IOP Conf. Series: Materials Science and Engineering **234** (2017) 012001 doi:10.1088/1757-899X/234/1/012001

Landing Distance Minimization to Prevent Overrun Accidents Using Field Theory and Stabilizing Air Traffic – A Novel Approach

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Abstract. Airplane is considered to be the pinnacle of engineering as it has proven that it is possible for a manmade object to fly. Before its invention, flying was just a dream for mankind. In such an esteemed domain, landing is the most challenging part and it is where a large number of accidents occur, especially due to overrun. As the name suggests, overrun accidents occur due to insufficient runway length. In the present study, the concept of planar electromagnetic fields is incorporated to minimize the landing distance of an aircraft, thus preventing the overrun accidents. As a result, unexpected losses can be avoided. In addition to this, the stability of air traffic control can be perpetuated and the fuel consumed during loitering time can be diminished.

1. Introduction

One of the major problems associated with aircrafts is the number of accidents due to over-run. According to the NTSB, 379 of 1332 runway accidents (1995 and 2007) were due to overruns causing 680 fatalities [1]. It is seen that 35% of the accidents have occurred due to landing overrun (LDOR), which is a serious snag [2]. There are lots of accidents that had occurred due to insufficient runway space. For an instance, Air India Express -811/812 landed 5200 ft from the beginning of Runway 24 of Mangalore International Airport in 2010. It overran, falling over a cliff and catching fire, leading to the demise of 158 lives [3]. Also, Cubana de Aviación Flight 1216 suffered an accident as a result of an overshoot on a wet runway and exiguous deceleration in 1999 [4]. All such accidents have occurred due to insufficient runway length. On the other hand, Air Traffic Control has become difficult to implement during rush hours. The number of commercial flights handled globally is 102,465 per day [5]. The traffic control has to be maintained at any cost, to avoid irregular handling of aircrafts. The aircrafts must wait till it is permitted to land during the time of which it loiters around the airspace, wasting a considerable volume of fuel. It is seen that the air traffic is continuously increasing since 2012 [6]. If this continues to exist, traffic management will be subjected to question in the future. A mutual solution to both these problems can be provided by reducing the landing distance.

2. Mechanics of Landing

In order to minimize the landing distance, it is essential to obtain an expression for the same. Figure 1 shows the forces associated with an airplane while landing, namely Lift (L), Drag (D), Thrust (T), Weight (W), Rolling Friction (R) [7].

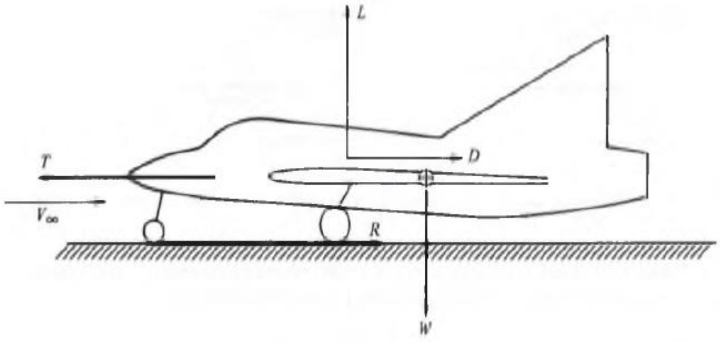

Figure 1. Forces on a flight while landing

The instantaneous acceleration acting in the opposite direction, is given by Newton's equations of motion [7],

$$F = T - \left(D + \mu_r(W - L)\right) \tag{1}$$

where μ_r is the *friction coefficient* whose value is 0.4 for a paved runway [7]. During landing, the thrust is theoretically zero [7]. Hence,

$$F = -\left(D + \mu_r(W - L)\right) \tag{2}$$

Substituting equation (2) in $s_L = -\frac{mV_T^2}{2F}$ [7], we have

$$s_L = \frac{1.69W^2}{\rho S g C_{L,max}\left(D+\mu_r(W-L)\right)_{0.7V_T}} \tag{3}$$

