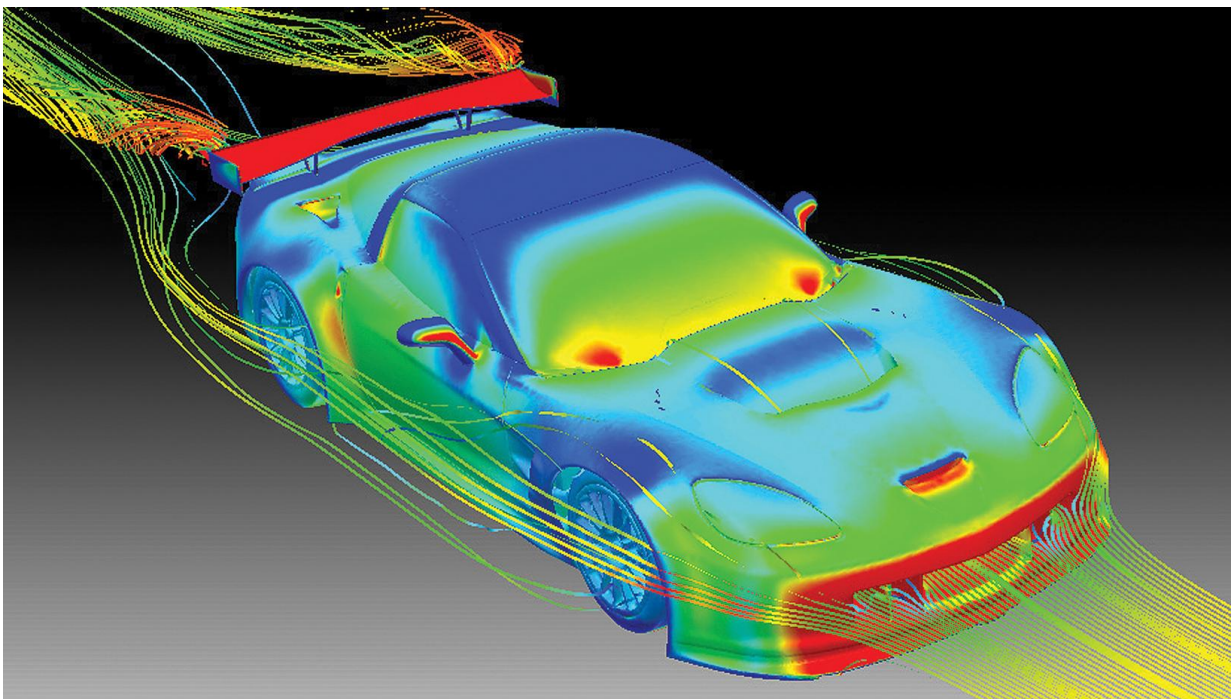


MCR Sport 2000 Car in wind tunnel

Pressure

High Velocity = Low Pressure
Low Velocity = High Pressure

Pressure has no direction as it is a scalar quantity.



This diagram shows the flow of air around this car with a colour visual of red indication high drag (Grassroots Motorsports, 2023).

Drag

Drag is a resistive aerodynamic force which opposes motion made from three components:

- Frontal pressure (Air pressure increases with a non streamlined body compared to a streamlined one)
- Rear Vacuum (Air cannot fill vacuum behind rear of car)
- Skin Friction (Friction generated by a vehicles surface)(John L. Monteith and Mike H. Unsworth 2013)

Lift

Lift happens when a vertical force acts upon the body of a vehicle, reducing or increasing the load on the tyres.

For lift, you want higher pressure below the object and lower pressure above the object.

For negative life you want a lower pressure below and a higher above.

When controlling the air around the car it's important to minimise turbulence (random chaotic motion) which would increase drag, this happens when inertial forces overwhelm viscous forces.

