TOTALSIM US

Racecar Aerodynamics

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TotalSim

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Agenda

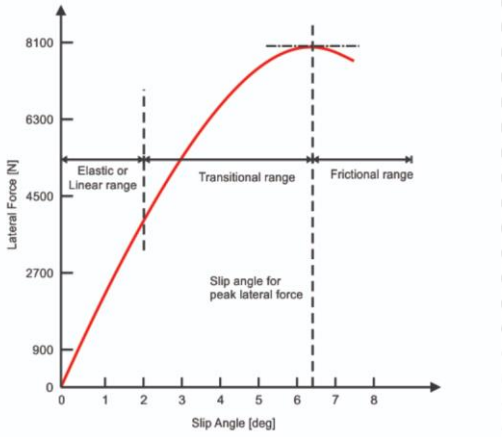
- Fundamentals
- Devices
  - Spoilers
  - Wings
  - Diffusers
  - Splitters
  - Flicks and Diveplanes
  - Vortex Generating Devices
  - Sideforce Generation
- Map Sensitivity
- Cooling
- Intakes
- Wakes and Drafting
- High Speed Cars
- Testing Methods

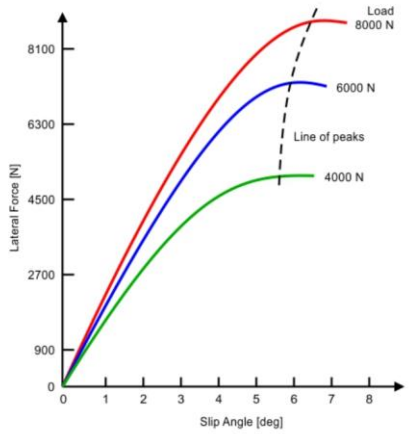
About Me

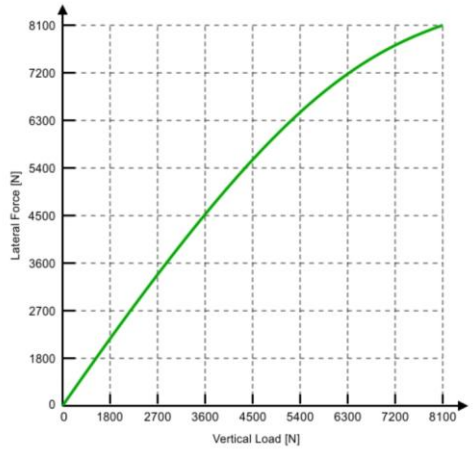
- Naethan Eagles
- 1990-1993 City University, London, UK BEng Aeronautical Engineering
- 1993-1996 BSRIA
- 1996-1998 Rolls Royce Aerospace
- 1998-2001 Reynard Motorsports
  - BAR F1, Reynard Champcar, Penske Champcar
- 2001-2011 Williams F1
  - FW22 – FW33, F2
- 2011 – TotalSim LLC
  - NASCAR, Indycar, GT3, GTD, Dpi, LMdh, + many more

Grip

- For track racing, the higher the grip level the faster a car can go around a corner
- The grip level is a function of the lateral force the tires can support before they start to slide
- We can increase the lateral force by increasing the vertical load acting on the tire
- We could do this by adding mass (weight) to the car but the downside of this is we would have to spend energy accelerating and decelerating that added mass
- Instead, we can add a vertical load by creating negative lift (Downforce) via the aerodynamics of the vehicle which adds no extra mass
- Downforce can also help us with straight line traction to “”get the power down”







