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A1_9 To Infinity and Beyond!

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Abstract

This paper investigates the conditions under which *Toy Story*'s *Buzz Lightyear* could take flight. At an optimum angle of attack of α = 13˚, a firework powering Buzz would approximately need to provide a force of 62 N, when Buzz is travelling at a velocity of 55.5 ms^{-1}, for Buzz to take off.

Introduction

Buzz Lightyear is one of the principal characters in Disney-Pixar's "Toy Story". At the end of the film, he manages to take flight due to a firework strapped to his back. This paper investigates under what conditions Buzz could take off.

Investigation

Firstly, the specifications of Buzz Lightyear are estimated given the values of the box he is packaged in [1]:

Specification	Calculation	Value
Mass, m_B		0.5 kg
Wingspan, W_1		0.18 m
Wingchord Length, W_2		0.04 m
Frontal Area of Wings, W_F	$W_F = W_1 \times W_2$	0.0072 m^2
Frontal Body Area, B_F		0.03 m^2
Total Area of Frontal View, A_F	$A_F = B_F + W_F$	0.0372 m^2
Body Area from Above, B_A		0.0169 m^2
Wing Area from Above, W_A		0.000864 m^2
Total Area from Above, A_A	$A_A = B_A + W_A$	0.0178 m^2

Table (1): Estimated Specifications of Buzz Lightyear.

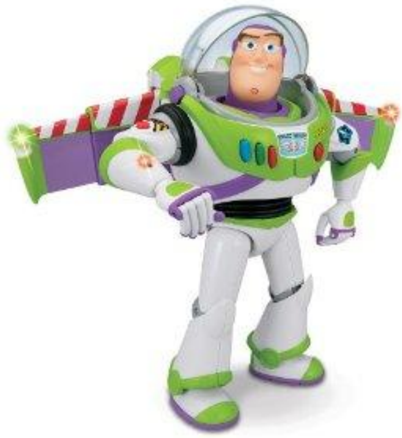

Figure (1): Buzz Lightyear [1].

The National Advisory Committee for Aeronautics (NACA), which was transformed into NASA in 1958, produced a series of NACA airfoils still used in aircraft manufacturing today [2]. Buzz's wings are modelled as a standard NACA profile, as shown in figure (2). This is an approximation, but allows experimentally determined values to be used for the wings' lift coefficient, C_L, and optimum angle of attack, α.

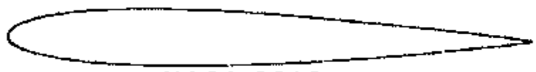

Figure (2): NACA 0012 Wing Profile [3].

For a lift coefficient, C_L, of 1.1, for normal atmospheric conditions, the angle of attack, α, which gives rise to maximum lift is 13° (for Reynolds number, $Re = 4.8 \times 10^5$) [4].

The lift coefficient is defined as:

$$C_L = \frac{2F_L}{\rho v^2 W_F}, [5] \qquad (1)$$

where F_L is the lift force (which equals the force due to gravity, mg at the point of take off), F_L = 14.72 N. m is the total mass of Buzz plus a 1 kg firework, 1.5 kg. ρ is the density of air = 1.205 kgm^{-3} (at 20˚C) [6] and v is the velocity to achieve lift. W_F is used in equation (1) as the wing area achieving lift because Buzz is positioned horizontally (face down) for take off.

Rearranging equation (1) for v gives the velocity Buzz would need to reach at α = 13˚ to achieve lift as 55.5 ms^{-1}.

Buzz will experience air resistance before getting to this velocity, so to get to this velocity the firework needs to provide enough thrust for it to overcome the drag force due to air resistance.

The drag force, F_D, on Buzz at this velocity can be determined from equation (2):

$$C_D = \frac{2F_D}{\rho v^2 A_D}, [7] \qquad (2)$$

where C_D is the drag coefficient, estimated as 1.3 (the upper limit of a human's drag coefficient is used since Buzz is so bulky and has a firework attached to his back) [8]. A_D is the area perpendicular to the direction of motion = 0.0257 m^2 (calculated from α, A_F and A_A using trigonometry).

So, rearranging equation (2) for F_D, the minimum reaction force that the firework, as the power source, must deliver in the direction of travel is approximately 62 N when Buzz is at a velocity of 55.5 ms^{-1}.

Conclusion

Theoretically, Buzz Lightyear could take flight at an angle of attack of α = 13˚ with a firework attached to his back. The firework would approximately need to provide a force of 62 N, with Buzz at a velocity of 55.5 ms^{-1}.

These values are based on the assumptions that Buzz's wings can be modelled with "NACA 0012" profiles and that Buzz has wheels or a surface causing negligible friction acting as his runway. Actual measurements of the toy, as opposed to approximations, would improve the accuracy of the result.

References

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[2]http://www.nasa.gov/centers/dryden/news/X-Press/stories/2005/032505_NACA_90th.html (15/03/2011)
[3]http://www7a.biglobe.ne.jp/~GYROS/fwdflt7a.html (27/02/2011)
[4]N. GREGORY and C. L. O'REILLY *Low-Speed Aerodynamic Characteristics of NACA 0012 Aerofoil Section, including the Effects of Upper-Surface Roughness Simulating Hoar Frost* (MoD, Aeronautical Research Council, Reports and Memoranda) p. 24.
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