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A4_11 Pokémon: The Twin Bird Takes Flight!

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Abstract

This paper investigates the physics of the Twin Bird Pokémon, Doduo, to determine the angular velocity required for such a flightless bird to achieve lift via the spinning of its two heads. It was found that the required rotational speed would be 1,930 rads^{-1} or 18,500 rpm to lift its body off the ground.

Introduction

The world of Pokémon is one that is notoriously expansive, including over 1000 species of Pokémon to date, all weird and unique in a large variety of ways. A lot of the exact science of the Pokémon world can be considered questionable of course, as is sadly the case with such unfortunately fictional worlds.

Doduo is one of the original 151 existing Pokémon, and is one of the odd ones that have made fans of the franchise question the exact physics of its world due to the fact that, according to the Pokédex: *"It can run faster than it can fly"* [1]. Upon inspection of Doduo in Figure 1, however, it is obvious that a Doduo does not appear to have any wings. As such the question is how on Earth can this Pokémon fly?

Analysis of Dimensions

According to the large amounts of media available relating to Pokémon, Doduo stands at 1.40 m tall with a mass of 39.2 kg [1]. From this value of height it can be determined from the physical measurement of the Doduo in Figure 1 that Doduo's neck has a length of roughly 0.32 m and a width of approximately 0.04 m, with its head having a diameter of 0.29 m. Modelling Doduo's two heads as propeller blades does provide a challenge in that his head and neck are of significantly different widths. To work around this, the "propeller width" will be used as a weighted average of width with respect to the lengths of Doduo's head and neck using Eq.(1) where w represents width, l represents length, subscript $neck$ and $head$ represent values for the neck and head respectively, and eff represents an effective value.

$$w_{eff} = \frac{l_{neck} w_{neck} + l_{head} w_{head}}{l_{head} + l_{neck}} \qquad (1)$$

Equations

While the lift force to raise a body off of the ground in general is a complicated quantity to calculate, the physics of lift due to spinning blades such as in the case of helicopters is marginally different as the blades move at different speeds depending on their distance from their axis. Although a specific relationship between the relevant quantities is not very well covered for helicopters, there is one approximate equation we can use Eq.(2) [2],

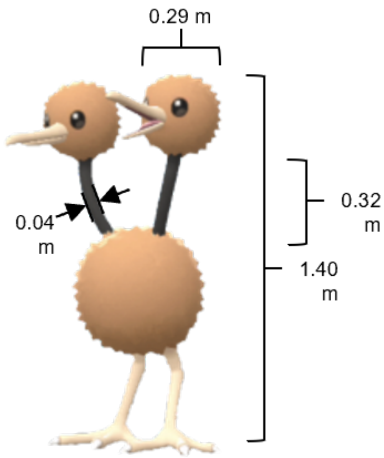

Figure 1: Doduo, the "*Twin Bird Pokémon*", with labelled height, head width, neck width and neck length.

$$T = \frac{1}{2}\rho(\omega R)^2 \pi R^2 C_T, \quad (2)$$

where T is the lift force produced, ρ is the density of the fluid being flown in, ω is the angular velocity of the blades, R is the radius of the blades. C_T is a lift coefficient given by Eq.(3) [2],

$$C_T = \frac{1}{4\pi R} n\, c\, C_l\, \alpha, \quad (3)$$

where n is the number of rotary blades, c is the blade's chord (distance from the leading edge to the trailing edge of the blade - in this case this will be used as the the effective width of the "blade", w_{eff}), C_l is the slope of how the lift coefficient changes with the blade's angle of attack (assumed to be $\pi^2/180$ [3] here for an average airfoil) and α is the most efficient angle of attack for the airfoil (taken to be 10° here as this is the lower range for airfoils and Doduo's heads are likely not very efficient airfoils).

For use in our calculation, Eq.(2) can then be arranged for the angular velocity, ω, to give Eq.(4),

$$\omega = \sqrt{\frac{2T}{\pi \rho R^4 C_T}}. \quad (4)$$

Results

C_T can be calculated using Eq.(3) where $R = l_{neck} + l_{head} = 0.61$ m, $n = 2$, $C_l \approx 0.11$ rad^{-1}, $\alpha = 0.17$ rad (converted from 10°) and $w_{eff} = 0.159$ m, to give $C_T = 3.86 \times 10^{-4}$.

Doduo's weight is given by multiplying its mass, 39.2 kg, by Earth's gravitational field strength, $g = 9.81$ ms^{-1} to give $W = 385$ N. This weight then becomes the lift force, T, required for our Doduo to achieve lift-off.

Using this value, the angular velocity required for lift can then be calculated using Eq.(3), with $T = 385$ N, $\rho = 1.225$ kgm^{-3} (density of air). [4] This calculation yields an angular velocity of 1,930 rad s^{-1}, equivalent to approximately 18,500 rpm.

Conclusion

Doduo's heads would have to spin together at 18,500 rpm for its lift to balance its weight, and hence has to spin at a speed greater than this for it to be able to lift off the ground. This is approximately 40 times as fast as regular helicopter blades, rotating at 400-500 rpm. [5] Amazingly, this speed means that the "tip" of the blade, Doduo's head, would reach a linear speed of 1179 ms^{-1}, making it so that Doduo's spinning heads are thankfully very clear of the speed of light but would reach approximately Mach 3.5, breaking the sound barrier with plenty of ease.

References

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[5] https://hangar.flights/helicopters/how-fast-do-helicopter-blades-spin/ [Accessed 08/11/2022]