Force and Pressure

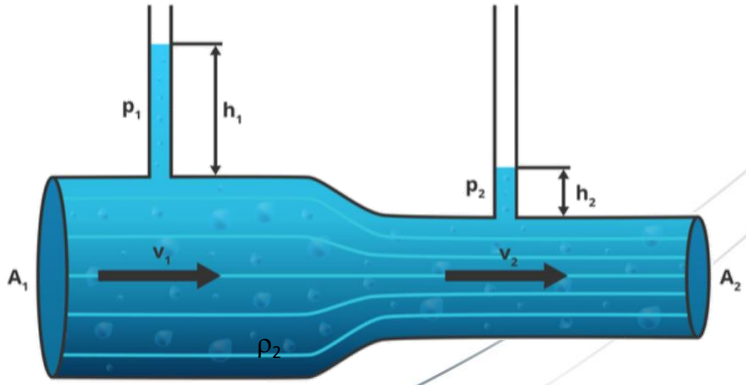
- Aerodynamic forces are created by pressure differences over the vehicle
- When a fluid (air) slows down its pressure increases
- When a fluid speeds up its pressure reduces
- This relationship is not linear but is quadratic, meaning if we double the speed our pressure will reduce by a factor of four and if we halve our speed our pressure will rise by a factor of four
- We can also lower the pressure by losing energy and raise the pressure by increasing the energy

Total Pressure = Static Pressure + Dynamic Pressure $P_T = P_s + \frac{1}{2}\rho V^2$

Bernoulli Equation: $P_{s_1} + \frac{1}{2}\rho_1 V_1^2 = P_{s_2} + \frac{1}{2}\rho_2 V_2^2$

Continuity Equation: $\rho_1 A_1 V_1 = \rho_2 A_2 V_2$

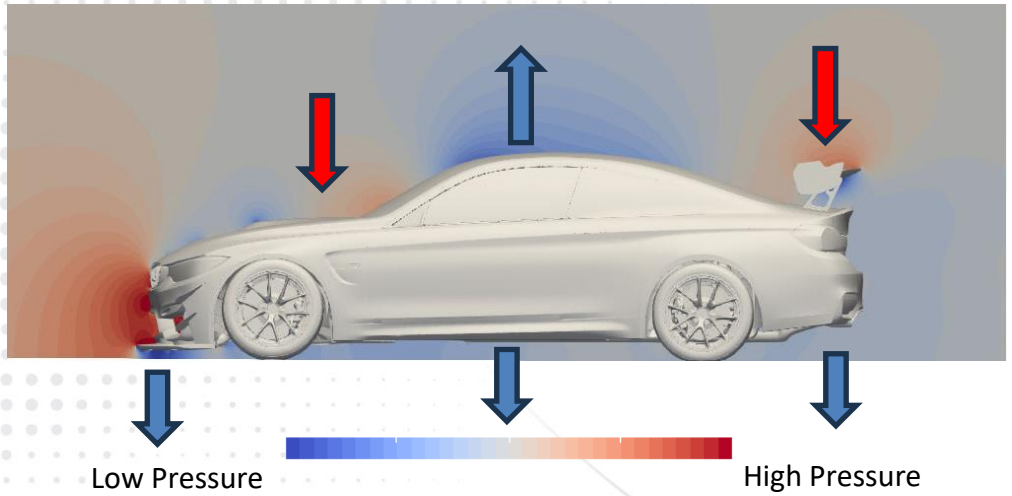
ρ_1



Downforce

- Downforce is created by the difference in pressure between the top and the bottom sides of a surface or body
- We increase Downforce by raising the pressure over the top of the vehicle
- We also increase Downforce by lowering the pressure on the bottom the vehicle
- Unfortunately, when we create Downforce we also create Drag
- We often non-dimensionalize Downforce into a coefficient call the Lift Coefficient

