Journal of Physics Special Topics

An undergraduate physics journal

A2 1 Fly You Fools! A Critical Look at Eagle-Based Aviation

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October 17, 2024

Abstract

We set out to determine the velocity the Great Eagles (*Aquila soron*) would need to physically fly. Particularly during the scene where Gandalf rescues Frodo Baggins and Samwise Gamgee from an erupting Mount Doom with the help of the Eagles. We determined that their stall speed was approximately 30 mph, which we found to be a feasible result.

Introduction

The Great Eagles of Tolkien's lore served as the heralds of Manwë, King of the Valar. In their most famous appearance, they came to the aid of Gandalf to help rescue Frodo and Samwise during the final act of *The Lord of the Rings* [1]. This provides a case study to examine the feasibility of the Great Eagles' ability to fly. In particular, the stall speed of the Eagles. The velocity at which an aerofoil starts to generate lift. To determine the stall speed, we can start with the lift formula [2], which can be re-arranged to make velocity the subject of the equation:

$$L = (1/2)\rho v^2 s C_L \Rightarrow v = \sqrt{\frac{2L}{\rho s C_L}} \qquad (1)$$

where L is given as the lift (the mass of the Great Eagle, Frodo and Gandalf times gravitational acceleration) in Newtons, ρ is the density of air (1.293 kg m^{-3}), s is the Wing Surface Area given in m^2, and C_L being the Coefficient of lift.

In this study, we assumed that the Great Eagles have a gait similar to the Golden Eagles (a species of raptor), which they are modelled after in the films. As such, we can use a dataset of measurements taken from African Raptors [3] to extrapolate the average mass and wing area of a Great Eagle. It should also be noted that this paper does not explicitly mention the square-cube law due to the use of real world data in our analysis. We assumed the flight muscles of birds could be scaled up to the sizes discussed in this paper, and that C_L is the same for Great Eagles as it is for Raptors, approximately one [4].

Wing Area & Body Mass

To determine the surface area of the wings, we fitted a 2^{nd} degree polynomial to our data set and extrapolated the wing area from the wingspan given in Tolkien's *The Silmarillion*, of thirty fathoms ($\sim$ 55 m) [5], as shown in Figure 1. Using the curve of best fit, we can extrapolate the wing surface area to be 908 m^2 from an approximate wing length of 27.5 m.

We can follow the same method to determine the mass via Figure 2, to be approximately 11080 kg for the Eagle. The masses of Frodo (27.7 kg) and Gandalf (71.3 kg) were derived from their heights in the films [6] and assumptions about the characters' BMI, being a healthy 22 for Gandalf and 18 for a malnourished Frodo.

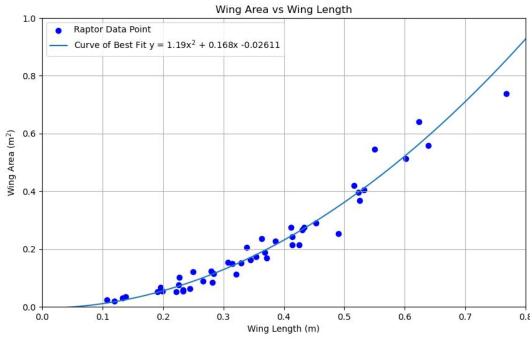

Figure 1: A graph of wingspan vs surface area of raptors, with a curve of best fit. Where wing length is taken to be the length of a single wing, approximately half of the wingspan.

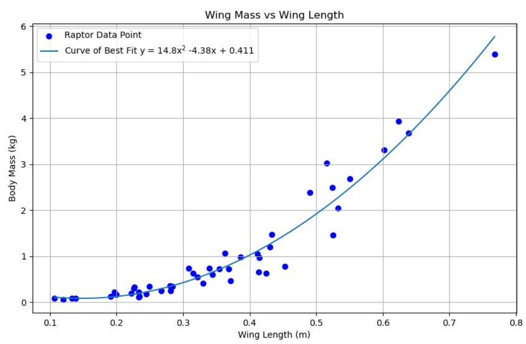

Figure 2: A graph of wingspan vs mass of raptors, with a curve of best fit

We can then calculate the total lift mass to be 11179 kg and multiply this by the earth-like acceleration on Middle-earth to get a lift force of 100611 N.

Analysis

With all variables defined, we can then solve the equation for the velocity needed to lift the Eagle, Frodo, and Gandalf is 13.1 ms^{-1}. This is approximately 29.3 mph.

Modern gliders have stall speeds of approximately 40 mph [7]. This shows that the Golden Eagles have a lower stall speed despite having a higher mass, which is understandable due to their much larger wing span.

Conclusion

Therefore, we conclude from our comparison to modern gliders that we believe these Eagles would indeed be feasible in Tolkien's Legendarium. Further investigation would be added by a more expansive dataset of raptors. This would aid us in a more reliable model of wing area and body mass, and in turn help better predict the stall speed.

References

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