Newfangled aircrafts make use of thrust reversal (T_R) during the landing ground roll, by ducting air from the jet engines and blowing it in the upstream direction, opposite to the usual downstream when normal thrust is produced [7]. This aids the deceleration and shortens the ground roll. Hence equations (2) and (3) become,

$$F = -(T_R + D + \mu_r(W - L))_{0.7V_T} \tag{4}$$

and,

$$s_L = \frac{1.69W^2}{\rho S g C_{L,max}\left(T_R+D+\mu_r(W-L)\right)_{0.7V_T}} \tag{5}$$

respectively. The above expression for s_L is the minimum landing distance required by an ideal aircraft to complete its landing.

3. Decelerating Planar Field

It has been seen that, though the reverse thrusters have been deployed, overrun continues to occur. To decrease the landing distance, thereby reducing the air traffic and hence the accidents due to over-run, this paper proposes the solution in this section.

3.1. Generation of field

The deceleration concept is based on Lenz's law and production of Foucault currents (loops of electrical current induced within conductors by a changing magnetic field in the conductor in planes, perpendicular to the field [8]). Superconductors (red bars) are laid below the asphalt layer (green plane) as in figure 2. The landing aircraft (grey cylinder) moves along $\vec{V}$. The wings are neglected as they are parallel to the field.

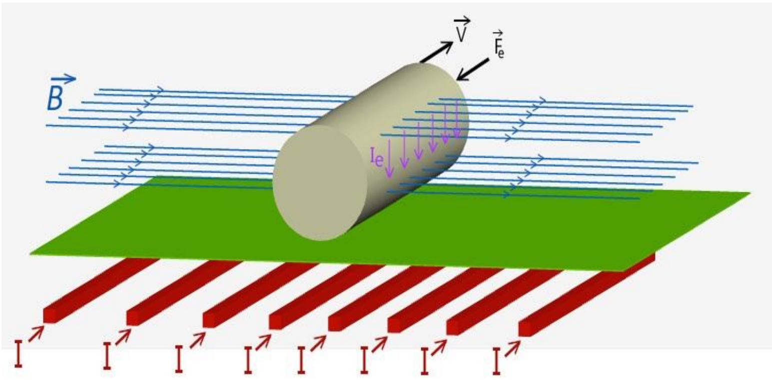

Figure 2. Flux, force and eddy current Representation

When current (I) is passed through the superconductors, the field $(\vec{B})$ is produced horizontally. The direction of $\vec{B}$ is given by cork rule. By Fleming's right hand rule, these Foucault currents are produced normally. Now, according to Fleming's left hand rule, a decelerating force $(\vec{F_e})$ is generated in the opposite direction to the aircraft's movement. Such a huge amount of field can be generated by means of high temperature superconductors [9]. The charges are restricted to the surface as the aircraft body is a Faraday's cage [10].

3.2. Expression for Decelerating force $(\vec{F_e})$

The decelerating force aids the drag (D), adding up to the net opposing forces. This results in the minimization of the landing distance. If $e = BlV_i$ is the emf induced in a straight conductor [11], the differential form of Lorentz force is given by [12],

$$d\vec{F_e} = \frac{e}{\rho_e l} B \sin\theta \, d\theta \tag{6}$$

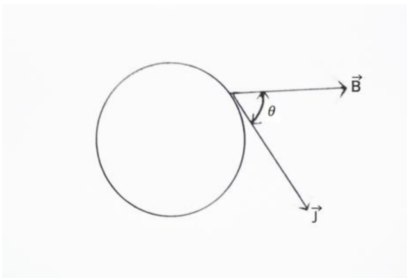

Figure 3. Eddy current density and flux density- Vector diagram

Figure 3 shows the cross sectional path of the cylinder showing the respective vectors. Considering only one section of the closed path of the reverse eddy current (i.e) current flows from $\theta = 0$ to $\theta = \pi$.

$$F_e = 4\frac{V_i B^2}{\rho_e} A \tag{7}$$

It is seen that the force generated is proportional to the square of the flux density (*B*).

