The Electromagnetic Drive: Cyclotron motion applied to spaceflight

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Abstract: In this research note it is proposed how the equilibrium between the Lorentz force and the centrifugal force in a crewed spacecraft acting as a tidally stabilised skyhook could prevent the spacecraft form deorbiting and reaching unbearable accelerations. A pair of superconducting electromagnetics would produce a constantly-increasing Lorentz Force, which would cancel the centrifugal force while producing the necessary acceleration. To avoid the effects of the centrifugal force, the crew would have to be immersed in water tanks. The proposed drive forms part of the Solar One project, a program intended to design the first crewed interstellar spacecraft.

Key-words: Lorentz force, centrifugal force, electromagnetic propulsion, skyhook, space tether, cyclotron motion.

1. Introduction

Space tethers are long cables which can be used for propulsion, momentum exchange, stabilization and attitude control, as well as maintaining the relative positions of the components of a large dispersed satellite or spacecraft sensor system.

One type of space tether is the skyhook. Specifically, a non-rotating skyhook is a vertical gravity-gradient stabilized tether.

Here I wish to discuss how a balance between the Lorentz force (which would act as the centripetal force) and the centrifugal force could provide a high yet bearable acceleration to a crewed skyhook-style spacecraft.

The idea is to attempt applying cyclotron motion for charged particles in a magnetic field to a crewed spacecraft orbiting either the Sun or Jupiter. A spacecraft orbiting at scape velocity would leave the desired orbit, and the Lorentz force would gradually weaken.

A possible balance between forces could be achieved with the proper configuration of a system formed by a pair of superconducting electromagnets,

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one on each side of the spacecraft. These elements would provide the Lorentz force to the spacecraft while cancelling the centrifugal force.

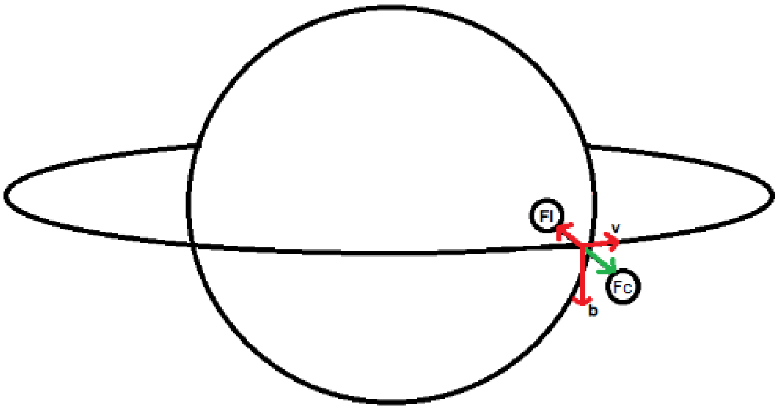

Figure 1: Balance between the Lorentz force (Fl) and the centrifugal force (Fc)

The electromagnetic system would constantly increase the Lorentz force in order to both prevent the spacecraft from deorbiting while it is being accelerated, and from producing an unbearable G-force to the crew. In theory, if the spacecraft is kept under a controlled constant acceleration, relativistic speeds could fall within the realm of plausibility.

2. Cyclotron motion around the Sun

To calculate the Lorentz force needed to keep the spacecraft in orbit and produce the accelerate desired, we first need to determine the field strength at the geostationary orbit. Considering that the Sun's Magnetic Dipole Moment is 3.5e+24 T.m^3, at 1.15 AU we obtain the following field strength:

$$\begin{aligned} B &= \frac{M}{r^3} \\ &= \frac{3.5\mathrm{e}24}{172{,}453{,}438{,}000^{\,3}} \\ &= 6.82\mathrm{e}-8 \ \text{Tesla} \end{aligned} \tag{1}$$

Water immersion increases tolerance to acceleration as the acceleration forces are equally distributed over the surface of the submerged body (Wood, 1991). In theory, using a liquid-filled capsule or tank only one centimetre thick between the astronauts and the shell would allow acceleration hundreds of G high (Rossini, 2007).

However, here I propose to greatly increase the size of such tank in a way that the crew only suffers the potential effects of an acceleration of 4 g. If the crew is immersed in a water tank of 900 cubic meters during 8.49 hours, the following acceleration would be needed to reach 1c:

$$\begin{aligned} F &= \frac{v_1 - v_0}{t} \\ &= \frac{300,000,000 - 10,000}{30,590} \\ &= 1,000\ g \end{aligned} \tag{2}$$

At 1.15 AU, the centrifugal force at the speed of light would be the following:

$$\begin{aligned} F &= \frac{m \cdot v^2}{r} \\ &= \frac{1,000,000 \cdot 300,000,000^2}{172,453,438,000} \\ &= 521,880,000,000\ N \end{aligned} \tag{3}$$

Now we have to calculate the necessary force to produce an acceleration of 1,000 g for the spacecraft:

$$\begin{aligned} F &= m \cdot a \\ &= 1,000,000 \cdot 9,806.65 \\ &= 9,806,650,000\ \mathrm{N} \end{aligned} \tag{4}$$

To cancel the centrifugal force of 5.2e11 Newton, the electromagnetic system would have to produce an opposite Lorentz force equally strong. However, the Lorentz force has to be 9.8e8 Newton higher than the centrifugal force in order to produce the acceleration desired. The total necessary charge would be the following:

$$
\begin{aligned}
F &= q \cdot v \cdot B \cdot \sin(\alpha) \\
q &= \frac{F}{v \cdot B \cdot sin(\alpha)} \\
&= \frac{531{,}686{,}650{,}000}{300{,}000{,}000 \cdot 0.0000000682 \cdot \sin(90)} \\
&= 25{,}986{,}639{,}785 \text{ C} = 7{,}218{,}511 \text{ Ah}
\end{aligned} \tag{5}
$$

3. Discussion

The crew would need to immersed in a physiological water solution within a non-expandable rigid container. The Advanced Concepts Team of the European Space Agency concluded in a 2007 study that this set-up could presumably allow the crew to withstand accelerations higher than hundreds of G (Rossini, 2007). However, in theory, an increase in the size of the water tank could distribute the forces even further.

The crew would have to withstand a g-force of 1,000 g. If we consider that the volume of a human is about 0.0664 cubic meters, and that the crew could withstand a maximum acceleration of 4 g during several hours (Poljak, 2019), the water tank in which the crew is immersed would have a weight of 900 tons. In principle, this would avoid the need of providing liquid ventilation to the crew, which is a technology not available at the moment.

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