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P1_2 Olympus Monza: Motorsport on Mars

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Abstract

A theoretical investigation is carried out to find an estimate of the speed a Formula 1 car could take through the famous 'Parabolica' corner at the Monza circuit if the same circuit were located on the Martian surface. It was found that the maximum possible speed through the corner was ≈ 88.2 km/h which is well below the 215 km/h achieved on Earth [1].

Introduction

In this evaluation, the speed of a Formula 1 car through a constant radius corner similar to that of 'Parabolica' is estimated in Martian surface conditions through simple analysis of the significant forces acting on the vehicle through the corner. These being mechanical grip and aerodynamic grip which must allow a frictional force sufficient enough to match the centripetal force required to maintain the turn. The following assumptions are taken in the proceeding calculations: The path taken around the corner is assumed to be a constant radius arc through the centre of the track. This allows us to simplify calculations and is a good approximation at this scale. The real path would be an arc of an ellipse forming a 'racing line'. These calculations also work on the premise that the frictional forces undergone are the peak frictional forces possible, however provided the same ratio to maximum is achieved on both planets (ie. similar driver performance) this factor falls into a later defined constant and won't affect the results. Monza is also a famously flat circuit, so much so that Eliud Kipchoge set a marathon world record there [2], hence, banking effects are neglected.

Evaluation

Firstly the centripetal force required to maintain the path is given by:

$$F_C = \frac{mv^2}{r}, \tag{1}$$

Where F_C is the centripetal force, m is the vehicle's mass, v it's velocity and r is the radius of the circular path. The maximum frictional forces required to meet this can be broken into:

$$f = \mu \; F_N = \mu \; (F_g + F_{aero}), \tag{2}$$

Where f is the maximum frictional force and μ is the coefficient of static friction between the tires and track

$$F_g = mg, \tag{3}$$

$$F_{aero} = \frac{1}{2} A\rho_{air} \; C_L v^2, [3] \tag{4}$$

F_g is the gravitational force acting on the car, g Earth's surface gravity, 9.81 m/s^2. F_{aero} is the aerodynamic 'downforce', ρ_{air} is the air density, A is the cross sectional area of the lift surfaces, C_L is the coefficient of lift and v is the relative velocity of the oncoming air, equal to the car's velocity previously defined as v.

Combining constant terms in Equation 4 gives:

$$F_{aero} = C\rho_{air}\ v^2, \tag{5}$$

Where C is a new constant, related to the car's aerodynamic properties and scaled by a factor inverse to the driver performance, as alluded to previously. As C is constant in both situations, this ratio is insignificant to the final result.

Equating the frictional forces produced to the centripetal force required now yields:

$$\frac{mv^2}{r} = \mu\ (mg + (C\rho_{air}\ v^2)), \tag{6}$$

Calculating the value of C

In order to find a value for the constant introduced in Equation 5 we will first consider the capabilities of the Formula 1 car at Earth's Monza.

Rearranging Equation 6 for C allows its value to be estimated through known factors. Monza has an average elevation of 177 m above sea level [4]. Therefore, we can assume air density is very close to at sea level, since deviations from this aren't significant until much greater elevation [5]. Hence, a value of 1.225 kg/m^3 is used [5]. The coefficient of friction is 1.6 [6] and constant radius used is 100 m. The mass of the Formula 1 car is taken as the minimum dry mass allowed, 752 kg [7], as at peak performance the cars will have minimal fuel mass. The speed through the corner is taken to be a constant 215 km/h $\approx$ (59.72 m/s)[1], whilst untrue, the limitation is in making the sharpest part of the corner so this is the only instantaneous force needed to balance.

These values produce an estimate for C of $\sim$2.15 m^2.

At Mars

Revisiting Equation 6 with this value and new Martian parameters we can rearrange to estimate the limitation on the value of v, the maximum cornering speed. The new values are g_{Mars}=3.71 m/s^2 and ρ_{Mars} =0.020 kg/m^3 [8].

These values lead to a Martian speed of $\approx$ 24.5 m/s = 88.2 km/h

Conclusion

The maximum speed found for a current Formula 1 car to take the 'Parabolica' corner, if it were located on Mars, is 89.8 km/h, which is unsurprisingly much lower than that possible on Earth. Formula 1 cars simply aren't set up to be run on Martian tracks. Further research may investigate whether a similar set up would still be optimal for overall lap time, much greater top speeds could be achieved on the straights due to the lower drag as a result of lower air density, or conversely whether it is better to simply increase the wing angle to increase cornering speed.

References

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