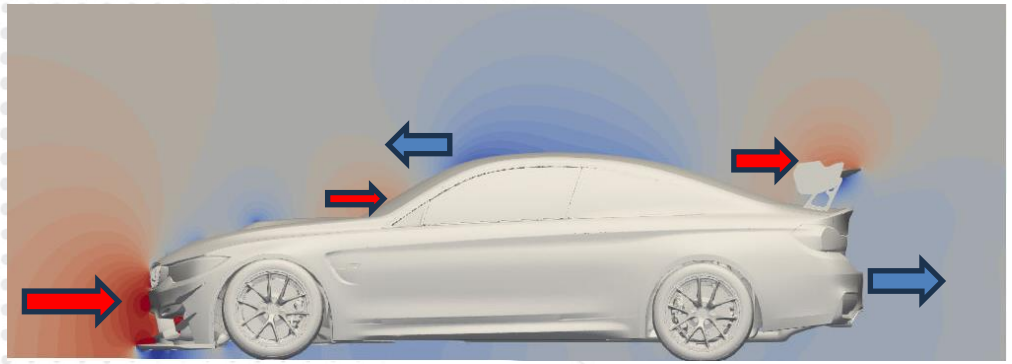
$$\text{Lift Coefficient, } C_l = \frac{Lift\ Force}{0.5 * Density * Velocity^2 * Area}$$



Drag

- Drag is created by the difference in pressure between the front and the back sides of a surface or body
- We increase Drag by raising the pressure at front of the vehicle
- We increase Drag by lowering the pressure at the rear of the vehicle
- Drag is also created by the friction between the body and the fluid. For most racecars this is a small effect, but it can become significant for high speed vheilces such as Streamliners and other land speed record vehicles.
- The opposite of Drag is Thrust and this works to reduce the overall Drag

$$\text{Drag Coefficient, } C_d = \frac{Drag\ Force}{0.5 * Density * Velocity^2 * Area}$$