3.3. Interface constraints

The superconductors produce the magnetic field (*B*), approximately given by [12],

$$B = \frac{\mu_g I}{2\pi r} \tag{8}$$

where μ_g is ground permeability. Figure 4 shows the vector component representation of flux density ($\overrightarrow{B}$) as the flux travels from ground to air. $\overrightarrow{B_g}$ is the flux density in the ground medium and $\overrightarrow{B_a}$ is that of the air medium. $\overrightarrow{B_g}$ and $\overrightarrow{B_a}$ make an angle Ø and α with the barrier, respectively. The flux density varies normally and tangentially (i.e) $\overrightarrow{B_g}$ as $\overrightarrow{B_{gn}}$ and $\overrightarrow{B_{gt}}$ and $\overrightarrow{B_a}$ as $\overrightarrow{B_{an}}$ and $\overrightarrow{B_{at}}$. From figure 4, these are given as $|\overrightarrow{B_{gn}}| = |\overrightarrow{B_{an}}| = |\overrightarrow{B_g}| \sin\emptyset$, $|\overrightarrow{B_{gt}}| = |\overrightarrow{B_g}| \cos\emptyset$, $|\overrightarrow{B_{at}}| = \frac{\mu_0}{\mu_g}|\overrightarrow{B_{gt}}|$ and $|\overrightarrow{B_{at}}| = \frac{\mu_0}{\mu_g}|\overrightarrow{B_g}| \cos\emptyset$ and the resultant flux density is given by,

$$|\overrightarrow{B_a}| = \left[\left(\frac{\mu_0}{\mu_g}\right)^2 \cos^2\emptyset + \sin^2\emptyset\right]^{1/2} |\overrightarrow{B_g}| \tag{9}$$

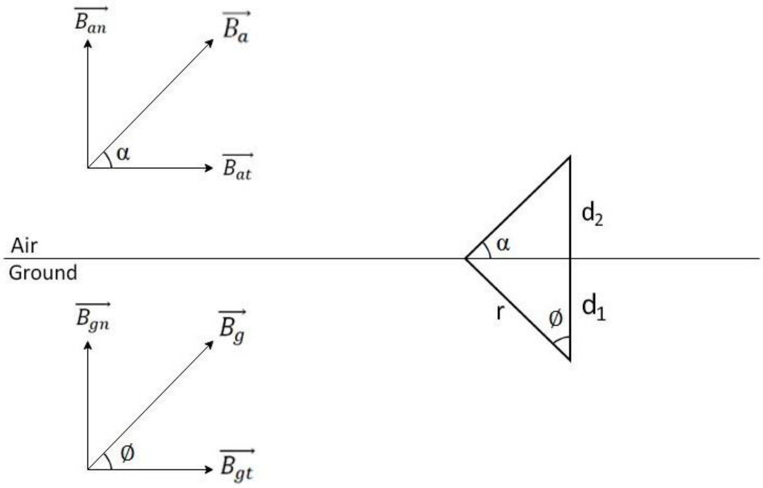

Figure 4. Vector representation of ground-air Barrier

From the boundary conditions [12], $\cot\alpha = \frac{\mu_0}{\mu_g}\cot\emptyset$. Substituting the known values,

$$r = \left[d_1\, d_2 \frac{\mu_0}{\mu_g} + {d_1}^2\right]^{1/2} \tag{10}$$

From ratios of trigonometry, $\cos\emptyset = \frac{d_1}{r}$; $\sin\emptyset = \frac{[r-{d_1}^2]^{1/2}}{r}$. Substituting the values of *r, cosϕ* and *sinϕ*, $|\overrightarrow{B_a}|$can be expressed as,

$$|\overrightarrow{B_a}| = \frac{I\mu_g[\mu_0]^{1/2}}{2\pi}\frac{[\mu_0 {d_1}^2+\mu_g d_1 d_2]^{1/2}}{\mu_g {d_1}^2+\mu_0 d_1 d_2} \tag{11}$$

