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P1 3 Head Over Wheels

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Abstract

In this paper we examine the TNT payload required to send Porsches of varying length and mass into a forwards flip or a sideways roll, producing graphical relationships between length, mass, and the required mass of TNT. We find specifically that for the 2021 Porsche 911 Turbo, a payload of 30.4 g would be needed for the specific flip described in this paper, based off of the flip cars can perform in the video game *Rocket League*.

Introduction

Cars in *Rocket League* can perform multiple actions that cars in the real world are incapable of. These include driving on walls, jumping into the air, and using a rocket-like propulsion to fly. The topic of this paper, however, is on their ability to flip forwards or backwards, or roll sideways, all while airborne. This paper will be focusing on the forwards flip and sideways roll.

When the flip or roll is initiated, a small detonation occurs underneath the car, providing the propulsion for the rotation and linear movement. We will be determining the energy required for an explosion to cause the events seen in-game, and comparing it to an equivalent TNT bomb. These scenarios are then extrapolated to draw a relationship between car size and TNT mass.

Method

The car used in this model is the 2021 Porsche 911 Turbo, as the car exists both in Rocket League and real life. In-game movements at a defined speed were timed to measure in-game sizes, and we found that the Rocket League Porsche measures 1.62 m in length, compared to 4.54 m in real life[1]. The density of a real life Porsche 911 is 147 kgm^{-3}, and we assumed that this and the relative dimensions of the car stay constant as the car changes size. Using the value of 1650kg[1] for a real life Porsche, we calculated the mass of the Rocket League Porsche to be 75.2kg. From the same measurements, we also found that the linear motion of the Rocket League Porsche during the flip is 7.13 m for both flip and roll, and the period of rotation for each is 1.30s.

By modelling the car as a cuboid and taking the moment of inertia[2]

$$I = \frac{1}{12} m_{car}(l^2 + w^2) \tag{1}$$

and by using the dimensions of length and width for the flip and height and width for the roll with the mass of the car, the kinetic energy required for the rotation and travel can be given as

$$E_k = \frac{1}{2} I\omega^2 + \frac{1}{2} m_{car} v^2 \tag{2}$$

where ω is 4.83 rads^{-1} and v is 5.48 ms^{-1}. The energy of the explosion, however, is double E_k as half of the energy is lost downwards, away from

the car. This explosion energy can be converted into a mass of TNT using the conversion ratio of 1J to 2.39×10^{-7} kg. These equations were then plotted to form a relationship between m_{car} and m_{TNT} in Figure 1 and a relationship between l_{car} and m_{TNT} in Figure 2.

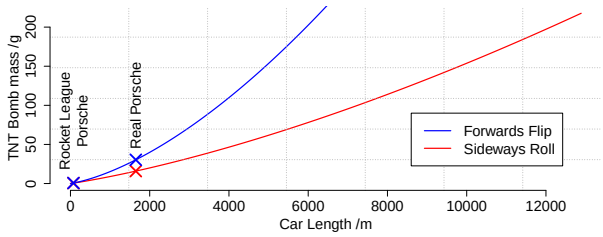

Figure 1: Relationship between mass of the Porsche in kilograms and mass of TNT in grams.

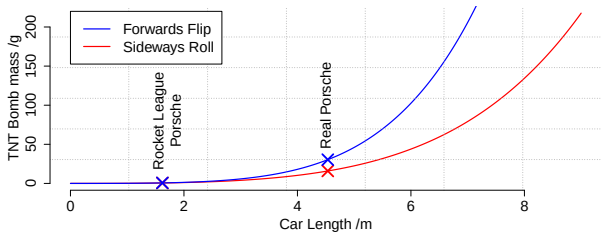

Figure 2: Relationship between length of the Porsche in metres and mass of TNT in grams.

Results

We can find the relationships between m_{TNT} and m_{car} and l_{car} shown in Figure 1 and Figure 2, by using knowledge that the final mass of TNT, m_{TNT}, must be proportional in some form to the length of the car, l_{car}, and the mass of the car, m_{car}. These proportionality relationships can be determined mathematically or graphically, and can be written as follows,

$$m_{TNT} \propto (Am_{car}^{\frac{5}{3}} + Bm_{car})$$
$$m_{TNT} \propto (Xl_{car}^{5} + Yl_{car}^{3}) \quad (3)$$

where by matching the curve on the graph to an equation we determined, the coefficients in Equation 3 for both flipping and rolling can be found. We solved each case to find coefficients for both actions, as shown below:

$[Forwards\ Flip]$

$$m_{TNT} = (8.05 \times 10^{-5})m_{car}^{\frac{5}{3}} + (7.18 \times 10^{-3})m_{car}$$
$$m_{TNT} = (9.66 \times 10^{-3})l_{car}^{5} + (0.127)l_{car}^{3} \quad (4)$$

$[Sideways\ Roll]$

$$m_{TNT} = (1.77 \times 10^{-5})m_{car}^{\frac{5}{3}} + (7.18 \times 10^{-3})m_{car}$$
$$m_{TNT} = (2.12 \times 10^{-3})l_{car}^{5} + (0.127)l_{car}^{3} \quad (5)$$

Equations 4 and 5 can be solved with the relevant values of m_{car} to show that m_{TNT} for a Porsche 911 in Rocket League is only 0.648 g to complete a single forwards flip, and that m_{TNT} to flip a real Porsche 911 is only 30.4 g.

Conclusion

From these results, it is clear that not much TNT would be required to produce either a forwards flip or a sideways roll, and that it is reasonable for the cars in *Rocket League* to carry enough to complete the large number of flips that occur in a standard game. For the standard Porsche, we can come to a similar conclusion that you can easily flip a Porsche with TNT if the driver so desires. As a comparison to our results, it takes around 1 kg of TNT to "destroy a small vehicle"[3], although this is ignoring other safety concerns that may be of interest including the use of a high explosive in close proximity to a very flammable petrol tank.

References

[1] https://newsroom.porsche.com/dam/jcr:059b218d-bf41-4508-ae8f-d9d634e4f280/2021%20911%20Turbo%20Technical%20Specifications.pdf [Accessed: 22 October 2023].

[2] https://resources.wolframcloud.com/FormulaRepository/resources/Moment-of-Inertia-of-a-Cuboid [Accessed: 22 October 2023]

[3] https://en.wikipedia.org/wiki/TNT_equivalent [Accessed: 24 October 2023]