Journal of Physics Special Topics

A3_2 Locking Aircraft Engine Fans

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March 19, 2011

Abstract

In this paper we investigate the behaviour of a typical passenger commercial aircraft when its control has been lost by the pilot due to failure of electronic systems. We also introduce the possibility of manually locking the engine fans, such that additional air resistant area is introduced. In the course of investigation it was found that the method cannot have a considerable effect on the descent time and the speed at ground level.

Introduction

Accidents in the commercial airspace are unfortunately frequent and it is a major task trying to reduce them and save lives. One of the scenarios is failure of the electronic systems, like the main computer, or loss of control of engine. The pilot can then have no effect on the plane's behaviour and it becomes a simple projectile of motion. A strong example of such an accident is Air France Flight 447 [1] which crashed in the middle of South Atlantic due to unknown reasons, with 228 fatalities. It is now known that both onboard computers stopped working in-flight. Experience has shown that such accidents almost never leave survivors [2].

At normal onboard equipment functionality, the pilot can often safely land the aircraft; on water or terrain. However, in the aforementioned scenario this is almost impossible due to angle to the horizontal and the speed of the aircraft near ground level.

A possibility has been considered of manually locking the engine propellers, which will give an increased area resisting the air, hence it shall alter the aircraft motion.

Model

In our scenario we consider a typical commercial aircraft, Boeing 737-800, at its nominal cruise speed, 0.785 Mach = 267 m/s [3], and at cruise altitude, 10000 m [3]. The airplane shall orient itself in the least air resistance state, i.e. it will always travel in same direction as its orientation and the angle of attack (AOA) is zero. The initial state of the aircraft in this model is normal cruising behaviour, at 2 degrees AOA, but we disregard this and set it to zero, since the error is expected to be minimal.

There are two forces acting on the aircraft: weights W and air resistance F_{air}. We can model the dynamics in 2-D using coordinates x and y.

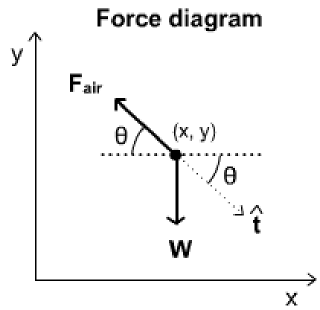

Figure 1: Force diagram of the aircraft in the model. The circle is the centre of mass of the aircraft, with coordinates (x(t), y(t)); $\hat{\boldsymbol{t}}$ is unit velocity vector.

From the above diagram we can find the resultant force:

$$\boldsymbol{F}(t) = \begin{pmatrix} -F_{air}(t)\cos(\theta(t)) \\ F_{air}(t)\sin\big(\theta(t)\big) - W \end{pmatrix}. \qquad (1)$$

Force of air resistance can be shown to be [6]:

$$F_{air} = \frac{1}{2} C_d \rho_{air} (A_{nl} + A_f)|\boldsymbol{v}|^2 \quad , \qquad (2)$$

where $A = A_{nl} + A_f$, A_{nl} = effective area excluding the fans, A_f = area of fans.
From [3] A_{nl} = 13.8 m^2 and A_f 3.8 m^2.

We find $\cos(\theta)$using vector dot product:

$$\cos(\theta) = \hat{\boldsymbol{t}} \cdot \hat{\boldsymbol{x}} = \frac{v_x}{|v|} = v_x / \sqrt{{v_x}^2 + {v_y}^2} \qquad (3)$$

where v_x = velocity projected in the x-direction. Likewise we can find $\sin(\theta)$.

Substituting (1), (2) and (3) into $\boldsymbol{F} = m\ddot{\boldsymbol{r}}$ yields two simultaneous nonlinear ordinary differential equations:

$$v_x' = -k v_x \sqrt{{v_x}^2 + {v_y}^2}, \qquad (4)$$

$$v_y' = k\left({v_x}^2 + {v_y}^2\right) \sqrt{1 - \frac{1}{\left(1 + \left(\frac{v_y}{v_x}\right)^2\right)}} - g, \qquad (5)$$

where g is the acceleration due to gravity, $k = C_d \rho_{air} A / 2m$, m is the mass of the aircraft (taken to be 60 tones [3]), C_d is the drag coefficient (0.03 for an airliner [6]) and ρ_{air} is the sea-level atmospheric density (taken as 1.2 kg/m^3 [7] and constant throughout the investigation).

