

A5_4 Hanging with Aang: Flying like the Last Airbender

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Abstract

In this paper we devise a model describing flight as depicted using gliders in Avatar: The Last Airbender. This allowed us to find the windspeeds needed to sustain level flight over a range of possible human masses. We found that for the show's protagonist, Aang, a windspeed of 15.11 ms^{-1} , was needed, and an average human would require windspeeds of 18.90 ms^{-1} .

Introduction

In the animated show Avatar: The Last Airbender [1], the main character Aang is able to fly using a glider. He does this by controlling the flow of air around it. In this paper we went about creating a model for the wind speed someone of a given mass would need to sustain level flight, by controlling air flow the same way Aang does. We then consider whether the model provides numbers which are within a reasonable boundary.

Method

When approaching the problem a number of assumptions were made. Firstly, the lift produced by the glider is applied to the center of mass for the system. Secondly, the model assumes that level flight has been reached when the lift on the glider and the weight of the person are equal. Thirdly, the diameter of the glider is 1.5 times Aang's height. Finally, the glider is assumed to be an aerofoil [2].

To construct a model for the wind speed required for flight based on the attached person's mass, we first had to form an initial equation for the balanced system. This was done by equating equations for lift and weight. Equation 1 shows

the equation for lift,

$$L = C_l \frac{\rho v^2}{2} A \quad (1)$$

where C_l is lift coefficient, ρ is air density, A is the wing area and v is the velocity. However, as our system is from the reference frame of the glider, v became wind speed. Equation 2 shows the equation for weight,

$$W = mg \quad (2)$$

where m is mass and g is gravitational acceleration. By equating Equation 1 to Equation 2 and then rearranging for v , Equation 3 is produced.

$$v = \left(\frac{2g}{\rho C_l A} \right)^{\frac{1}{2}} m^{\frac{1}{2}} \quad (3)$$

The only unknown constant in the equation is A but this can be calculated using our third assumption and Aang's height, h . In the show, the glider wings form a semicircle [1] which have a diameter, x . Based on the initial assumptions, $x = 1.5h$ can be substituted into the equation for the area of a semicircle to produce Equation 4.

$$A = \frac{9\pi}{32}h^2 \quad (4)$$

The model was then formed by plotting Equation 3.

Results

For calculating A , we used a value of Aang's height $h = 1.37$ m [3]. This produced a value of $A = 1.66$ m². The model could then be constructed using values of: $g = 9.81$ ms⁻², $\rho = 1.225$ kgm⁻³, $A = 1.66$ m² and finally $C_l = 1.65$. The value for C_l was based on the coefficient of lift of an aerofoil being approximately 0.11 per degree of angle of attack [4], with the angle taken to be 15 degrees. This was based on the maximum angle of attack for an aerofoil just prior to stalling [4]. When this function was plotted in R, it produced Figure 1.

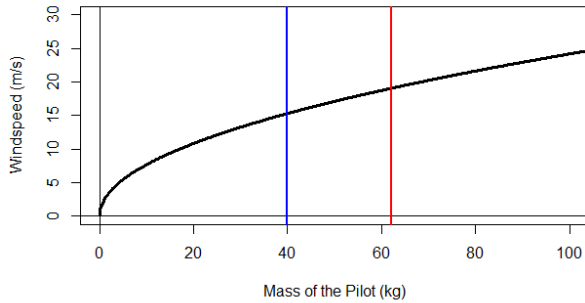


Figure 1: A plot of Equation 3 over a range of m values, black curve, with a blue vertical line showing Aang's mass, and a red one showing the mass of an average human.

Figure 1 includes 2 vertical lines. The blue line appears at $m = 40$ kg, which represents Aang's mass [3], and corresponds to a windspeed of $v = 15.11$ ms⁻¹. The red line appears at $m = 62$ kg, which represents average human mass [5], and corresponds to a windspeed of $v = 18.90$ ms⁻¹.

Conclusion

These windspeeds taken from the model are moderately strong. Using the Beaufort scale [6], to relate windspeed to observed conditions, these windspeeds are considered a high 7 and a low

8. A Beaufort level 7 is classed as a high wind and corresponds to winds able to sway trees and make walking difficult. A Beaufort level 8 is a classed as a gale and corresponds to winds able to break twigs off trees and make walking much more difficult. Although these values are not unreasonable windspeeds, it is worth considering our initial assumptions may have affected the model. Firstly, if lift were applied in the system to not directly oppose the weight acting on the centre of mass then the system would be unable to maintain the balance needed to fly. Secondly, the assumption of level flight does not account for the increased windspeed that would be required to take off. Finally, the assumptions that relate to the glider's physical properties, wing diameter and the aerofoil nature of the wing, affect A and C_l respectively and would affect the absolute values returned, and not the general shape of the plot.

In conclusion, the windspeeds that our model suggests need to be generated by a person to sustain flight are not outside a realistic boundary of windspeeds.

References

- [1] "Avatar: The Last Airbender", 2005, Nickelodeon
- [2] <https://tinyurl.com/y3j6oxfl> [Accessed 4 December 2020]
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- [6] <https://tinyurl.com/yyvo7pn9> [Accessed 4 December 2020]