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A1_4 Chickens Go In, High-performance Aircraft Come Out

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Abstract

This paper investigates how much thrust the plane from the film Chicken Run (2000) would require to take off. By using Mr Tweedy to scale the plane and making assumptions for the wing structure, body drag, and internal structure, a final thrust value of 18,000 N is found.

Introduction

In the 2000 film Chicken Run a group of savvy chickens design a chicken-powered plane to escape their fate of becoming chicken pies. The plane uses both a propeller and a 'flapping' motion to generate thrust and lift. This paper aims to deduce the thrust required for the plane to achieve flight in the take-off time seen in the film.

Theory

The wings were modelled as fixed aerofoils. During the escape, Mr Tweedy (one of the two owners of the chicken farm), is hit on the head by the tail of the plane. Assuming Mr Tweedy is the average UK male height of 177 cm [1], we can deduce the distance between the tail and the ground. By performing a pixel count for other dimensions of the plane and comparing these to the pixel number of the known tail-to-ground distance, other dimensions can be ascertained:

Fuselage Height (d)	3.0 m
Fuselage Length (l)	6.3 m
Wingspan (w)	12 m

Table (1) - Plane dimensions.

The mass of the plane was found by assuming the plane to be a cylindrical skin with flat circular surfaces of radius $r = d/2 = 1.5$ m at the front and rear ends. We also assumed a '+' shaped (when viewed along the height axis of the cylinder) internal support structure that runs the length of the body. The mass of the wings was assumed to be negligible. The volume of material used across the surface area was multiplied by the expected width of the wooden structure (x):

$$V = (2\pi r^2 + \pi ld + 2ld)x. \quad (1)$$

Bats wings were used as a model, because of the visual similarities. The greater bulldog bat was chosen as the model species, because of its similarly shaped wings. Relevant aerodynamic properties were collated into a table for the lowest angle of attack, matching what is seen in the film:

Aspect ratio	9.0
Coefficient of Lift ($C_{\rm L}$)	0.616
Coefficient of Drag ($C_{\rm D,wing}$)	0.0274

Table (2) - Aerodynamic properties of bat. [4]

The drag equation is given by [2]

$$DragForce = \frac{1}{2} C_{\rm D} \rho_{\rm air} A v^2, \quad (2)$$

where $\rho_{\rm air}$ is the density of the air (kg/m^3), A is the reference area perpendicular to the aircraft's direction of motion (m^2), C_D is the coefficient of drag, and v is the velocity of the aircraft (m/s). The aspect ratio in Table (2) was used to find the total surface area, via

$$AR = \frac{w^2}{S}, \tag{3}$$

where w is the tip-to-tip wingspan (m), and S is the surface area of both wings (m^2) [3]. Take-off occurs when the lift force equals the weight [2]:

$$mg = \frac{1}{2} C_L \rho_{air} S v^2, \tag{4}$$

where g is the acceleration due to gravity, and C_L is the lift coefficient. The net force of the aircraft was found by accounting for the resistive effects of drag forces on the thrust force (F).

$$m\frac{dv}{dt} = F - \frac{1}{2}\rho_{air} v^2 (C_{D,body} A_{body} + \frac{1}{2} C_{D,wing} S). \tag{5}$$

By separating and integrating with respect to v and t, the relationship between v and t for an undefined thrust F was determined as

$$t = m\frac{\tanh^{-1}(v\sqrt{k}/\sqrt{F})}{\sqrt{kF}}, \tag{6}$$

$$k = \frac{1}{2}\rho_{air}(C_{D,body} A_{body} + C_{D,wing} S). \tag{7}$$

Results

The width of a wooden plank was taken as $x = 0.045$ m [5]. This, combined with the Table (1) data used in Eq. (1), gives a volume of 5.0 m^3. The wood used was assumed to be pine, owing to its use in construction. Its average density is $\rho_{pine} = 601$ kg/m^3 [6], giving a total mass of $m = V * \rho_{pine} = 3000$ kg. The masses of any passengers or complicated internal structures were neglected. Drag was calculated by again assuming the body of the aircraft to be a cylinder. The coefficient of drag for a cylinder is given by $C_{D,body} = 0.8$ [7], the density of air is $\rho_{air} = 1.225$ kg/m^3, and the reference area is given by $A_{body} = \pi(d/2)^2 = 7.2$ m^2. Inputting values from Tables (1) and (2) into Eq. (3), a total surface area value of $S = 17$ m^2 was found. The drag of the wing was then found by taking the total surface area of the wing S and substituting the coefficient of drag [from Table (2)], into Eq.(2). Using Eq. (4), the required velocity for take off was found to be 69 m/s. The time taken for lift-off in the film was 50 s. By inputting these values into Eq. (6) and varying thrust F, obtained the final thrust, via an iterative approach, as $F = 18{,}000$ N.

Conclusion

This result is a reasonable value, modern fighter jets can produce upwards of 150 kN of thrust for planes that can weigh in excess of 10 tonnes. Further research could look into modelling the drag of the body and wings more accurately through appropriate modelling software. Furthermore, a more accurate model of internal structures and passenger weights would improve the accuracy of the plane mass.

The chickens are indeed up to something.

References

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