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A4_14 Artificial gravity of Interstellar

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Abstract
In this paper, we discuss the concept of generating an "artificial gravity" by rotating a ring in outer space, a similar method to that seen in the film Interstellar. We found that due to a constant rotation rate, there will be a difference in acceleration at different regions of the spacecraft. The difference of acceleration between the head and the feet is 5% which is marginal at the outer ring of the spacecraft. However, there may be motion sickness as well as health affects due to a long term flight.

Introduction

Interstellar is a science fiction film that was released in 2014. The film is mainly set on the spacecraft "Endurance", where the crew is sent into space to find another habitable world to colonise before the Earth is uninhabitable due to blight. The spacecraft "Endurance" uses the concept of rotating the outer ring to generate an "artificial gravity" which the crew uses for their time in space. The aim of this paper is to go through the calculations of creating this effect and discussing the implications of the different accelerations experienced throughout the spacecraft.

Method

The "Endurance" uses the method of rotating the outer ring of the spacecraft to generate an acceleration perpendicular to the direction of motion. This is known as centrifugal force, which is a relative pseudo-force that acts parallel to the axis of rotation. This allows the crew within the ring of the spacecraft to experience a force acting downwards which can be similar in magnitude to the acceleration due to gravity at the Earth's surface. This can be seen in Figure 1 as the effect of centripetal force is acting in the opposite direction to the centrifugal force, therefore we can find the magnitude of the centrifugal force F_c using Equation (1) as stated in [1]:

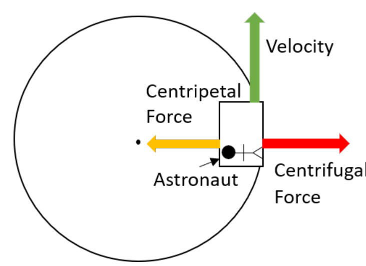

Figure 1: Diagram illustrating centripetal and centrifugal forces

$$Fc = \frac{mv^2}{r} \quad (1)$$

Where m is the mass of the object rotating, v is the tangential velocity, and r is the radius of rotation. For this investigation, we want to find the acceleration acting parallel to the axis of rotation. We can rearrange Newton's second law of motion and substitute into Equation (1) to give the centrifugal acceleration a_c as shown in Equation (2):

$$a_c = \frac{v^2}{r} \tag{2}$$

Assumptions

The assumptions made in this paper for the dimensions of the spacecraft and rotational velocity are given as 64 m as the diameter of "Endurance" spacecraft and 5.5 rpm (revolutions per minute) is the rotation rate [2]. We are also making the assumption of a height of a human to be 1.75 m [3] and the feet will be placed at the outer edge of the ring which can be seen in Figure 1. We will need to convert rpm to m s^{-1} for the use in Equation (2). This is done using Equation (3), where N_{rpm} is the number of revolutions.

$$v_{m\ s^{-1}} = \frac{2\pi r}{60} N_{rpm} \tag{3}$$

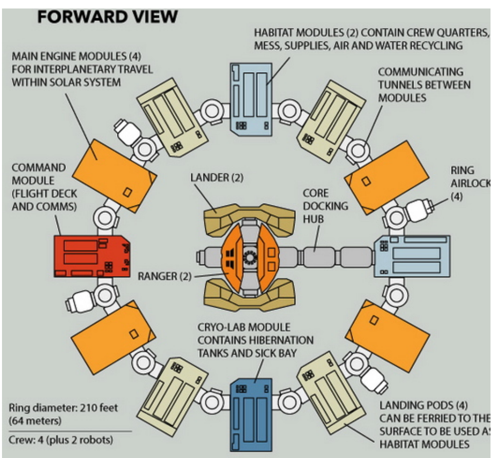

Figure 2: Design of the Endurance [2]

Results

To calculate the acceleration, we had to convert 5.5 rpm to m s^{-1}, using Equation (3), which is dependant on the radial distance of the object rotating and found the velocity to be 18.43 m s^{-1} for the radius of 32 m. When using Equation (2) to find the acceleration at the edge of the spacecraft, we found the apparent acceleration to be 10.6 m s^{-2}. This could be compared to the acceleration experienced at your feet. However, when calculating the acceleration experienced at the height at your head, using a radius of 30.25 m, the velocity will be decrease which in turn decreases the acceleration experienced at your head. We calculated the velocity to be 17.42 m s^{-1} and a acceleration of 10.03 m s^{-2}. Therefore there is only a 5% difference experienced between the top of your head to your feet if we are using the height of 1.75 m [3]. A major difference of acceleration would be experienced at the centre of the spacecraft in "Ranger 2" which can be seen in Figure 2. The radius of rotation will be 1.75 m if we assume a standing position in the "Ranger 2" which will give a velocity of 1.008 m s^{-1} and an acceleration of 0.581 m s^{-2} which is a micro-gravity environment.

Discussion

For the long space travel they conduct over 7 years in transport to Saturn, we do not know what the real-life affects of a varying artificial gravity will do for humans in space. The concept of creating a pseudo-gravity is important as a lack of it can cause muscle degradation and complications to the health of the astronauts [4]. To change the radius of the ring to be smaller would increase the difference of acceleration between the head and the feet which could be a problem that would need to be investigated, this may also increase motion sickness effects [5].

Conclusion

In conclusion, the method for creating artificial gravity by rotating a outer ring of a spacecraft is credible with a acceleration generated that is close to what we experience on Earth's surface with a 5% difference between the head and feet. The concept could be used in real-life applications in space missions to Mars and exploration to outer solar system with a long period in space.

References

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