Drag Coefficient, $C_d = \frac{Drag\ Force}{0.5 * Density * Velocity^2 * Area}$

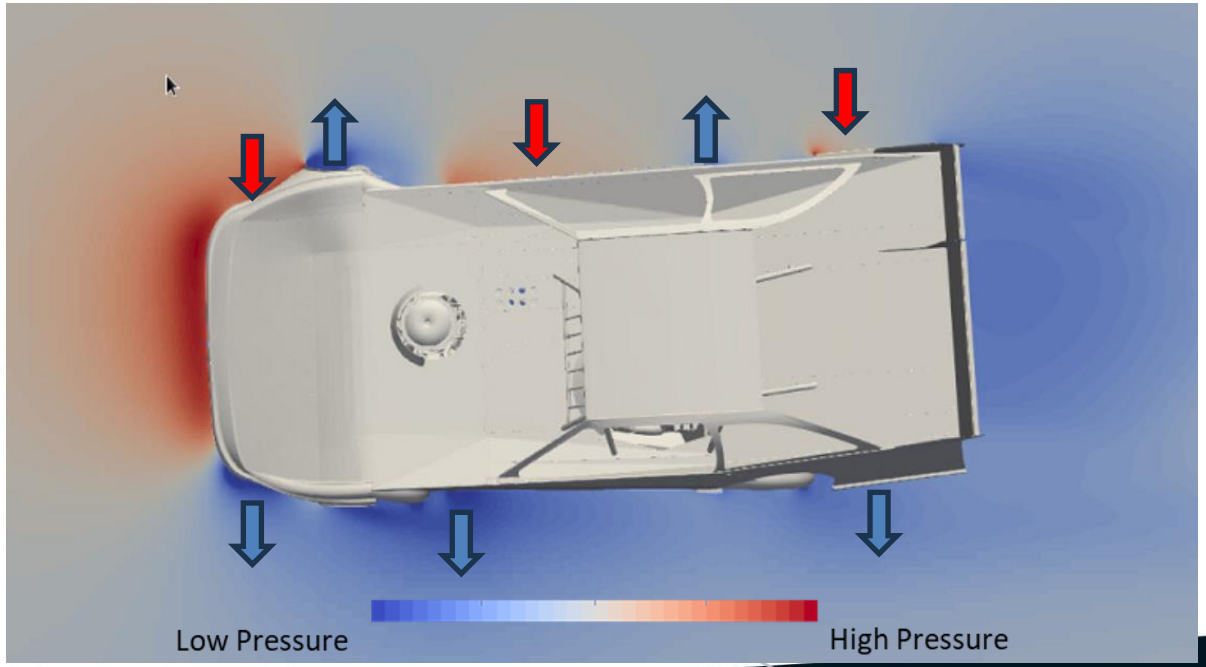
Low Pressure

High Pressure

Sideforce

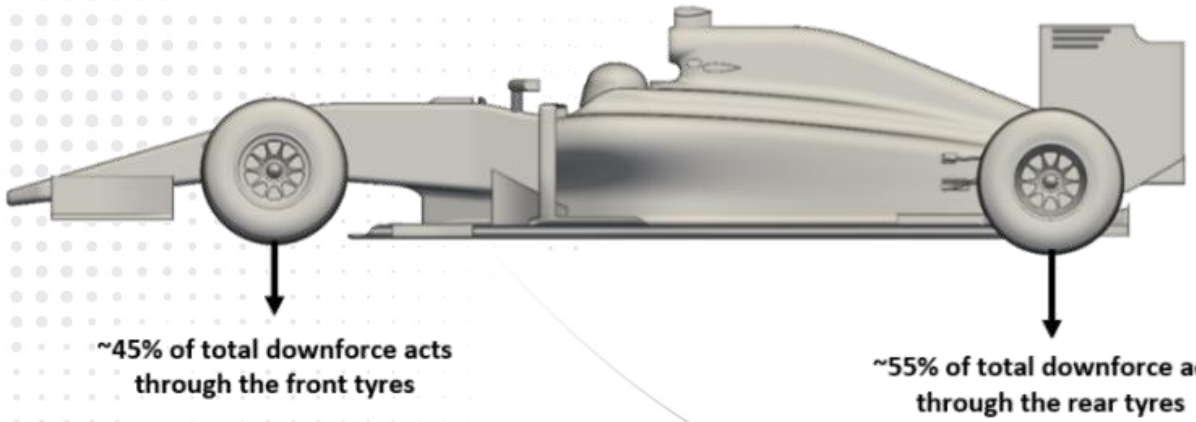
- Sideforce is created by the difference in pressure between the left and the right sides of a surface or body
- Sideforce acts with or against the lateral force the tire is creating so can help increase cornering speeds or hurt them
- We can increase Sideforce by raising and lowering the pressure on left and right sides of the body

$$\text{Side Coefficient, } C_s = \frac{Side\ Force}{0.5 * Density * Velocity^2 * Area}$$



