Journal of Physics Special Topics
An undergraduate physics journal

A2_3 Mission: Incruiseable

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December 1, 2018

Abstract

This paper considers the feasibility of Tom Cruise holding onto an airbus military A400m during take-off in a scene in the film *Mission Impossible: Rogue Nation.* It was found that he would experience a continual force of 1810 to 4020 N for over a minute, depending on his velocity and posture. Comparatively, the deadlift Guinness World Record holder, Eddie Hall could deadlift 4910 N for just 10 seconds, making Tom Cruise's stunt seem likely a *Mission: Impossible.*

Introduction

In the film *Mission Impossible: Rouge Nation*, Tom Cruise holds onto the outside of a military aircraft during take-off. This seemingly unlikely stunt is explored in this paper in a purely dynamical sense. Each force required for Cruise to hold still on the plane is considered individually. These consist of: the frictional force between Cruise's shoes and the surface of the aeroplane wing, the gravitational force, the drag force due to air resistance and the force exerted by his arms holding him in place.

Theory

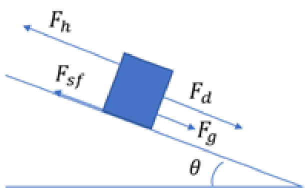

Figure 1: Forces acting on Cruise during take-off

From Figure 1, the resultant components of the gravitational force acting on Cruise and the frictional force between his shoes and the surface of the aeroplane wing are given by Equations 1 and 2 respectively:

$$F_{\rm g} = mgsin\theta \tag{1}$$

$$F_{\rm sf} = \mu_{\rm s} mgcos\theta \tag{2}$$

Where F_g is the force due to gravity, m is Cruise's mass (taken to be 68 kg [1]), g is the gravitational acceleration, θ is the angle of Cruise's shoes to the plane and μ_s is the coefficient of static friction.

It is assumed that there is negligible turbulence on the top side of the wing, thus the air will flow in a direction parallel to the surface of the wing. In this case, the drag force applied on Cruise's body when the aeroplane is performing a take-off is calculated by:

$$F_{\rm d} = \frac{1}{2}\rho_{\rm air} v^2 C_{\rm d} A \tag{3}$$

Where F_d is the drag force, ρ_{air} is the density of air, v is the plane's velocity, C_d is the drag coefficient of Cruise and A is the area of Cruise.

To calculate the drag force applied on Cruise's body his height and chest dimensions were taken to be 1.70 m and 0.56 m (estimated via halving his chest circumference) respectively [1]. Assuming Cruise's surface area is comprised of a rectangular body, his surface area can be calculated to be 0.952 m^2. Using the drag coefficient of a human body of $1.08 \leq C_d \leq 1.59$ in an upright position [2], in conjunction with the three distinct take-off velocities of the A400m and the assumption that the aeroplane is operating at 20° where $\rho_{\text{air}} = 1.23$ kgm^{-3}, the drag force acting on Cruise can be calculated.

The three distinct velocities are as follows: $V_1 = 56.6$ ms^{-1} (where take-off can no longer be aborted), $V_2 = 62.8$ ms^{-1} (where the nose of the plane pitches upwards and $V_3 = 66.4$ ms^{-1} (the safety take-off velocity [3]).

Finally, F_{h} is the exerted force required for Cruise to hold still in this position. Assuming that $g = 9.81$ ms^{-2} allows for the calculation of all components of the forces acting on Cruise by using Equation 4:

$$F_{\text{h}} = F_{\text{d}} + F_{\text{g}} - F_{\text{sf}} \tag{4}$$

When calculating the static frictional force between Cruise's shoes and the surface of the aeroplane, the surface of the wing is assumed to be acting as a clean, dry aluminium surface. Hence, the coefficient of static friction between rubber and clean metal of $\mu_{\text{s}} = 0.6$ [4] can be used. The angle of the wing when the plane is still on the ground is $\theta = 15°$ (this applies to V_1), and as the plane reaches V_2 and starts to rotate, it rolls an additional angle of +10° [3]. Hence, its total angle with respect to the ground is $\theta = 25°$ for V_2 and V_3.

Results

The values chosen in the theory were substituted into Equations 1-4 and the results ascertained for the force required for Cruise to hold onto the plane have been displayed in Table 1 for both the minimum and maximum drag coefficients. To compare these results with a real-life example, the deadlift Guinness World Record holder, Eddie Hall, once lifted 500 kg for 10 s [5], exerting approximately 4910 N. Therefore even

C_{d}	Velocity (ms^{-1})	F_{h} (N)
1.08	V_1	1810
	V_2	2410
	V_3	2710
1.59	V_1	2770
	V_2	3590
	V_3	4020

Table 1: The exerted forces required for Cruise to remain in place at various velocities and drag coefficients

Eddie Hall would struggle over an extended period of time for all sections of the take-off.

Conclusion

This paper has shown that without any safety equipment, Cruise would not be able to hold onto the outside of an A400m wing upon take-off. With more time and more intricate calculations, the force Cruise could possibility exert could be calculated for a range of different velocities and drag coefficients. With this information, it would be possible to see what types of aeroplanes Cruise would be able to hold onto.

References

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[3] http://aviationweek.com/defense/pilot-report-proves-a400m-s-capabilities [Accessed 21 November 2018]

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[5] http://www.guinnessworldrecords.com/news/2018/5/video-worlds-strongest-man-eddie-hall-shares-his-intense-eating-and-training-re-524420 [Accessed 13 October 2018]