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AERODYNAMICS IN CAR DESIGN

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***Abstract*--As an object moves through the atmosphere, it displaces the air that surrounds it. The object is also subjected to gravity and drag. Drag is generated when a solid object moves through a fluid medium such as water or air. Drag increases with velocity -- the faster the object travels, the more drag it experiences. Drag has a tremendous effect on the way a car accelerates, handles and achieves fuel mileage. This is where the science of aerodynamics comes into play. Aerodynamics is the study of forces and the resulting motion of objects through the air. For several decades, cars have been designed with aerodynamics in mind, and car makers have come up with a variety of innovations that make cutting through the "wall" of air easier and less of an impact on daily driving. Essentially, the lower the Cd, the more aerodynamic a car is, and the easier it can move through the wall of air pushing against it. To measure the aerodynamic effectiveness of a car in real time, engineers have borrowed a tool from the aircraft industry -- the wind tunnel. The car inside never moves, but the fans create wind at different speeds to simulate real-world conditions. Sometimes a real car won't even be used -- designers often rely on exact scale models of their vehicles to measure wind resistance. As wind moves over the car in the tunnel, computers are used to calculate the drag coefficient (Cd). There's more to aerodynamics than just drag -- there are other factors called lift and down-force. To improve car aerodynamics: 1.The best thing is to have low ground clearance, 2. Minimize the frontal area, 3. Addition of spoilers, etc.**

1. INTRODUCTION

As an object moves through the atmosphere, it displaces the air that surrounds it. The object is also subjected to gravity and drag. Drag is generated when a solid object moves through a fluid medium such as water or air. Drag increases with velocity -- the faster the object travels, the more drag it experiences. Drag has a direct effect on acceleration, **a = (W - D) / m.** As an object accelerates, its velocity and drag increase, eventually to the point where drag becomes equal to weight -- in which case no further acceleration can occur. Let's say our object in this equation is a car. This means that as the car travels faster and faster, more and more air pushes against it, limiting how much more it can accelerate and restricting it to a certain speed. How does all of this apply to car design? Well, it's useful for figuring out an important number -- drag coefficient, **Cd = D / (A * .5 * r * V^2)**. This is one of the primary factors that determine how easily an object moves through the air.

2. NEED FOR AERODYNAMICS IN CARS:

Imagine what would happen if you drove your car into a brick wall at 65 miles per hour (104.6 kilometers per hour). Metal would twist and tear. Glass would shatter. Airbags would burst forth to protect you. But even with all the advancements in safety we have on our modern automobiles, this would likely be a tough accident to walk away from. A car simply isn't designed to go through a brick wall. But there is another type of "wall" that cars are designed to move through, and have been for a long time -- the wall of air that pushes against a vehicle at high speeds. Most of us don't think of air or wind as a wall. At low speeds and on days when it's not very windy outside, it's hard to notice the way air interacts with our vehicles. But at high speeds, and on exceptionally windy days, air resistance (the forces acted upon a moving object by the air) has a tremendous effect on the way a car accelerates and achieves fuel mileage. This is where the science of aerodynamics comes into play. Aerodynamics is the study of forces and the resulting motion of objects through the air. Essentially, having a car designed with airflow in mind means it has less difficulty accelerating and can achieve better fuel economy numbers because the engine doesn't have to work nearly as hard to push the car through the wall of air.

3. DRAG:

Drag is generated when a solid object moves through a fluid medium such as water or air. Drag increases with velocity -- the faster the object travels, the more drag it experiences. Drag has a direct effect

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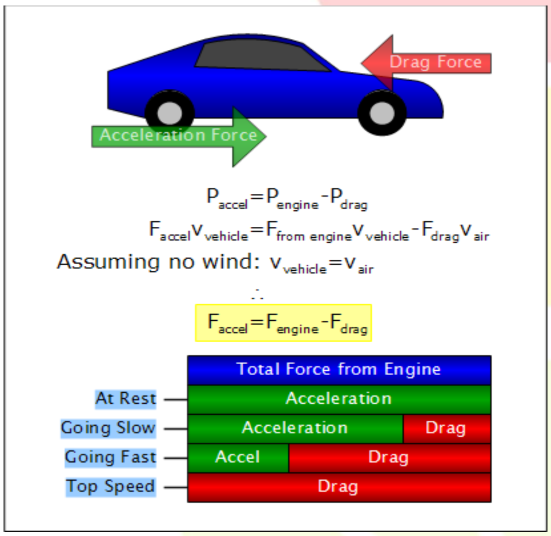
on acceleration, **a = (W - D) / m.** As an object accelerates, its velocity and drag increase, eventually to the point where drag becomes equal to weight -- in which case no further acceleration can occur. Drag, in vehicle aerodynamics, is comprised primarily of two forces 1.Frontal Pressure, 2.Rear Vacuum.