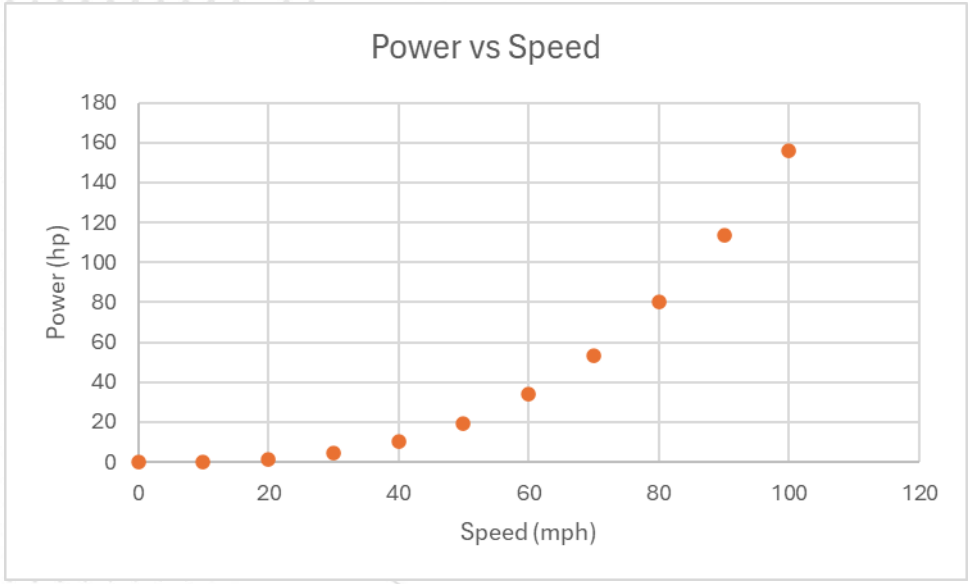
Balance

- The distribution of Downforce on the front axle is called Front Downforce and the rear axle is called Rear Downforce
- The ratio of Front Downforce to Total Downforce is called % Front or CoP
- The weight distribution and tire characteristics dictate what the optimal CoP is for a given racecar. Too much Front and the car will oversteer (loose), too little it will understeer (push or tight)
- Often the handling characteristics of the car will govern the ultimate laptime so having the right CoP with less downforce can be better than the wrong CoP and more downforce
- Similarly, Sideforce distribution across the axles (% FrontSide) is an important consideration and having the right distribution can be more important than having more Total Sideforce



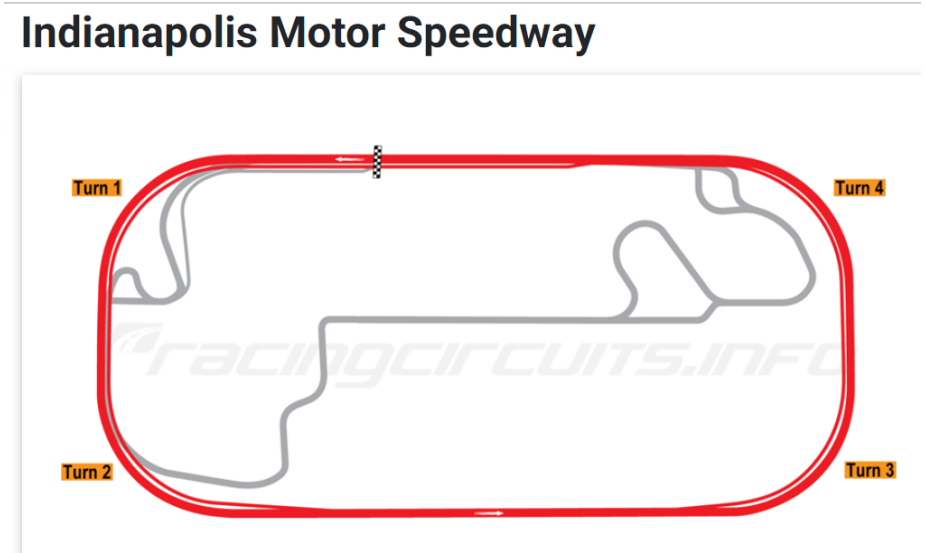
Power

- Drag is the force that acts to slow the vehicle down and we need to supply Power to overcome this drag and maintain speed. The more power we can supply the higher the speed we can achieve. Put another way, the lower the drag the less power we need to hit a given speed
- The relationship between Power and speed is cubic, meaning that to double the speed we need to supply eight times the Power for a given Drag
- The available Power will determine the Drag we can overcome which in turn will determine our terminal speed. The amount of Drag we are willing to carry will in turn impact the Downforce we can create which will limit our maximum cornering speed



