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S5_2 Do We Have Liftoff?

J. Edwards, J. Hancock, S. Nayak

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

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Abstract

We investigated whether a dragon the size of the ones seen in the HBO show "*Game of Thrones*" (specifically Drogon) would actually be able to fly in the real world. We estimated Drogon's mass to be roughly 1.26×10^6kg, whereas the lift generated by his wings would be about 3.29×10^6N when taking off from stationary, and thus would not be able to take off as his weight is roughly a factor of 4 greater than generated lift. He would, however be able to take off if he ran or jumped at a sufficient speed.

Introduction

Dragons are often portrayed in popular media, in all sorts of shapes and sizes and nearly always flying. But could a dragon the size of Drogon in the HBO show "*Game of Thrones*" actually fly? We aim to solve this problem by calculating the mass of Drogon from his size, and then estimating the lift that his wings would be able to generate, assuming that gravity on Planetos is the same as on Earth.

Estimations

As there is no definitive text on the size and mass of Drogon in the show, we have had to make many estimations about his physical properties including density, length and wingspan.

Given that dragons do not exist in real life, the mass as used in our estimations was derived from comparison with that of their most similar real life counterparts, Komodo dragons. The biggest males can reach a mass of 165kg, and a length of 3.1m [1]. Mass is found via:

$$M = \alpha L^3, \tag{1}$$

where M is mass, L is length, and α is a constant of proportionality. The above values give a value of $\alpha = 5.54$. Drogon's length has been estimated to be 61m [2], and we can therefore calculate his mass as a massive 1.26×10^6kg, with a corresponding weight of 1.23×10^7N, assuming gravity is the same as on Earth. The final estimation employed is that the wings of the dragons are roughly 3 times as long as they are wide, which can be seen in the clip referenced throughout the paper. The closest real-world analogy to dragons' wings is bats' wings, and they will be considered as having the same lift coefficient.

Equations and Calculations

The lift generated by a wing is given by [3]:

$$L = \frac{1}{2}\rho v^2 A C_l, \tag{2}$$

where L is lift, ρ is air density, v is relative velocity of the wing compared to air, A is the surface area of the wing, and C_l is the lift coefficient of said wing. In the show, Drogon sweeps his wings through roughly 60 degrees, and has a wingspan of 44.8m, meaning each wing has a rough length of 22.4m. A line that moves through 60 degrees sweeps out one sixth of a circle, of radius wing length, which in this case has an area of $\frac{1}{6}\pi(22.4)^2 = 259.2\text{m}^2$. Therefore the distance per unit length that the wing moves through is 11.65m. The velocity of the air relative to the wing when the dragon is stationary is just the velocity of the wing itself, which is given by:

$$v = f_{wing} d_{stroke}, \tag{3}$$

where f and d are the wing frequency and the stroke length, respectively. When taking off, Drogon flaps his wings at about 2Hz [5], giving the wing a velocity of 23.3ms^{-1}. If the density of air is 1.225kg m^{-3}, as on Earth, then Eq. (2) gives a lift of 3.29×10^6N, given a lift coefficient of 30 (as with a bat's wing on the downstroke)[6].

Discussion

We have shown that the magnitude of Drogon's weight is roughly 4 times that of the lift generated by purely flapping his wings whilst stationary, and thus it would not be possible for him to take off this way, as seen on the show. However, it would be possible for the dragon to take off (albeit slowly) by increasing some factor or factors in Eq. (2). Obviously, the easiest factor to increase would be the relative speed of air moving against the wing, which only has to increase by a factor of 2, due to the v^2 dependence of lift. There are two dimensions in which to increase speed: horizontal and vertical. If the speed increase is coming from the horizontal direction, the dragon will need to run forwards $\sqrt{3}$ times as fast as the wings are flapped (by Pythagoras), which means that it would have to run at a speed of 40.3ms^{-1}. Alternatively, the dragon could jump upwards (or drop from a height, such as a cliff) at a speed of 2 times the wing velocity, 46.6ms^{-1}. Using simple SUVAT equations, acceleration due to dropping from a height would enable a final velocity of this magnitude after 4.75s, requiring a cliff at least 110.7m high. These values are, of course, the minimum required for lift to occur, so the dragon would have to move faster than this for noticeable upwards acceleration to occur.

Conclusion

We found that the dragons shown in the HBO show *Game of Thrones* could not take off just by flapping their wings while stationary, as they are depicted to do, but they could actually take off if they ran at a speed of 40.3ms^{-1}, jumped upwards/dropped downwards at a speed of 46.6ms^{-1}. These values could be slightly lower if the dragon moved in both the horizontal and vertical directions at the same time.

References

[1] `goo.gl/y67EJg` [Accessed 22 November 2017]

[2] `goo.gl/eZR536` [Accessed 22 November 2017]

[3] `https://wright.nasa.gov/airplane/lifteq.html` [Accessed 22 November 2017]

[4] `goo.gl/SqBNZH` [Accessed 22 November 2017]

[5] `https://www.youtube.com/watch?v=24e_JTp0UEs` [Accessed 22 November 2017]

[6] `goo.gl/tBTmgd` [Accessed 22 November 2017]