The engine exerts a force, while the aerodynamic drag opposes the engine's force. The remaining force from the engine is used for acceleration.

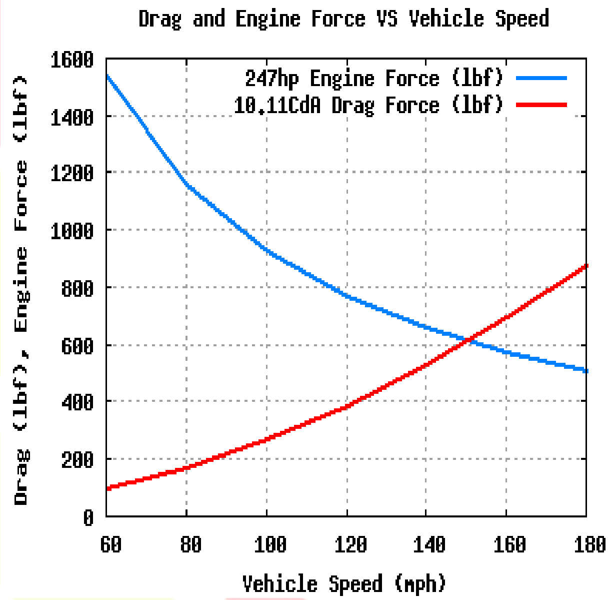
4. FRONTAL PRESSURE

Frontal pressure is caused by the air attempting to flow around the front of the car. As millions of air molecules approach the front grill of the car, they begin to compress, and in doing so raise the air pressure in front of the car. At the same time, the air molecules travelling along the sides of the car are at atmospheric pressure, a lower pressure compared to the molecules at the front of the car. The compressed molecules of air naturally seek a way out of the high pressure zone in front of the car, and they find it around the sides, top and bottom of the car.

5. REAR VACUUM:

Rear vacuum is caused by the "hole" left in the air as the car passes through it. To visualize this, imagine a car driving down a road. The shape of the car punches a big hole in the air, with the air rushing around the body. At speeds above a crawl, the space directly behind the car is "empty" or like a vacuum. This empty area is a result of the air molecules not being able to fill the hole as quickly as the car can make it. The air molecules attempt to fill in to this area, but the car is always one step ahead, and as a result, a continuous vacuum sucks in the opposite direction of the bus. This inability to fill the hole left by the bus is technically called flow detachment**.**

6. CO-EFFICIENT OF DRAG:



The above graph shows the force that the engine can exert, and the force due to aerodynamic drag. When the drag force becomes equal to the force the engine can exert, the car reaches its drag-limited top speed. In this case, the car's top speed is approximately 150mph.

The aerodynamic abilities of a car are measured using the vehicle's coefficient of drag. The co-efficient of drag is given by the relation **Cd = D / (A * .5 * r * V^2)**. Essentially, the lower the Cd, the more aerodynamic a car is, and the easier it can move through the wall of air pushing against it. Remember the boxy old Volvo cars of the 1970s and '80s? An old Volvo 960 sedan achieves a Cd of .36. The newer Volvos are much more sleek and curvy, and an S80 sedan achieves a Cd of .28. This proves smoother; more streamlined shapes are more aerodynamic than boxy ones. Let's look at the most aerodynamic thing in nature -- a teardrop. The teardrop is smooth and round on all sides and tapers off at the top. Air flows around it smoothly as it falls to the ground. It's the same with cars -- smooth, rounded surfaces allow the air to flow in a stream over the vehicle, reducing the "push" of air against the body. Today, most cars achieve a Cd of about .30. Many have questioned the "unique" looks of the Toyota Prius hybrid, but it has an extremely aerodynamic shape for a good reason. Among other efficient characteristics, its Cd of .26 helps it achieve very high mileage. In fact, reducing the Cd of a car by just 0.01 can result in a 0.2 miles per gallon (.09 kilometers per liter) increase in fuel economy.