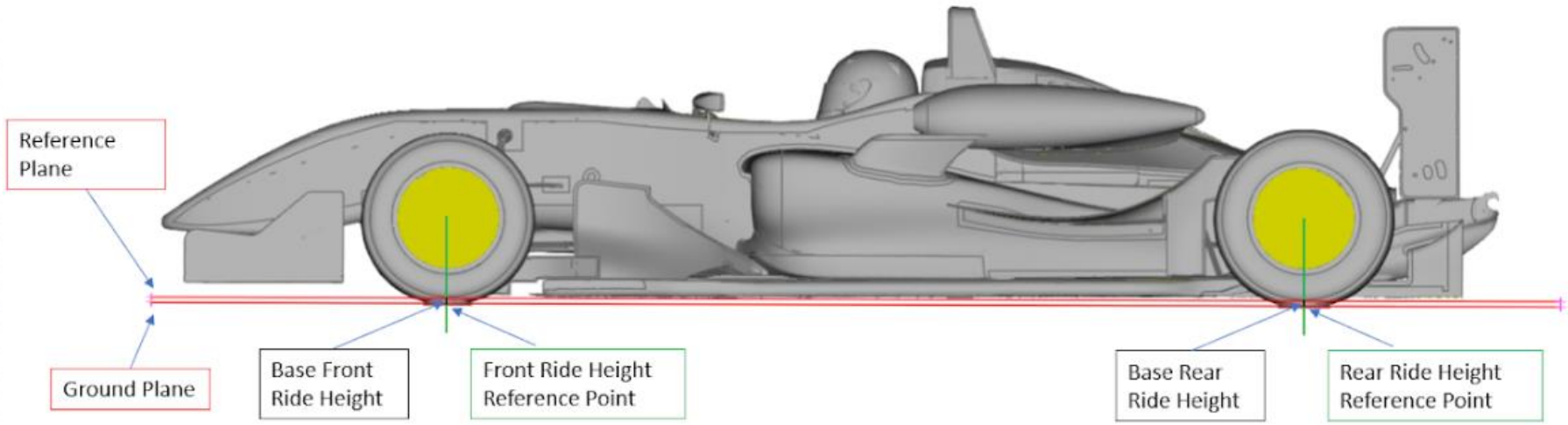
Efficiency

- The amount of Drag that we create for each unit of Downforce we create is called the Efficiency
- Different circuits will have different optimal Efficiencies
- For Indy Road Course we want an Efficiency of about 3 i.e. for every 3 units of Downforce we can accept one unit of Drag and will still go faster
- For Indy Speedway this changes to 7 i.e. We need to add approximately seven units of Downforce for every unit of Drag to go faster or what actually happens is we take 7 units of downforce away to get 1 unit less drag



Rideheight

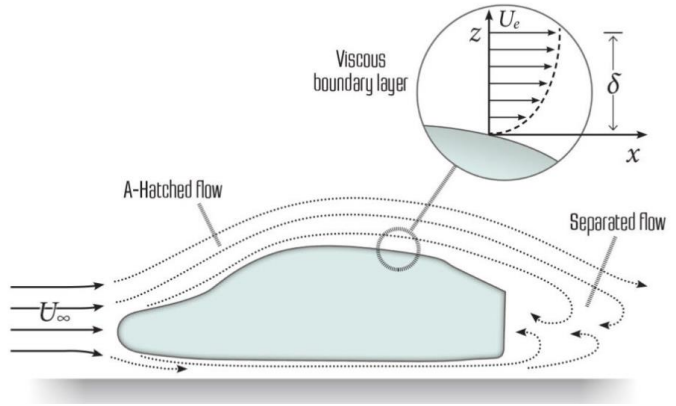
- Rideheight describes the position of the car relative to the ground
- Typically, it's a distance measured from a reference plane attached to the car to the ground
- The Front Rideheight is usually given at the front axle and the Rear Rideheight is usually given at the rear axle
- Often with Splitter cars the splitter clearance is given instead of, or in addition to, the Front Rideheight
- Different types of car will have different optimal rideheights depending on their aerodynamic characteristics