We solve these equations numerically.

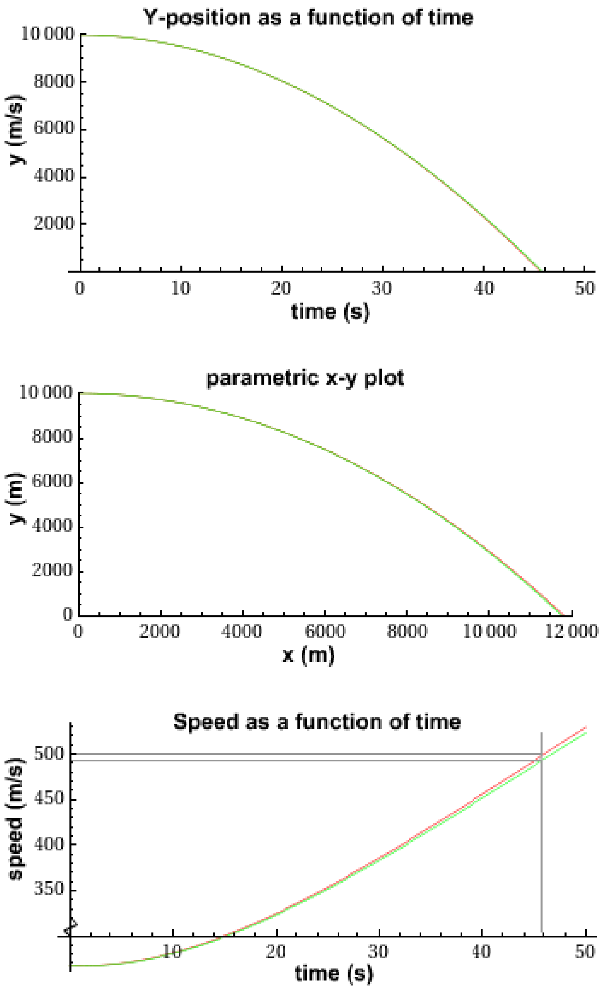

Figure 2: Plots showing the 1) change of altitude with time, 2) x-y coordinate evolvement, and 3) change of speed with time, for both the "locked" scenario (red) and "not locked" scenario (green). Note that it is very difficult to distinguish between them.

Some findings of the simulation are summarised in table 1.

	$\boldsymbol{t}$ (s)	$\boldsymbol{\theta}$ (deg)	$\lvert v_x \rvert$ (m/s)	$\lvert v_y \rvert$ (m/s)	$\lvert v \rvert$ (m/s)
No lock	46	59	427	500	180
Lock	46	62	425	483	160

Table 1: Parameters of the aircraft at ground-level.

Conclusion

First of all we note from figure 2(1) that it takes the aircraft under a minute to reach ground level (y = 0). With such short time given it will be completely unrealistic to let the passengers out with parachutes. This method shall also not work due to high speeds (around 500 m/s, when skydiving planes fly at approximately 70 m/s [5]).

The reader should also notice how indistinguishable the trajectories are for both scenarios. We can thus conclude that the method has not altered any of the important parameters considerably, which is mainly due to small drag coefficient.

Both scenarios yield similar degrees of incidence, that is 59 and 62, and are both unsatisfactory.

When fans are not locked the speed is approximately 500 m/s, and with locked fans it is 483 m/s. This change in speed is minor and we can therefore conclude that locking the engine fans will unlikely increase the chances of survival in such an accident.

Bibliography:

[1]http://aviation-safety.net/database/record.php?id=20090601-0 (8/2/11)
[2]http://aviation-safety.net/database/ (8/2/11)
[3]Boeing Flight Crew Operations Manual (737-600/ -700/ -800/ -900/ -900ER) (2010)
[4]http://www.boeing.com/commercial/737family/background.html (8/2/11)
[5]http://www.utilityaircraft.com/pac750xl.html (8/2/11)
[6]http://www.diracdelta.co.uk/science/source/d/r/drag%20coefficient/source.html (23/2/11)
[7]http://www.engineeringtoolbox.com/air-altitude-density-volume-d_195.html (23/2/11)
[8]http://www.aerospaceweb.org/question/aerodynamics/q0184.shtml (23/2/11)