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P5_1 You can fly

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Abstract

Many humans dream of flying like a bird. Although it is not possible on Earth, it is on Titan. This paper explores the dimensions of a wingsuit allowing a human to easily take-off from the surface of Titan. It was calculated that the wing area would be approximately 4.7m^2 assuming an initial run up speed of 6m/s. This value is larger than the average wingsuit wing area of 1.4m^2. For this area the human will have to run at a speed of 11m/s, which has only been reached by a small number of humans.

Introduction

J. M. Barrie comments in his novel *Peter Pan* "the moment you doubt whether you can fly, you cease for ever to be able to do it" [1]. However, if you live on Saturn's largest moon Titan this may not be the case: you can fly as long as you have the right equipment! This paper will explore the physics of human flight on Titan.

Humans have already designed equipment which allows us to fly through the air on Earth: a wingsuit. This special jumpsuit is an aerofoil which allows a human to fly through the air from gravity induced vertical free fall [2]. This paper will look at the dimensions required for using a wingsuit to take-off from the surface of Titan.

Theory

As the wing on the wingsuit acts as an aerofoil, to begin our analysis it is useful to use Bernoulli's equation for an incompressible fluid, which is

$$P_1 + \frac{1}{2}\rho {v_1}^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho {v_2}^2 + \rho g h_2, \quad (1)$$

where P_1 and P_2 are the pressures below and above the wing respectively, ρ is the density of the air, v_1 and v_2 are the speed of the air across the lower and upper surface of the wing respectively, g is the acceleration due to gravity and h_1 and h_2 are the heights above a certain reference surface. We modelled the atmosphere of Titan as an incompressible fluid as this is often done for the aerodynamics of Earth's atmosphere. Figure 1 shows the change of the air's streamlines around an aerofoil.

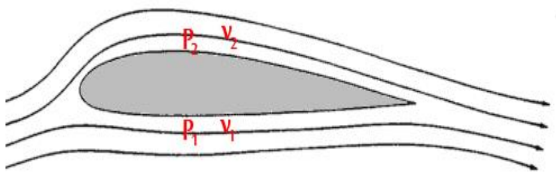

Figure 1 - the change in streamlines around an aerofoil.

Taking the reference surface to be the surface of Titan we can equate h_1 and h_2 as the aerofoil is relatively thin and facing horizontal to the ground during take-off. Therefore, any difference between the heights is negligible. We re-arranged equation (1) so that

$$P_1 - P_2 = \frac{1}{2}\rho({v_2}^2 - {v_1}^2). \quad (2)$$

If we set m to be the ratio of the streamline path of the air above the aerofoil to that below the aerofoil, such that

$$m = \frac{v_2}{v_1}, \quad (3)$$

then equation (2) can be re-arranged to form the equation

$$P_1 - P_2 = \Delta P = \frac{1}{2}\rho {v_1}^2(m^2 - 1). \quad (4)$$

Furthermore, using the relation

$$\Delta P = \frac{Mg}{A}, \quad (5)$$

where M is the mass of the object and A is the surface area of the aerofoil, we can manipulate equation (4) to be in terms of area such that

$$A = \frac{2Mg}{\rho {v_1}^2(m^2-1)}. \quad (6)$$

Analysis

Our aim was to calculate the area of the wing which would help a human take-off from the surface of Titan. The calculated value can be compared to the wing area of a common wingsuit to see if it is logistically possible for flight from Titan to happen.

To do this we assume a man of average weight $M = 70$kg. The density of air at the surface of Titan is given to be $\rho = 5.5$kg/m^3 and the acceleration due to gravity has been calculated to be $g = 1.4$m/s^2 [3]. The value for m for an aerofoil can be assumed to be 1.1 [4]. Large birds must have an initial speed to be before take-off to generate enough lift [5]. Assuming a wingsuit would work in a similar way for take-off, we assume that the man will take off at $v = 6$m/s, the average human running speed. Substituting these values into equation (6), we calculated the area of the wings to be approximately 4.7m^2.

Discussion

On average the wingsuit wing area is approximately 1.4m^2 [2], noticeably much smaller than the calculated value above. The difference could suggest that the take-off speed is too slow for a human to realistically take-off and carry on flying on Titan. To resolve this issue, we re-arranged equation (6) in terms of the take-off speed,

$$v = \sqrt{\frac{2Mg}{\rho A(m^2-1)}}. \quad (7)$$

We used 1.4m^2 as the area of the wing and calculated that the man will have to take-off at a speed of 11m/s. This speed has been reached but only by the fastest human runners, for example, Usain Bolt, who ran almost 12m/s [6]. For an average human to take off with the standard wingsuit they would require some sort of propulsion device to give them enough speed to take-off. However, this suggestion arguably defeats the point of a human flying unaided with technology like a bird.

A wingsuit is designed to reach speeds of up to 36m/s [2]. We used equation (6) to calculate the area of the wing that would be needed for this speed. The area required for a wing to fly on Titan after take-off is therefore approximately 0.1m^2. This calculation shows how effortless and relatively easy it is for a human to fly on Titan like a bird, without any sort of propulsion device.

Furthermore, for humans who aspire to fly a lot more work would need to go into preparing a human to fly on Titan. The temperature of the atmosphere is approximately 94K [3]. However, once this issue is resolved, it can be seen that it is possible to fly unaided on Titan.

Conclusion

In this paper, we have shown that it is possible for a human to fly on Titan assuming they wear a wingsuit with a wing area of 4.7m^2. The human will need to begin by running to a speed of at least 6m/s to take-off. For a wingsuit wing area of 1.4m^2 the human will have to run at a speed of 11m/s, which has only been reached by a small number of humans.

Further study can look into the Physics of flying after take-off on Titan, including the dynamics of propulsion through the air.

References

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