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P4_2 How to fly your dragon

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Abstract

In this paper we calculate the minimum area and length of a dragons wing for it to be able to fly. The minimum area was calculated to be $224m^2$ and the wingspan $71.2m$.

Introduction

Dragons are found in many myths and legends and are also commonly found in video games and table top fantasy games. Dragons are known for their large size, this leads to the interesting question of how large a dragon's wings would need to be to support its weight while in flight. For this we look at the common 'western' style of dragon with four legs and two wings, as the eastern style of more serpentine, wingless dragons flight is more closely related to magic. The dragon used in these calculations will be based on dragons found in the Dungeons & Dragons 5th Edition (D&D) game.

To calculate the required wing size, we must assume a manner of flight, for this article we will compare dragons to large birds, due to both being large winged creatures of reptilian origin, this means it would spend most of its time in the air gliding, as it takes large amounts of energy to us its wings to keep itself air-borne. This enables us to model the wings as aerofoils, to a reasonable approximation, this means that the lift force provided by the wings can be calculated by equation (1)[1];

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

where n is the increased length along the top side of the wing, A is the area of the wings, ρ is the density of the air and v is the velocity of the dragon. This lift force needs to be greater than or equal to the downward force from gravity on the dragon. As these dragons are assumed to use the same mechanics as large birds for flight this paper will not calculate if a dragon could take off from the ground, as we assume that like large birds they would also need to use thermals [2].

For flight to be possible the force of lift on a dragon while flying would have to be greater than or equal to the downward force due to gravity which is calculated using $F = mg$ where m is the mass of the dragon and $g = 9.81\text{ms}^{-2}$. It was assumed that HP, a value roughly approximating the life of a creature that is often related to size for larger creatures, was linearly related to the mass of larger creatures. Using this assumption the average of all adult dragons HP in the game was compared to the HP of an Allosaurus. This was done because an Allosaurus would have

had a body structure comparable to that of western dragons and estimates of the mass of an Allosaurus have been calculated [3]. An Allosaurus was thought to have had a mass of 2.3 tons [3] and it has a HP of 51 [4], the average dragon HP of adult dragons is 215, this would give the average mass of adult dragons to be approximately 9696kg. From equation (**??**) this gives the weight of the dragon as $F = 95118$N. In combat a dragon can fly, at maximum, 160 feet in a 'turn. A 'turn is a 6 second period of time thus the maximum combat flight speed is 26.6 feet per second. The speeds in D&D are written such a creature that can move 120 feet in a turn, in combat, can move at 100 feet per second out of combat. This means that the max flying speed of a dragon is 133 feet per second or 40.6ms^{-2}.

The surface area of the dragon's wings was then calculated to be 448m^2 using equation (1), setting F_l to be equal to the weight of the dragon, $v = 40.6\text{ms}^{-2}$, $\rho = 1.225\text{kgm}^{-3}$ and assuming a C_l of 0.21. This surface area is the combined total for both the dragon's wings, giving each wing a surface area of $A = 224\text{m}^2$. Therefore the area for each wing is $A = 224\text{m}^2$. To calculate the length of the wing we need to assume a width, for this the length of different body parts need to be found. From the D&D monster manual [4] the length of the neck and head can be taken to be about $2m$ long, the body about 5m and the tail about 4m long, giving the total length of the dragon to be roughly 11m. The wings have been assumed to be roughly oval in shape as shown by figure 1 which means if the wing is assumed to be 8m across, equation (2)

$$A = ab\pi \tag{2}$$

gives a 'b' of 17.8m, giving a total wing length of 35.6m and a total wingspan of just over $71m$.

Conclusion

We have found that the length of a dragons wing would need to be a minimum of 35.6m for it to be able to maintain flight, while this length is about three times longer than the distance from its nose to tail it may still be plausible, as some large birds have a ration of about half this [5], but whose bodies are much less dense. It is worth noting that depending on the method of fire breathing that is applied to the dragon, oil or gas, the dragon may have large volumes of hydrogen stored in its body which would allow for slightly reduced wing size, An effect that may merit further study.

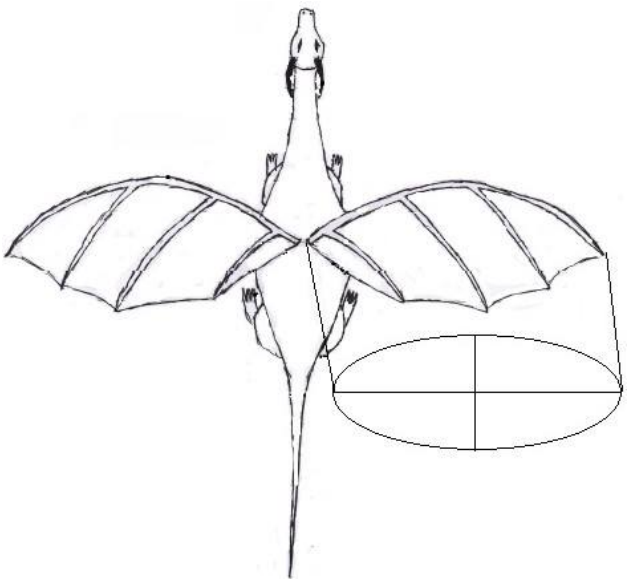

Figure 1: An Illustration of a dragon highlighting the oval-like shape of its wings.

References

[1] `https://www.grc.nasa.gov/www/k-12/airplane/lifteq.html`

[2] `https://www.quora.com/How-do-the-largest-flying-birds-get-airborne-Do-t` 11/10/2016

[3] `https://en.wikipedia.org/wiki/Allosaurus`

[4] Wizards of the coast *Monster Manual* (2014)

[5] `http://hubpages.com/animals/top-10-largest-birds-on-earth-wingspans`