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A1_1 Can an F1 car drive upside down?

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Abstract

We discuss whether it is possible for a Formula one car to generate enough negative lift (downforce) to stick to the ceiling of a tunnel, also whether such an experiment is possible We find that while an F1 car can generate enough downforce to do this at 111mph, a practical experiment may not be possible due to the high cost.

Introduction

Downforce is the force applied to a car by using the aerodynamic properties of aerofoils. Just as aerofoils are used to make aeroplanes overcome gravity and fly, they are also used by Formula one cars and other race cars to keep them on the track, by pushing them onto the track and giving the wheels more traction.

However, the racing cars approach a problem. While downforce generated by these wings give the car better traction, they also limit its top speed as the shapes of the wings generate more drag. Therefore, in racing there is always a trade-off between top speed (drag) and traction through corners (downforce).

There have been many instances where people have said that a Formula one car could generate enough downforce to stick to the ceiling of a tunnel. Many people disagree with this and say that while it could generate enough downforce to do so; it would not be able to get into such a position to prove this. However there are just as many that believe this to be true, this paper aims to provide a physical solution to this debate.

Theory

Figure 1 (below) proposes a scenario in which a car would be able to drive on the ceiling of a tunnel:

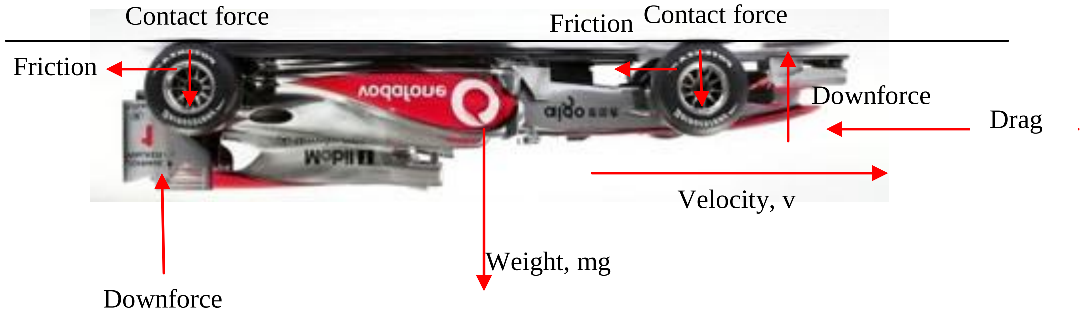

Figure 1: A simple force diagram of a Formula one car that is driving on the ceiling, here the downforce must be greater than the weight of the car in order for it to experience any traction from the ceiling. (Image credit adapted from: www.blogspot.com) [1]

The downforce formula is given by:

$$F_{wing} = \frac{1}{2}(WHAoA)(C_d\rho v^2) = \frac{1}{2}\beta(AoA)(C_d\rho v^2) \qquad (1)\ [2]\ ,$$

where F is the downforce per wing, W is the wingspan, H is the height of the wing, AoA is the angle of attack, C_d is the drag coefficient, ρ is the air density, v is the velocity of the air going over the wing and β is the effective area for each wing.

Since the 2009 specification car has two wings consisting of a total of 5 aerofoils (2 front and 3 rear) of different sizes, the total downforce of the car is given by:

$$F_{car} = \frac{1}{2}(AoA)(C_d\rho v^2)\left(\beta_{f1} + \beta_{f2} + \beta_{r1} + \beta_{r2} + \beta_{r3}\right) \qquad (2)\ .$$

Since the downforce must overcome the weight of the car, the car must travel at a velocity of:

$$v > \sqrt{\frac{2mg}{(AoA)(C_d\rho)(\beta_{f1} + \beta_{f2} + \beta_{r1} + \beta_{r2} + \beta_{r3})}} \qquad (3).$$

The wing dimensions have been taken to be: β_{f1}= (1.4×0.06m^2), β_{f2}= (1×0.06 m^2), β_{r1}= β_{r2} = β_{r3} = (0.75×0.06 m^2); where these values are based on the maximum sizes of the FIA regulations for 2009 [3]. The mass of a formula one car in 2009 (m in (3)) had to be a minimum of 605kg including the driver [3].The optimum angle of attack (AoA) has been taken to be 17 degrees [4]; and the value for the drag coefficient has been taken to be 0.83 [5].

Substituting the above values into (3) and remembering that g=9.81ms^{-2} and the air density to be 1.22kgm^{-3} we get that:

$$v > 49.71\ ms^{-1} = 111.86\ mph\ .$$

The top speed of a formula one car is somewhere in the range of 200mph (88.88 ms^{-1}), so in theory a formula one car can drive on the ceiling.

Possible Experiments

While this paper has proved that a formula one car does possess the necessary properties to drive on the ceiling of a tunnel in theory, it is very hard to do it in practice. For instance, the fuel intake, engine and the suspension would have to be modified to be able to drive upside down.

The radius of curvature would also have to be taken into account; as if this is too small then too much air would go underneath the car and hinder the aerodynamics of the car.

An experiment could be done in a wind tunnel, with the car restrained to the ceiling until the wind speed reaches in excess of that shown above, then the restraints removed. This, however, would not be done as building a formula one car is very expensive and should it go wrong, would be a massive cost to the manufacturers.

References

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