Journal of Physics Special Topics

An undergraduate physics journal

A1_3 Flying on the Moon

S. Toomer, J.P. McCarthy, L. Connolly, M. Howard, N. Rahimi

Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH

December 6, 2018

Abstract

Given the lesser gravity experienced on the Moon, if a large enough base with an Earth like atmosphere were constructed, it may be theoretically be possible for humans to fly like a bird using synthetic wings. In this paper, we calculated the area of said wings required to achieve soaring flight to be 6.05 ± 2.46 m^2. The value for flapping (bird like) flight may be lower, but is beyond the scope of this paper.

Introduction

The dream of flight has been a part of human history for millennia and has only been achieved relatively recently. The main factor holding us back is the weight of the human body. The acceleration due to gravity on the Moon is only 1.62 ms^{-2} [1], around 16.5% of that of Earth. This means you would only have to produce enough lift to counteract around a sixth of your Earth weight. This means that it is very feasible, given large enough wings and an Earth like atmosphere (contained within some sort of lunar base), that a human would be able to fly like a bird on the moon. In this paper we will find the size that these wings must be in order to achieve soaring flight, as the mechanics of flapping flight are much more complicated and beyond the scope of this paper.

Theory

When in flight, there are four forces that act upon an object. These are weight, lift, drag and thrust. Modelling a human as a particle with wings of a negligible air resistance, with a combined mass of 80.0 kg, weight is the main force that needs to be overcome. This means that in order to avoid falling, the lift generated must be greater than or equal to the weight of the human. Using Eq. (1) and a value for m of 80.0 kg, the lift must be greater than or equal to 130 N.

$$W = mg \tag{1}$$

The equation for the lift of a soaring body is shown below, as well as its rearranged form in terms of wing area. [2]

$$L = \frac{C_L \rho v^2 A}{2} \Rightarrow A = \frac{2L}{C_L \rho v^2} \tag{2}$$

Where C_L is the coefficient of lift, ρ is air density, v is the flow speed of the air over the wing and A is the wing area. This means that the minimum condition for flight to be possible is $L = W$ = 130 N. Most of the other variables are fairly easily ascertained, however the coefficient of lift is generally determined experimentally, which is beyond the scope of this paper. Many things can affect this value, but typically for an aerofoil, C_L = 1.40 [3]. For a comfortable breathable atmosphere on the base, air density should be similar to that of Earth. At 15.0 °C, the air density at sea level is 1.23 kgm^{-3} [4]. v is a bit trickier. Due to the low gravity on the moon it would be hard to build speed via a run up, so for the purposes of this paper, a delivery system providing 5.00 ms^{-1} of flow speed over the wing is assumed.

Results and Error

Entering these values int Eq. (2) gives us a wing area of 6.05 m^2. This means that each wing has an area of around 3.03 m^2, For easier visualisation of this value, if each wing has an average width of 1.50 m, the wings would together have a span of around 4.03 m. The error in this value is quite high, however, due to the number of estimates used in the calculation. Values for the coefficient of lift are generally defined by the shape of the wing, so this value can be said to have an error of no more than ±0.1 [3]. The value used for v is in essence an arbitrary estimate, it's error is also arbitrary. This means that the error must cover the range of potential air speeds over the wing. Due to this an error of ±1ms^{-1} was chosen to account for a decent range of possible air speeds arround the original estimate. Air density varies with temperature, so assuming in the climate controlled base, there is a temperature range of ±5°C, the error in ρ is ±0.02 kgm^{-3} [4]. This means the error in A can be found through Eq. (3)

$$\Delta A=\sqrt{\left(\frac{-2L}{C_L^2\rho v^2}\Delta C_L\right)^2+\left(\frac{-4L}{C_L\rho v^3}\Delta v\right)^2+\left(\frac{-2L}{C_L\rho^2 v^2}\Delta\rho\right)^2} \tag{3}$$

This results in an error of $\Delta A = 2.46$ m^2

Conclusion

In this paper we have found that the original premise is correct, it would be possible for humans to take non-powered flight in an aerated lunar environment. In order for soaring flight to be achieved the area of the wings must be 6.05 ±2.46 m^2. One thing to note is that the majority of the error in this value comes from the error in the estimate of v, meaning that the best way to improve the accuracy of this paper is to find a more concrete value for the flow velocity and its error. This value is fairly reasonable, and would result in a wingspan of around 4 m (see Results and Error section). This is just for soaring flight. If the method of flight used was a more bird like flapping, the wing area may be even lower, but that is beyond the scope of this paper.

References

[1] `https://en.wikipedia.org/wiki/Gravitation_of_the_Moon` [Accessed 27 November 2018]

[2] `https://www.grc.nasa.gov/www/k-12/airplane/lifteq.html` [Accessed 27 November 2018]

[3] `https://www.researchgate.net/figure/Typical-values-\\of-airfoil-maximum-lift-coefficient-for-various-fig2_273923634` [Accessed 30 October 2018]

[4] `https://www.engineersedge.com/calculators/air-density.htm` [Accessed 30 October 2018]