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A1_5 Determining the Smallest Migratory Bird Native to Britain able to carry a Coconut

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Abstract

In Monty Python's Holy Grail the opening scene contains an argument between King Arthur and a Guardsman on how King Arthur obtained the coconut in his possession. The King argues that a bird could have carried it on its return from migration, this paper discusses if any British bird is capable of this.

Introduction

The opening scene of the 1975 comedy "Monty Python and the Holy Grail" has an argument between King Arthur and a Guard of a castle he is visiting. The Guard makes the observation, in response to King Arthur claiming to have ridden the length and breadth of the country, that he has no horse and points out that King Arthur is using coconuts to simulate the clopping sound of Horses hooves (used because Monty Python had a pitiful small budget for the movie and couldn't afford horses). In an attempt to explain where the coconuts came from Arthur argues that a migratory bird could have brought them from the tropics [1].

Theory

Like aircraft, a bird's wing generates lift due to the air flow on the wing, since the air has a lower pressure above the wing and higher below the action of lift is produced. Unlike an aircraft, however, the birds do not have mechanical devices to increase the air flow across the wings. Instead bird's wings produce thrust by flapping their wings. When a bird flaps, as opposed to gliding, its wings continue to develop lift as before, but the lift is rotated forward to provide thrust, which counteracts drag and increases its speed, which has the effect of also increasing lift to counteract its weight, allowing it to maintain height or to climb. The orientation of forces across the wing can be seen below in figure (1)[2].

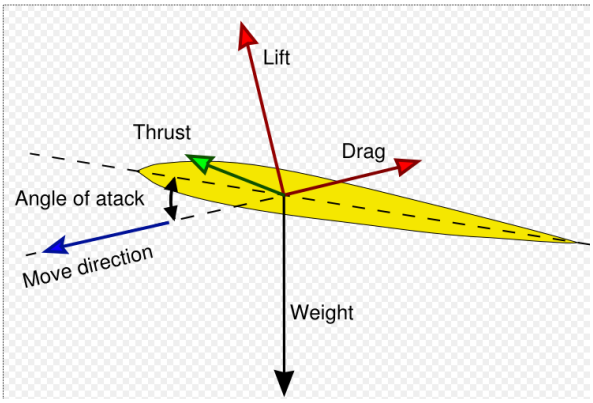

Figure 1 Forces acting on a wing. The lift force has both a forward and a vertical component

As has been mentioned, lift is needed to counteract the weight of the bird, however, weight is not the only force to impede flight. Drag is also present from two main sources: frictional drag between the air and body surface; and form drag, caused by the frontal area of the bird. The lift generated by the bird will be the same with or without the coconut so when determining the bird able to carry a coconut we must consider how the weight and drag of the coconut affects the flight.

Coconut Dimensions

For simplicity the coconut will be modelled as a sphere. Coconuts range in masses but since the source of this problem is "Monty Python and the Holy Grail" we can use the 1lb quoted in the film, this is 0.45kg. Since weight is a function of mass and acceleration due to gravity this gives us a weight for the coconut of 4.4N. The average diameter of a spherical coconut is

0.38m [3]. To minimise the form drag a bird will grasp the coconut so as to show the smallest amount of coconut thus the area of the coconut causing the drag will be 0.3m^2. We can now use the drag equation (1) to calculate the drag force of the coconut,

$$F_d = \frac{1}{2}\rho A C_d v^2. \qquad (1)$$

We already know the area, A, and the density, ρ, is simply 1kgm^{-3}. Since we are modelling the coconut as a sphere the drag coefficient, C_d, is 0.47. The only variable in this problem is the velocity, v, of the bird.

The Bird and Coconut

We can now construct the entire system of bird and coconut. To stay in the air the lift, F_l, generated must be large enough to counteract both the drag and weight of the bird and coconut system,

$$F_l = \frac{\rho v^2}{2}(A_b C_{db} + A_c C_{dc}) + g(m_b + m_c). (2)$$

The extra drag force of the coconut can be calculated from the values already given for the coconut and is in fact 4.4+0.071v^2 N. The actual lift generated by a bird is dependent on the power generated from the wing muscles and as such varies greatly from bird to bird independent of size to weight ratio. So for the purposes of this article we can make the assumption that your average bird can take 10% extra drag during flight. With this 10% we can construct equation (3) from the right hand part of equation (2),

$$\frac{\rho v^2}{2} A_b C_{db} + g m_b = 0.1\left(\frac{\rho v^2}{2} A_c C_{dc} + g m_c\right). (3)$$

Obviously the bird carrying the coconut is going to have to be much larger than the coconut thus putting us in the realms of large migratory birds. For this case we can estimate the velocity of the system to be 20 ms^{-1} [4]. Using these values, equation (3) can be used to produce equation (4), showing the relation between cross sectional area and mass of bird required,

$$8A_b + 9.81m_b = 328. \qquad (4)$$

Discussion

Unfortunately, equation (4) does not give a wing span to mass ratio that would make it easy to find the bird we're looking for. Instead the most expedient solution will be to use trial and error. Thankfully we have some clearly defined parameters; first the bird must be migratory, secondly it must be quite large, and thirdly it must be native to both Britain and a tropical region. One such bird that falls into the criteria is the white stork [5].

Using the stork's mass, 4.4kg [5], in equation (3) the answer comes out that the stork would require a cross sectional area of 36m^2. This is a little high and it can be easily extrapolated that no migratory bird would be able to carry a coconut. However, this is assuming a flight that is predominated by gliding not taking into account the extra lift that would be generated from flapping the wings. On the other hand, the great albatross, with a mass of 11kg and a wing span of 3.5m [6], is possibly large enough to satisfy the equations as it requires a mere 28m^2 of cross sectional area to carry a coconut but it would never actually go from tropical shores to British shores.

Therefore, King Arthur could not have been using coconuts as a substitute for a horse and, considering the age in which he was around, it would have, probably, been cheaper to buy a horse than to send to the tropics for coconuts.

Reference

[1]Python (Monty) pictures, Monty Python and the Holy Grail, 1975
[2] http://en.wikipedia.org/wiki/Bird_flight
[3]www.dimensionsguide.com/coconut-sizes/
[4]http://www.npwrc.usgs.gov/resource/birds/migratio/speed.htm
[5] http://en.wikipedia.org/wiki/White_Stork
[6]http://en.wikipedia.org/wiki/Great_albatross