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P5_6 The SpinLaunch Orbital Accelerator

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Abstract

In this paper we analyse the proposed SpinLaunch orbital accelerator. Despite successful test launches with the sub-orbital accelerator, critics have questioned the full-scale feasibility. The analysis in this paper determines the carbon fibre tether used in the accelerator is suitable, requiring a thickness ranging between 5.5 and 11 cm to support the projectile discussed in this paper.

Introduction

SpinLaunch is a company aiming to revolutionise how satellites and payloads are sent into orbit by using an accelerator to launch satellites. The company claims there are "industry plans to launch ten times the number of satellites over the next decade" and that their accelerator can enable "zero emission" launches, allowing for a more sustainable future [1].

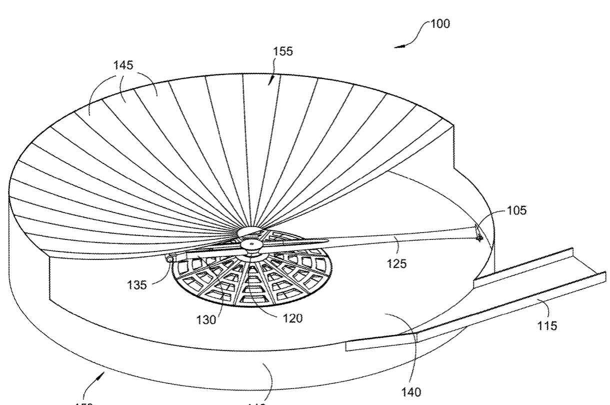

Figure 1: Patented design of the orbital accelerator, displaying the payload (105), high-strength carbon fibre tether (125) and counterweight (135) [2].

The orbital accelerator is yet to be constructed, however it will be a scaled-up version of the sub-orbital accelerator used for test flights. Figure 1 shows the design patent of the accelerator. The proposed dimensions are as follows: an accelerator diameter of 100 m, a carbon fibre tether of length 45 m (assumed to be T1000 carbon fibre, the strongest known carbon polymer at the time of design), a projectile with a total mass of 9500 kg (inclusive of 200 kg payload), and a projectile length of 3 m [3, 4, 5].

The calculations in this paper investigate critiques of SpinLaunch by evaluating the feasibility of the accelerator, with particular focus on the forces experienced by the carbon fibre tether.

Calculations

Due to the nature of a centrifuge, the tether will be subjected to high tensile forces which it must be able to withstand. The centripetal force on the tether can be calculated using the equation below for circular motion:

$$F = \frac{mv^2}{r} \tag{1}$$

where 'F' is the force experienced by the tether, 'm' is the mass of the projectile (9500 kg), 'v' is the launch velocity of the projectile (2222 m

s^{-1}) and 'r' is the radius of motion (45 m) [3]. For the discussed scenario, this equates to a force of 1.10×10^9 N. To calculate the minimum required dimensions of the tether to sustain the forces required, the equation below for the area of the tapered tether is used [6].

$$A_x = m\,\frac{v^2}{\sigma\,r}\exp\left[\frac{v^2\,\rho}{2\,\sigma}\left(1-\frac{x^2}{r^2}\right)\right] \qquad (2)$$

In the equation for the minimum area of the tether 'A_x', 'σ' is the tensile strength of the material (6.37 GPa), 'ρ' is the density of the material (1800 kg m^{-3}) and 'x' is the distance from the centre of the rotation [5].

At the centre of rotation, $x = 0$, the cross-sectional area of the tether must be at least 0.329 m^2 and 0.164 m^2 at the point connecting to the payload where $x = 45$ m. Assuming a rectangular cross-sectional area and the tether width equal to the length of the projectile used in testing, 3 m, these cross-sectional areas correspond to 0.11 m and 0.055 m heights respectively [4].

Discussion

The tether dimensions calculated in this paper are reasonable given the full scale of the accelerator, with additional room to increase these dimensions to include a 'safety region'. However, there is another issue that faces this venture. When a spinning object's weight is unevenly distributed it begins to vibrate, this is the mechanism for vibration feedback in many devices [7].

Once the payload is released, vibrational forces threaten to unbalance the centrifuge. As the projectile is released, a counterweight falls onto a reinforced pad. This increases the reset period of the accelerator dramatically as the counterweight must be reset and any debris cleared up. There is also a significant amount of energy wasted as the energy required to accelerate the counterweight is equal to that of the projectile. To negate this wastage, we propose a second projectile in place of this counterweight, released within one-half revolution of the first, minimising vibrations.

Conclusion

The calculations in this paper prove that SpinLaunch's accelerator, for launching satellites from the ground, is not restricted by the forces subjected to the tether. Given a presumed tether width of 3 m, a tether thickness greater than 5.5 cm will support the projectiles discussed in this paper.

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