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Did Mark Watney make it Home from Mars?

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Abstract
At the conclusion of the 2015 film 'The Martian' astronaut Mark Watney cuts a hole in his space suit, and uses the escaping air as a mini thruster in order to make it to his rescuers. This paper finds that the air would not provide enough force to propel Watney with enough acceleration to make it home.

Introduction

In the 2015 film 'The Martian', Matt Damon's character Mark Watney is abandoned on Mars after a dust-storm forces his team mates to leave the planet. As well as surviving the storm, Watney is able to grow potatoes, communicate with Earth, and survive alone for around 480 days. Unfortunately during his rescue, Melissa Lewis cannot quite reach Watney and it looks as though the rescue mission will fail. Incredibly Watney decides to pierce his space suit, and uses the escaping air as a thruster travelling 312 m to the awaiting Lewis [1]. This paper will investigate whether the pressure in Watney's suit is enough to travel that distance as quickly as shown in the film.

Assumptions

We are assuming that Watney's suit can be pierced to release air, without being resealed which is a concern of some Astronauts commenting on the film [2]. The suit is assumed to be pressurised to 2.4 kPa of pure oxygen [3]. We assume that Watney travels the 312 m distance in a straight line, and corrections are made only by Lewis (which is accurate to the film) in order to intercept with Watney. It is shown that the hole cut into the glove is roughly 1 cm in diameter, and can be assumed to be round [1].

Force exerted by escaping gas

The gas in Watney's suit is pressurised to 2.4 kPa, and is escaping from a hole of area 7.85×10^{-5} m^2 [1, 3]. The force exerted in this case is found by equation 1:

$$F = PA \tag{1}$$

$$F = 2400\ \times 7.85 \times 10^{-5} = 0.19\ N$$

It can be assumed that Watney has a mass of 60 kg (less than average due to reduced diet and surface gravity), and the space suit worn has a mass of 9 kg [4]. We can use the equation 2 to work out the acceleration due to the escaping gas:

$$a = \frac{F}{m} \tag{2}$$

$$a = \frac{0.19}{69} = 0.003\ ms^{-2}$$

As acceleration will be constant, an equation of motion (equation 3) can be used in order to find whether this acceleration is high enough for Watney to reach safety in time:

$$t = \left(\frac{2d}{a}\right)^{0.5} \tag{3}$$

$$t = \left(\frac{2 \times 312}{0.003}\right)^{0.5} = 456\ s$$

Considering the notable difference in orbital velocity between Watney and the ship, 456 seconds is much too long, and so these assumptions would not have resulted in Watney reaching the ship.

Using the acceleration shown in the film

In the film, the total time taken to travel 312 m was 37 seconds [1]. The two main assumptions in the previous model were Watney's mass, and the pressure of his suit. Since the weight chosen was conservative it cannot be assumed that his mass was any lower than previously stated, therefore the pressure of his suit must have been higher. Using equations 1-3 and values already stated, the pressure of Watney's suit in the film can be found based on his acceleration and force. Acceleration is found first using a rearranged equation 3:

$$a = \frac{2d}{t^2}$$

$$a = \frac{2 \times 312}{37^2} = 0.46\, ms^{-2}$$

By a rearranged equation 2, the force required to accelerate Watney is found to be:

$$F = ma$$

$$F = 69 \times 0.46 = 31.7\, N$$

Finally, pressure is found using a rearranged equation 1:

$$P = \frac{F}{A}$$

$$P = \frac{31.7}{7.85 \times 10^{-5}} = 396{,}000\, Pa$$

Almost 400 kPa of pressure is approximately equal to 4 atmospheres [5]. As well as this being extremely uncomfortable, Watney would be suffering from oxygen toxicity as the air is pure oxygen [6].

Conclusion

These calculations have shown that under normal operating pressures, the force generated would not be enough to allow Watney to travel the 312m to his rescue. In order for him to accelerate as quickly as shown in the film, the pressure of the suit must be very high - enough that Watney would be at risk of oxygen toxicity.

References

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