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P3_5 "The Expanse" Science or fiction?

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Abstract

In this paper we discuss and explore the feasibility of the propulsion and energy sources in the series *"The Expanse"* by means of discussing if the vessel could feasibly carry the reaction mass required to produce the energy the drive consumes, assuming a high efficiency of 95%. We find that the series is well seated in physics and these vessels could feasibly carry the fuel required. In the case of the MCRN Tachi: assuming the tanks can hold $\sim 20\,\mathrm{t}$ of reaction mass the ship could burn at $0.3g$ for at least 2 months before running out of fuel.

Introduction

"The Expanse" is a science fiction TV series based on the books by James S. A. Corey [1], both the TV and book series are stated to be *"reasonably well seated in physics"*. In this paper we intend on proving whether this series is actually well rooted in physics, by looking at propulsion method of the vessels in the series. We are only going to calculate the energy required for this propulsion, assuming that they have harnessed the power of nuclear fusion well (to $\sim$ 95% efficiency), and whether the vessels could feasibly carry the amount of reaction mass required. Throughout this paper when we refer to the series we are referring to both the books and the TV series as these are synonymous with one-another.

Method

To investigate the propulsion systems within *"The Expanse"* we need enough in-scene information to construct our calculation. The scene we have chosen to use is in the first book when the MCRN Tachi escapes an exploding ship. In the scene it is stated that the hero crew underwent a "high-g" burn: burning at 12g for *"nearly half an hour"* (page 239) [1]. For this calculation we are going to use a reference frame at the instant the burn is initiated making the initial velocity zero. To calculate the energy required we will use kinetic energy Eq.(1) and the suvat equation Eq.(2) to calculate the energy the on-board fusion reactor needs to produce [2].

$$E_{kinetic} = \frac{1}{2}mv^2 \tag{1}$$

$$v = u + at \tag{2}$$

Where $E_{kinetic}$ - kinetic energy, v - final velocity, u - initial velocity, a - acceleration, m - mass, t - time. Using the information given in the book we know the MCRN Tachi is capable of a short duration maximum burn of $\sim 20\,\mathrm{g}$, and sustained maximum burn of $12\,\mathrm{g}$, with an assumed dry mass of $\sim 250\,\mathrm{t}$ (page 761) [1]. In the case of this escape scene we are going to assume a constant acceleration of $12g \approx 120\,\mathrm{ms}^{-2}$, and that this burn is exactly 30 minutes. Next we compare the energy calculated to the energy output of helium fusion (the series' fusion fuel) at $\sim 95\%$ efficiency, Eq.(3).

$$ {}^{3}_{2}He + {}^{4}_{2}He \longrightarrow {}^{7}_{4}Be + \gamma \qquad (3) $$

Results & Discussion

Final velocity after the burn we found $v \approx 220\,\mathrm{kms}^{-1}$ using Eq.(2). Then we found a target energy required for 12 g burn for 30 minutes to be $E_{kinetic} \approx 6 \times 10^{15}\,\mathrm{J} \approx 2\,\mathrm{Twh}$ from Eq.(1). Next we calculate the energy released per reaction from the fusion and compare this to the rate at which we must *"burn"* produce the energy consumed in the 30 minute manoeuvre; using the mass deficit formula Eq.(4)[3].

$$ \Delta m = m_{initial} - m_{final} \qquad (4) $$

We calculated the mass deficit to be $\sim 2 \times 10^{-3}\,\mathrm{u} \approx 2 \times 10^{6}\,\mathrm{eV/reaction}$. This is the calculated energy released from one reaction so we multiplied this by the amount of reactions that 1 kg of reaction mass would provide; the energy released per unit mass to be $\sim 8 \times 10^{9}\,\mathrm{Wh/kg}$ which means the reaction mass burnt in this escape scene is $\sim 250\,\mathrm{kg}$. If we assume the burn to energy ratio is constant, the efficiency of the energy transfer from reactor to the engine is completely (100%) efficient, and for simplicity the mass of the MCRN Tachi remains constant, since mass fuel burnt is less than 1% vessel mass. We find that the ship uses $\sim 500\,\mathrm{kg/hour}$ at 12 g. Hence we can say that to sustain a burn of 0.3 g, the standard cruising burn in the series [1], will burn fuel at a rate of $\sim 13\,\mathrm{kg/hour}$. In the universe the ships decks are stacked on top of one another like a tall office building with the engine at the bottom allowing for linear thrust to create artificial gravity. 0.3 g is chosen in the series for comfort as many citizens have lived their entire lives in lower than Earth gravity. In the series it is common for long duration burns in the order of months, calculating the required *"reaction mass"* for a two month duration trip to be $\sim 20\,\mathrm{t}$ of fuel. This number isn't actually that massive when putting this full tank size into perspective through comparison to % mass of fuel to mass of vehicle; MCRN Tachi mass is $\sim 250\,\mathrm{t}$ - burning $\sim 20\,\mathrm{t}$ of fuel in a *"standard"* journey which is $\sim 10\%$ fuel by mass. Lets argue the average car is $\sim 1.5\,\mathrm{t}$ and uses $\sim 60\,\mathrm{L}$ of fuel given the density $\rho_{fuel} \sim 1\,\mathrm{kg/L}$ this means for a car $\sim 5\%$ fuel by mass similar to the MCRN Tachi, proving the carry ratio is not too extreme for the ship.

Conclusion

We have found that the energy required to accelerate the MCRN Tachi at 12 g for 30 minutes to be $\sim$ 2 Twh, which is feasible with a highly advanced nuclear fusion reactor *"burning"* Helium-4 & Helium-3 (the fuel in the series [1]) into Beryllium-7 at 95% efficiency. We found a maximum burn rate of $\sim 500\,\mathrm{kg/h}$, and a *"standard"* burn rate of 13 kg/h meaning the vessel could burn at 0.3 g for up to two months, only using $\sim$ 20t of fuel. The vessels do not burn an incomprehensible amount of fuel compared to vessel mass; similar in-fact to fuel mass percentage of a standard car, and could well within reason be stored in internal tanks within the hull of the ships. Hence we agree that the series is well rooted in physics, given our assumption of the efficiency of the reactor. In this simple energy calculation we have neglected to include or explore any other feasibility's, including the use of the chosen fuel (helium-3) given scarcity of this on Earth. Nor have we considered the energy requirements of the life-support and other subsystems on the MCRN Tachi, however this is safe to assume negligible compared to the massive energy requirements of the propulsion system.

References

[1] J. S. A. Corey, *Leviathan wakes*. Orbit New York, 1st ed. ed., 2011. Pages i–239–761.

[2] P. A. Tipler, *Physics for scientists and engineers : with modern physics*. New York, NY ; Basingstoke: W.H. Freeman, 6th ed.. ed., 2008.

[3] K. S. Krane, *Introductory nuclear physics*. New York, NY: Wiley, 1988.