Substituting the value of $\overrightarrow{B_a}$ in equation (7), we obtain

$$F_e = 4\left(\frac{V_i I^2 \mu_g^2 \mu_0}{(2\pi)^2 \rho_e} \frac{\mu_0 {d_1}^2 + \mu_g d_1 d_2}{\left(\mu_g {d_1}^2 + \mu_0 d_1 d_2\right)^2}\right) A \quad (12)$$

The g-force bearable by an average passenger inside an aircraft is 1.16 g [13]. But in case of fighter jets, the pilots alone are considered. They are trained to endure higher g-forces [14]. Now, equation (4) is updated as,

$$F = -(T_R + D + \mu_r(W - L) + F_e)_{0.7V_T} \quad (13)$$

Now the minimum landing distance equation with respect to equation (13) is,

$$s_L = \frac{1.69W^2}{\rho S g C_{L,max}(T_R + D + \mu_r(W-L) + F_e)_{0.7V_T}} \quad (14)$$

The above expression for s_L gives the minimum landing distance in terms of F_e. All the other quantities in equation (14) are fixed. By varying the value of F_e, s_L is varied inversely.

4. Results and discussions

Let us consider an Airbus A380 for analysis. Table 1 shows the values of the forces associated with landing and other data [15]. The aircraft body is usually made up of aluminium and other composites to bring about homogeneity [16].

Table 1. Specifications of an Airbus A380

6S	845m^2
T_R	160*kN*
W	3861*kN*
L	1947*kN*
D	31.13*kN*
V	68.056 *m/s*

Three cases are simulated namely the normal landing (red), planar field landing (blue) and the imprudent landing (green), as shown in figure 5. Now let us consider that an external force is generated with the help of planar field when an Airbus A380 is landing. For typical landing (red), the landing distance is 1931.8 *m*. The same A380 associated with planar fields (blue), takes only 1072.6 *m* (55.52% of typical distance). The corresponding value of F_e is calculated to be 266.9 kN. The blue curve in the velocity graph shows a linear decrease which indicates a smooth landing. Taking into account the passenger comfort, the maximum reducible distance (green) is found to be 500 m from simulations. But the g-force is just below the maximum bearable limit of 1.16 as shown in figure 6. This can be implemented under absolutely emergency conditions, but not recommended for normal cases. Due to this reason, it can be referred to as imprudent landing.

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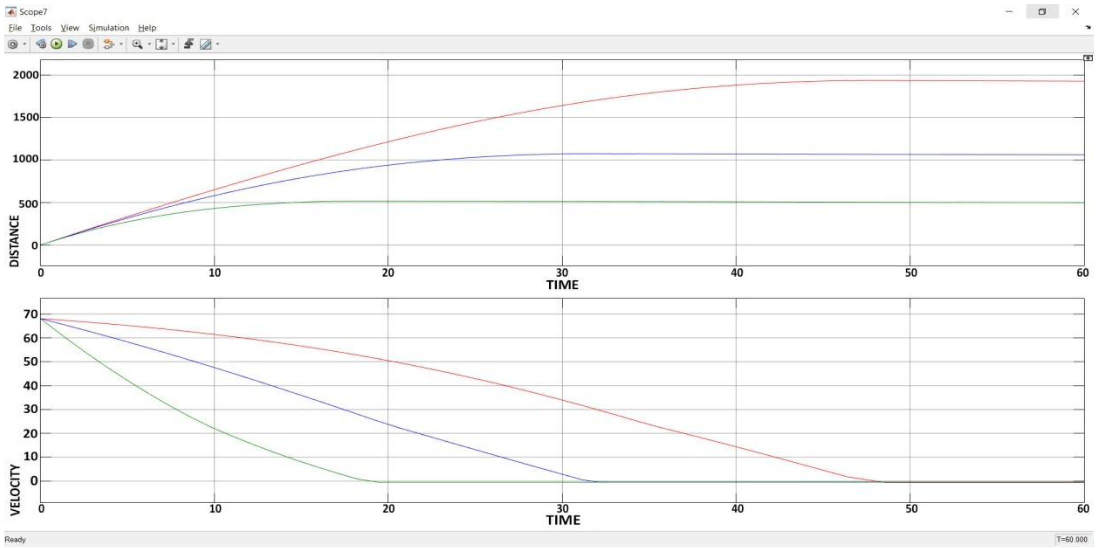