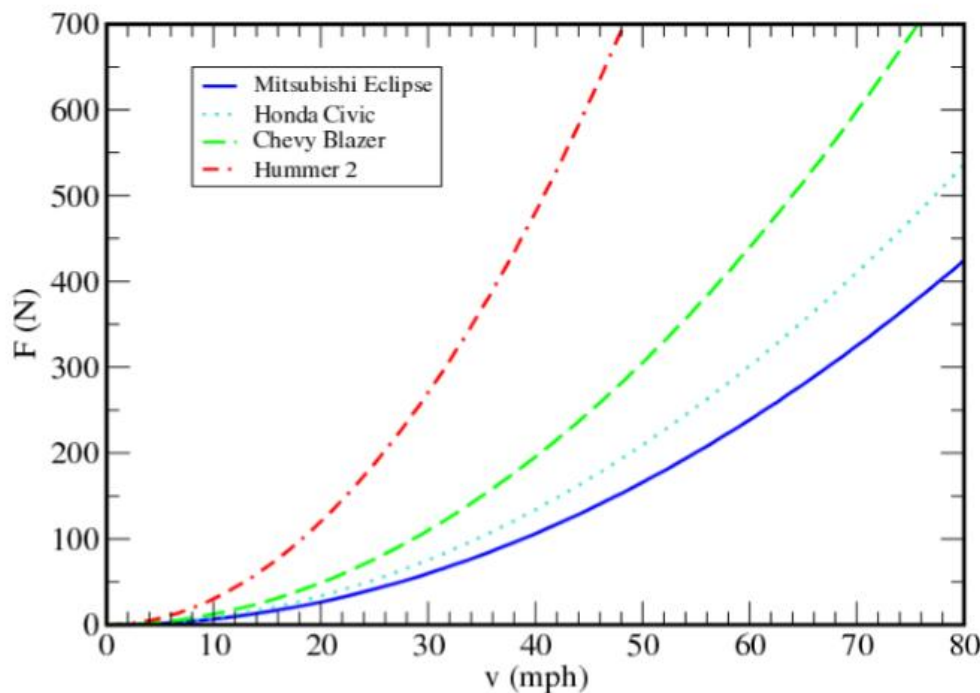
Key Equations for Aerodynamics:

$$P = \frac{Force}{Area} = \frac{F}{A} = \frac{F \cdot d}{A \cdot d} = \frac{W}{V} = \frac{Energy}{Volume}$$

$Drag\ Force = C_D \times 1/2 \rho V^2 \times A$

$Lift\ Force = C_L \times 1/2 \rho V^2 \times A$

This table shows the correlation between speed, and the force aero resistance is producing.



This table shows different drag coefficients for a variety of vehicles.

Modern Car like Toyota Prius	0.26
Sports Car, sloping rear	0.2 - 0.3
Common Car like Opel Vectra (class C)	0.29
Saloon Car, stepped rear	0.4 - 0.5
Convertible, open top	0.6 - 0.7
Bus	0.6 - 0.8
Old Car like a T-ford	0.7 - 0.9
Tractor Trailed Truck	0.96
Truck	0.8 - 1.0

Separation

When changing the aerodynamic, sometimes it cannot always be controlled effectively. For example, when the airflow cannot reach parts of a vehicle this is due to an obtrusive body shape that the air cannot hold on to. This can differ on the vehicle’s changing velocity.

This creates turbulence and is **NOT** good as it creates a total loss of lift and drag.

Conclusion

Its clear aerodynamics isn’t simple just from the basic principles however how it can be manipulated around vehicles to achieve speed especially in a motorsport context is extremely impressive.

References

Grassroot Motorsports. “Simple Talk on the Complex Subject of Aerodynamics.” *Grassrootsmotorsports.com*, 16 June 2023, grassrootsmotorsports.com/articles/wing-it-simple-talk-complex-subject-aerodynamics/.

Britannica. “Bernoulli’s Theorem | Definition, Derivation, & Facts.” *Encyclopædia Britannica*, 4 Nov. 2022, www.britannica.com/science/Bernoullis-theorem.

H. Unsworth, Mike, and John L. Monteith. “Skin Friction - an Overview | ScienceDirect Topics.” *Www.sciencedirect.com*, 2013, www.sciencedirect.com/topics/earth-and-planetary-sciences/skin-friction.