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P1 7 Modelling the Thrust of a Rocket League Car

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Abstract

The popular video game *Rocket League* allows players to use boost to accelerate their cars forward. This paper calculates the thrust required to achieve the in-game acceleration and models it as a propulsion system with varying exhaust velocities. It was found that a thrust of 17.76 kN is required, and real-world propulsion systems exist with comparable thrust and exhaust velocities, indicating that the game's physics, while simplified, are not entirely unrealistic.

Introduction

The popular video game *Rocket League* [1] where cars play football in an enclosed cage, allows players to boost their car along the ground and even into the air. This paper explores the power of the boost displayed in-game, calculating the thrust power and then modelling it as a propulsion system with varying exhaust velocities. The feasibility of such a system will be compared to real-world engines and thrusters to comment on the physics of the game.

Thrust Calculation

The boost from a car in *Rocket League* is expelled from the rear of the vehicle, thrusting the car forward in the direction it is facing. While in-game there are many different car types that a player can choose, one specific car that can be chosen is a 2021 BMW M240i [2], and for this paper we will make our calculations based upon the specifications of this car. The thrust force can be determined from the measured acceleration and aerodynamic drag, considering these as the main forces acting along the direction of motion. From stationary, a car can reach a max speed of 2300 uus^{-1} in 2.32 seconds [3], where 1 uu is equal to 1 cm. This equates to a max speed of 23 ms^{-1} and an acceleration of 9.91 ms^{-2}. The force of drag the car experiences can be calculated with the equation,

$$F_{\text{drag}} = \frac{1}{2} C_d \rho A v^2 \tag{1}$$

Where C_d is the coefficient of drag, ρ is the mass density of air, A is the area moving through the air and v is the velocity. We will calculate F_{drag} here using the maximum velocity for v; this worst-case scenario ensures that the computed thrust will be sufficient to overcome resistance throughout acceleration. Using $C_d = 0.3$, $\rho = 1.29$ kgm^{-3} [4], $A = 2.58$ m^2 [5], and $v = 23$ ms^{-1}. The force of drag is calculated to be 264.09 N. Taking drag and thrust to be the main forces acting on the car, Newton's second law can be written as,

$$F_{\text{thrust}} - F_{\text{drag}} = ma \tag{2}$$

This equation can be rearranged to find $F_{\text{thrust}} =$ 17.76 kN using $m = 1765$ kg [5]. This thrust can

v_e ($\mathrm{m\,s^{-1}}$)	I_{sp} (s)	$\dot{m}$ ($\mathrm{kg\,s^{-1}}$)	m_p (kg)	P_{exhaust} (MW)	P_{prop} (MW)	Prop. % of mass
500	50.99	35.52	106.56	4.44	6.34	6.04
1000	101.97	17.76	53.28	8.88	12.69	3.02
2000	203.94	8.88	26.64	17.76	25.37	1.51
3000	305.91	5.92	17.76	26.64	38.06	1.01

Table 1: Propellant requirements, power, and specific impulse for different exhaust velocities.

be further analysed by treating it as a propellant-based system; the power output can be modelled assuming a rocket-type propellant is used. The rocket thrust equation, ignoring the nozzle pressure for simplicity, can be written as,

$$T = \dot{m} v_e \tag{3}$$

Where T is the thrust, $\dot{m}$ is the mass flow rate of the propellant and v_e is the exhaust velocity. Considering a car can go from maximum boost to none in ~ 3 seconds [3], we set $t_{\text{burn}} = 3$ s. The total propellant mass used can be expressed as $m_p = \dot{m} t_{\text{burn}}$. The kinetic power of the exhaust can be written as,

$$P_{\text{exhaust}} = \frac{1}{2}\dot{m} v_e^2 = \frac{1}{2} T v_e \tag{4}$$

Showing that a higher exhaust velocity carries away more energy even if the mass flow is smaller. A factor of efficiency can also be added in due to real propellants not being 100% efficient, a standard efficiency of engines of these types can range from 40 - 70% [6], and for these calculations we will use 70%. Therefore the power required from the propellant, P_{prop} needs to be higher than that required for the thrust. This can be calculated by dividing the power required at the exhaust, P_{exhaust}, by the propellant efficiency, η_{prop} (70%). Using these equations in conjunction with the thrust already calculated, propellant systems were modelled with varying exhaust velocities. Exhaust velocities in rocketry are more commonly referred to as a specific impulse, I_{sp}, which can be found by simply dividing the exhaust velocity by the standard gravitational acceleration, g. Results can be seen in Table 1.

Real-World Feasibility

Comparisons to real-world engines/thrusters are not unfeasible for the results obtained in Table 1. Novart's Hyperion Motor [7] is an example with a specific impulse of 275 s and a thrust of 10 kN. Another more well-known example is SpaceX's Kestrel engine that can be seen in the second stage of the Falcon 1 Launch Vehicle [8], displaying 31 kN of thrust and a specific impulse of 325 s. Although real-world engines can be compared to our results, several simplifications were made in the calculations used to find the thrust and power. For example, the engine's weight was not included and if it was, it would lead to an increased required thrust. Also the density of the in-game atmosphere in *Rocket League* was assumed to be equivalent to that of Earth, though this cannot be confirmed. Forces such as rolling friction were also considered negligible, even though they would have a minor effect on the actual thrust calculation.

Conclusion

It was concluded that the thrust system depicted in *Rocket League* is not entirely unrealistic. Simplified thrust calculations yielded a required force of 17.76 kN, which was modelled as a propellant-based system to find the power required for varying exhaust velocities. The resulting values were comparable to real-world engines such as Novart's Hyperion motor [7] and SpaceX's Kestrel Engine [8]. Table 1 also illustrates the trade-off between propellant mass and exhaust velocity, highlighting a choice between a higher-powered, lighter system and a lower-powered, heavier one.

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