7. MEASURING DRAG USING WIND TUNNELS:

To measure the aerodynamic effectiveness of a car in real time, engineers have borrowed a tool from the aircraft industry -- the wind tunnel. In essence, a wind tunnel is a massive tube with fans that produce airflow over an object inside. This can be a car, an airplane, or anything else that engineers need to measure for air resistance. From a room behind the tunnel, engineers study the way the air interacts with the object, the way the air currents flow over the various surfaces. The car inside never moves, but the fans create wind at different speeds to simulate real-world conditions. Sometimes a real car won't even be used -- designers often rely on exact scale models of their vehicles to measure wind resistance. As wind moves over the car in the tunnel, computers are used to calculate the drag coefficient (Cd). Wind tunnels are really nothing new. They've been around since the late 1800s to measure airflow over many early aircraft attempts. Even the Wright Brothers had one. After World War II, race car engineers seeking an edge over the competition began to use them to gauge the effectiveness of their cars' aerodynamic equipment. That technology later made its way to passenger cars and trucks. However, in recent years, the big, multi-million-dollar wind tunnels are being used less and less. Computer simulations are starting to replace wind tunnels as the best way to measure the aerodynamics of a car or aircraft. In many cases, wind tunnels are mostly just called upon to make sure the computer simulations are accurate.

8. WIND TUNNEL: TYPICAL LAYOUT

A typical design of an automotive wind tunnel

- Model scale - 40 to 60%
- Contraction ration - 5 to 7:1
- Wind speed - 40 to 80 m/s
- Rolling road
- Boundary layer suction
- Temperature control

9. IMPROVING AERODYNAMICS OF A CAR:

- *Cover Open wheels:* Open wheels create a great deal of drag and air flow turbulence, similar to the diagram of the mirror above. Full covering bodywork is probably the best solution, if legal by regulations, but if partial bodywork is permitted, placing a converging fairing behind the wheel provides maximum benefit.

- *Converge Bodywork Slowly:* Bodywork which quickly converges or is simply truncated, forces the air flow into turbulence, and generates a great deal of drag. As mentioned above, it also can affect aerodynamic devices and bodywork further behind on the car body.

- *Use Spoilers:* Spoilers are widely used on sedan type cars such as NASCAR stock cars. These aerodynamic aids produce down-force by creating a "dam" at the rear lip of the trunk. This dam works in a similar fashion to the windshield, only it creates higher pressure in the area above the trunk.

- *Use Wing:*. Wings are the inverted version of what you find on aircraft. They work very efficiently, and in less aggressive forms generate more down-force than drag, so they are loved in many racing circles. Wings are not generally seen in concert with spoilers, as they both occupy similar locations, and defeat each other's purpose.

- *Use Front Air Dams:* Air dams at the front of the car restrict the flow of air reaching the underside of the car. This creates a lower pressure area under the car, effectively providing down-force.

- *Keep Protrusions Away From The Bodywork:* The smooth airflow achieved by proper bodywork design can be messed up quite easily if a protrusion such as a mirror is too close to it. Many people will design very aerodynamic mounts for the mirror, but will fail to place the mirror itself far enough from the bodywork.

- *Rake the chassis:* The chassis, as mentioned in the aerodynamics theory section above, is capable of being slightly lower to the ground in the front than in the rear. The lower "Nose" of the car reduces the volume of air able to pass under the car, and the higher "Tail" of the car creates a vacuum effect which lowers the air pressure.

- *Cover Exposed Wishbones:* Exposed wishbones (on open wheel cars) are usually made from circular steel tube, to save cost. However, these circular tubes generate turbulence. It would be much better to use oval tubing, or a tube fairing that creates an oval shape over top of the round tubing.

10. ADVANTAGES OF AERODYNAMICS IN CAR:

By making a vehicle more aerodynamic it is possible to reduce the power requirements of the

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vehicle because there is less resistance to motion. The vehicle can travel faster, for longer and on less fuel. It is also possible to give the vehicle more down-force, the force created when the air travels over the surfaces of the vehicle. This force, as the name suggests, acts downwards, pushing the car onto the road and gets larger as velocity increases. This enables the vehicle to go around corners at higher speeds as it is being forced onto the road.

11. CONCLUSION:

Cars have been designed with aerodynamics in mind, and carmakers have come up with a variety of innovations that make cutting through that "wall" of air easier and less of an impact on daily driving. Essentially, having a car designed with airflow in mind means it has less difficulty accelerating and can achieve better fuel economy numbers because the engine doesn't have to work nearly as hard to push the car through the wall of air. Engineers have developed several ways of doing this. For instance, more rounded designs and shapes on the exterior of the vehicle are crafted to channel air in a way so that it flows around the car with the least resistance possible. Some high-performance cars even have parts that move air smoothly across the underside of the car.