Figure 5. Distance (above) and velocity (below) variation while landing – for normal (red), planar (blue) and imprudent planar (green) landing of an Airbus A380

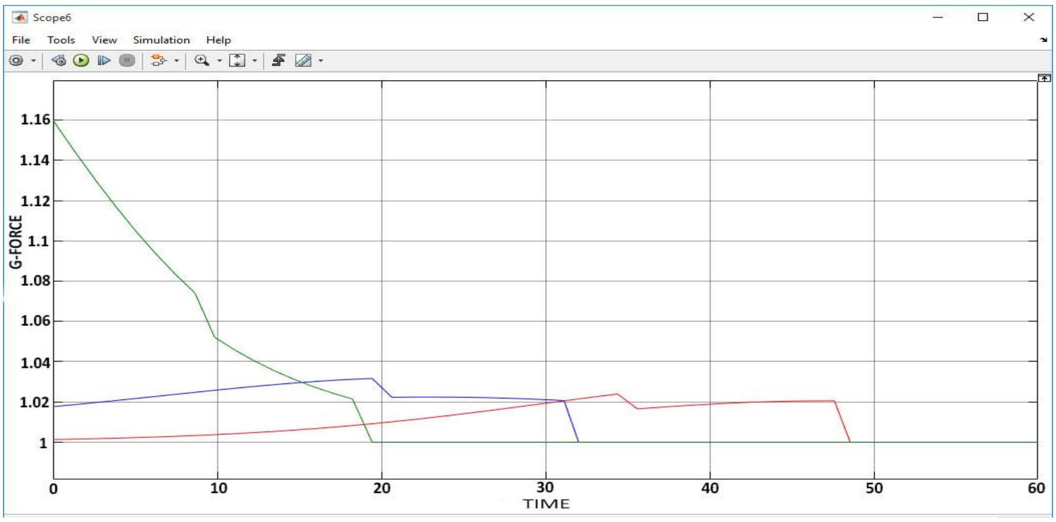

Figure 6. g-force comparison associated with normal (red), planar (blue) and imprudent planar (green) landing of Airbus A380

5. Conclusion

It has been verified that, on applying the concept of planar fields, it is possible to minimize the landing distance of an aircraft. Subsequently, overrun of aircrafts can be avoided and the accidents due to it can be circumvented, with the features of typical landing. As the landing will be completed quickly, air traffic becomes easy to manage. The volume of fuel that is wasted due to loitering, can be conserved. This idea can be applied to the aircraft carrier ships having shorter runways and the places minimum a distance is inevitable. The discussed braking technique is comparatively superior, as it is applied to the whole aircraft body and the stress is distributed uniformly. Hence, this technique is safe and electrically compatible as the field is restricted to the surface. The value of the externally generated force (F_e), is limited due to the g-force bearable by humans. However, this concept can be extended to the cases where F_e has no limit, which includes defense applications such as decelerating a high speed missile and hindrance to bombings.

Acknowledgements

We kindly express our gratitude to Mr. M Veerasundaram, Asst. Professor, Department of Electrical and Electronics Engineering, Sri Sai Ram Institute of Technology, Chennai, Mr. G Swaminathan, Asst. Professor, Department of Mechanical Engineering, Sri Sai Ram Engineering College, Chennai, Ms. D Ezhilmathi, Asst. Professor, Department of English, Sri Sai Ram Institute of Technology, Chennai and Dr. Tharinni Mai, Senior Librarian, Sri Sai Ram Institute of Technology, Chennai for their moral support and encouragement in completing and developing this paper. We also thank our parents for supporting us throughout this technical venture.

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