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P2_2 Racing on the Edge

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Abstract

Motor speedway is one of the largest spectator sports in the world with half of the world's top 10 largest stadium-type facilities being speedway tracks [1]. The racing involves driving round an oval track with banked corners, allowing for consistently high speeds throughout the lap. This paper looks at the feasibility of a speedway track where the bank angle of the corners is increased to 90 degrees. We found that if the straight sections of track were removed, it would indeed be feasible.

Introduction

The Indianapolis Motor Speedway (IMS) is the largest stadium-type spectator facility in the world [2]. The track consists of a 2.5 mile oval track with corners banked at $9^{o}12'$ [3]. The cars are able to maintain a much higher average speed round the corners, as a component of the normal force is rotated to point towards the centre of curvature and acts in the same direction as the centripetal force. In the extreme case with 90^{o} banking, the only force acting to keep the car on the track is that of static friction.

Below we will examine whether or not the combination of the normal force and downforce would create enough static friction to keep the car on the track.

Theory

We start by making an assumption that the track is circular rather than an oval. This is to ensure that the calculated centripetal force always acts on the vehicle (as *r* in equation (3) is constant). In this case we have modelled the track on the Indianapolis Speedway track; with a circumference of 2.5 miles. This results in a circular track of radius 639.8m. We also assume for simplicity that the vehicle is already travelling at a given speed on the vertical banking.

The best way to illustrate this problem is by drawing a free-body diagram, such a diagram is shown in figure (1):

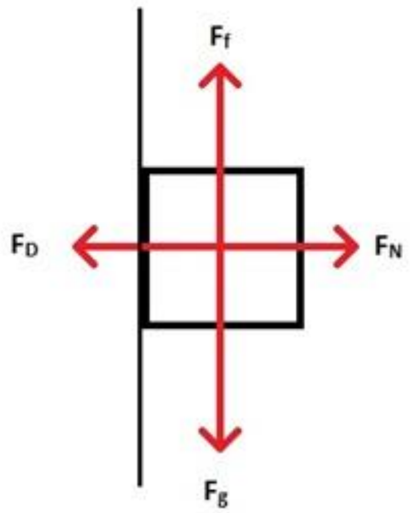

Figure 1 – A free-body diagram showing forces acting on the centre-of-mass of a vehicle travelling on a vertically banked track.

In figure (1), F_f denotes the maximum force of static friction. F_N denotes the normal force, F_g the force due to gravity and F_D the downforce.

In order for the car to stay on the track, F_g must not exceed F_f. F_f can be calculated by

$$F_f = \mu_s F_N, \qquad (1)$$

where μ_s is the coefficient of static friction. The coefficient of static friction is a measurable property and depends on the materials being used. In this case, μ_s for rubber on dry asphalt is 0.9 [4].

The magnitude of the net force F_{NET} is equal to the magnitude of the centripetal force F_C, as the vehicle is only accelerating in the radial direction. This in turn is equal to the normal force F_N minus the downforce F_D,

$$|F_{NET}| = F_C = F_N - F_D. \qquad (2)$$

The downforce is a measurable figure for different vehicles at different speeds. The centripetal force is calculated by

$$F_C = \frac{m_v v_t^2}{r}, \qquad (3)$$

where m_v is the mass of the vehicle, v_t is the tangential velocity and r is the radius of the track. By rearranging equation (2) for the normal force and substituting for F_C, the result can be used in equation (1) to set up the inequality,

$$F_g \leq \mu_s \left(\frac{m_v v_t^2}{r} + F_D\right). \qquad (4)$$

By definition, if the inequality in equation (4) is satisfied, then the vehicle will stay on the track.

Results and Discussion

For this investigation, we chose to study two different vehicles. The first vehicle is an Audi TT road car, the second is an open-wheeled Penske-Reynard-Honda racing car. This was in order to get a direct comparison between an average road car, and a purpose-built racing car.

We first analysed both vehicles travelling at 150mph (67.06 ms^{-1}). At this speed the Audi generates -1717N of downforce (it actually generates lift) [5]. The racing car generates 12233N of downforce [6]. The mass of the Audi is 1390kg [7] and the mass of the racing car is approximately 700kg [8].

When the above figures were applied to equation (4) we found that F_g for the Audi was around 6400N larger than the frictional force, meaning the car would fall. However, F_g for the racing car was 8571N less than the frictional force, meaning the car would easily be able to stay on the vertical banking.

We also applied equation (4) for the racing car at 200mph (89.41ms^{-1}), and found that the centripetal force alone (8733N) would be enough to keep the car on track.

Conclusion

The results discussed above show that given the right vehicle, the vertically banked race track would be feasible. However, it is unlikely to ever become a reality as such a track would likely be both hugely expensive and very dangerous in the event of a crash. The results at 150mph do however help to illustrate how much influence downforce has over the performance of a car.

References

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