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P1 2 Ceiling It

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Abstract

This paper investigates whether a Formula 1 car could drive inverted on the ceiling of the Monaco tunnel during a Grand Prix. A minimum speed of 211 $\mathrm{kmh^{-1}}$ is identified at which aerodynamic downforce balances the car's weight, providing just enough adhesion to remain upside down. Beyond this threshold, usable tyre grip for steering and braking would increase with speed. However, the maximum speed achievable through the tunnel in a Grand Prix setting is insufficient to generate the lateral acceleration required for practical control, making the scenario impossible.

Introduction

The defining feature of modern Formula 1 cars is their extraordinary aerodynamic downforce. Generated by the wings and bodywork, this force pushes the car onto the track, increasing grip and stability [1]. At sufficiently high speeds, the downforce can even exceed the car's own weight, inspiring one of the sport's most popular thought experiments: could an F1 car drive upside down? The tunnel section of the Monaco Grand Prix provides a natural test case, offering a long, enclosed stretch of track where such an event could be imagined. The purpose of this paper is to investigate whether an F1 car could feasibly drive on the ceiling of the Monaco tunnel, and whether it could remain controllable while doing so.

Theory and Results

In order to drive upside down, the downforce of a Formula 1 car must equal its weight. Weight, W, can be defined by the following expression:

$$W = mg, \tag{1}$$

where m is the mass of the car and g is acceleration due to gravity. The standard mass of an F1 car including the driver is 800 kg [2]. Therefore, the weight of an F1 car is 7850 N. Downforce, F_D, can be expressed as [3]:

$$F_D = \frac{1}{2}\rho v^2 A C_L, \tag{2}$$

where ρ is air density (taken as 1.20 $\mathrm{kgm^{-3}}$ at sea level), v is velocity, A is planform area and C_L is the lift coefficient. Planform area is the area of a car's bodywork that contributes to downforce. For an F1 car this can be simplified to the area of the front and rear wings and the area of the car floor. The lift coefficient is a dimensionless parameter that characterises the ability of a body to generate downforce. The planform area of an F1 car is around 1.00 $\mathrm{m^2}$ and the lift coefficient is around 3.80 [4]. Since downforce must equal weight, Equations 1 and 2 can be rearranged to find velocity:

$$v = \sqrt{\frac{2F_D}{\rho A C_L}}. \tag{3}$$

The minimum velocity that an F1 car could, in theory, drive upside down is therefore 58.7 $\mathrm{ms^{-1}}$

or 211 kmh^{-1}. F1 cars can travel at speeds up to 360 kmh^{-1}, but the maximum speed through the Monaco tunnel is around 260 kmh^{-1} due to the nature of the track [5]. While this makes our speed of 211 kmh^{-1} seem feasible, the car would have no grip at this lower limit. When the car is inverted, the tyres must provide sufficient frictional force to allow not only adhesion to the ceiling but also steering and braking.

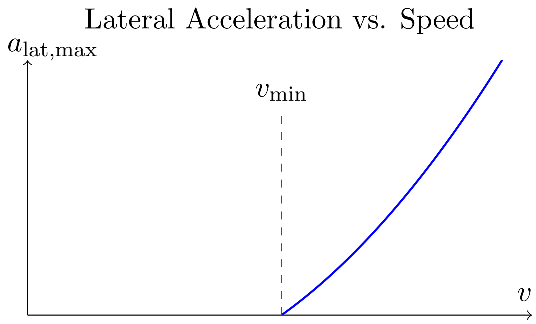

Figure 1: Qualitative behaviour of maximum lateral acceleration, $a_{\text{lat,max}}$, as a function of speed, v. At the critical speed, v_{min}, adhesion is possible but no lateral control is available; usable grip increases quadratically at higher speeds.

The frictional force depends on the normal force, N, acting on the tyres, given by:

$$N = F_D - W. \tag{4}$$

At the minimum velocity these forces balance and the normal force vanishes, meaning that no grip is available for control. The maximum frictional force is then:

$$F_f = \mu N = \mu(F_D - W), \tag{5}$$

where μ is the coefficient of friction between the tyres and the surface. This sets the limit on the maximum lateral force that can be generated during cornering. Dividing through by the car's mass gives the maximum lateral acceleration:

$$a_{\text{lat,max}} = \frac{F_f}{m} = \frac{\mu N}{m} = \frac{\mu}{m}(F_D - W). \tag{6}$$

Substituting for downforce:

$$a_{\text{lat,max}} = \frac{\mu}{m}(\frac{1}{2}\rho v^2 A C_L - W). \tag{7}$$

This expression shows that at the minimum velocity, v_{min}, the available lateral acceleration is zero (since downforce and weight are equal), and it increases quadratically with speed beyond that threshold, as shown in Figure 1.

Discussion

The analysis shows that, in theory, a Formula 1 car could drive on the ceiling of the Monaco tunnel at a minimum speed where its downforce exceeds its weight. However, the adhesion that the minimum speed provides is insufficient as further tyre grip is required for stability and control. Even at maximum tunnel speeds, typically around 260 kmh^{-1} during race conditions, the available grip would still be marginal. The car could stick to the ceiling, but it would lack the lateral acceleration required to steer safely. Furthermore, this study neglects turbulence, structural clearances, and the impracticality of transitioning from the track to the ceiling. Taken together, these factors suggest that while the physics permits adhesion, race conditions in Monaco do not allow the scenario to be realised.

Conclusion

This paper has explored whether a Formula 1 car could drive upside down in the Monaco tunnel. A theoretical minimum speed was found at which downforce balances weight, with higher speeds providing usable grip for control. However, the speeds achievable in Monaco are insufficient to sustain safe inverted driving.

References

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