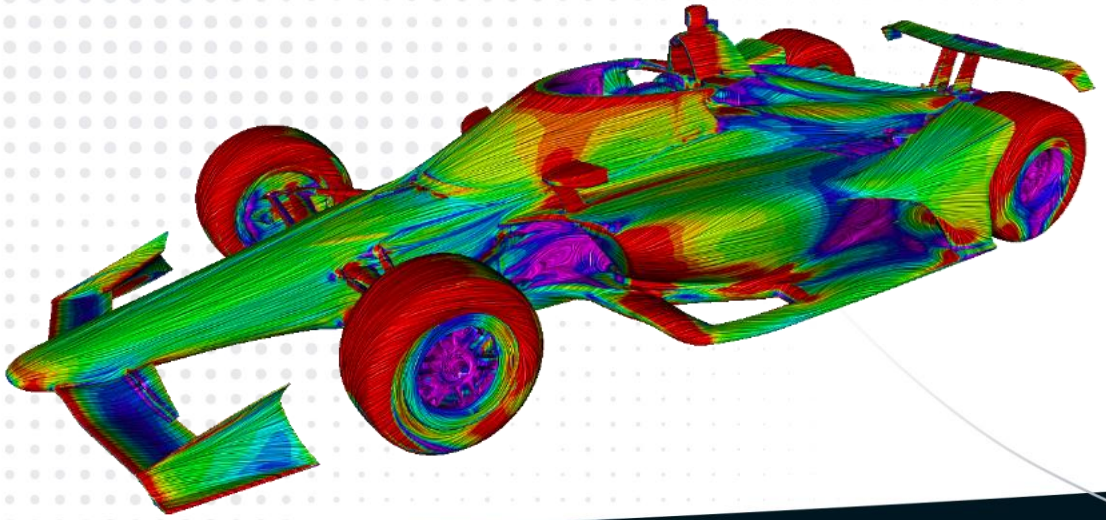


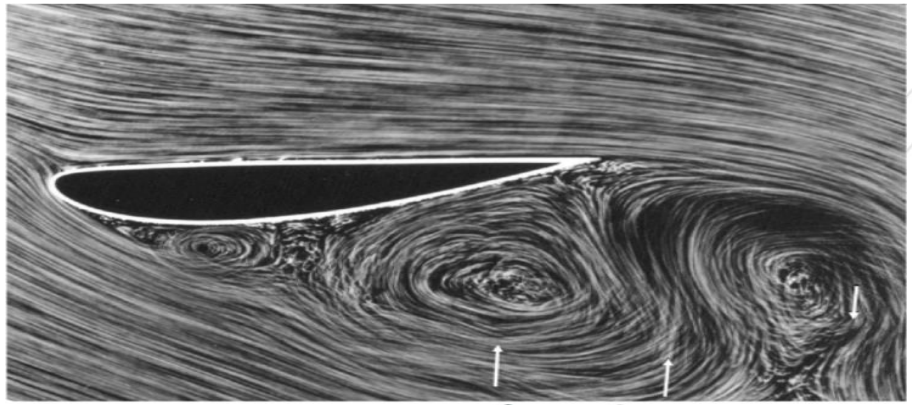
Temperature

- When a gas (air) get hotter its density drops
- When a gas gets hotter its viscosity increases (get stickier)
- Lower density air creates less Downforce and less Drag
- The higher the viscosity the higher the Drag due to friction
- Lower density air also means less power for normally aspirated engines as there is less oxygen per unit volume available for combustion

Attached and Separated Flow







TotalSim Details

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IMPROVE DESIGN AND PROCESSES

LEVERAGE TOTALSIM'S MODELING AND SIMULATION EXPERIENCE

TotalSim is a full-service computational fluid dynamics consulting and solutions firm. We provide clients with decades of aerodynamic, fluids and thermal engineering knowledge and insight into automotive, racing, aerospace, architectural systems, and industrial sectors.

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HOW WE ENGAGE WITH YOU

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- Motorsports teams rapidly turning around CFD results to directly impact track performance
- Aerospace clients providing consulting services for:
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  - External aerodynamic performance
  - Internal flows
  - Thermal management
  - Performance mapping/ Aero database generation
- Wind tunnel and physical testing to provide guidance on whether it is a appropriate or needed relative to a specific design.
- Marine vessels improving handling, overall performance, and passenger comfort
- Architectural Systems CFD solutions enable our customers to account for everything from HVAC to Pedestrian Comfort.
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- Flow through valves and inside separation tanks
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- Architectural Systems
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SOFTWARE EXPERIENCE

- STAR-CCM+ Provider & Consulting
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