DESIGN OF MAG-LEV PANEL TO ASSIST TAKE-OFF AND LANDING OF AIRCRAFT

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Abstract: **Air transportation is now in an accelerated growth, to make it reliable and cost-efficient several researchers are going on. In this paper, the design of an aircraft which is assisted by a panel for take-off and landing by using magnetic levitation phenomenon has been proposed. In this design, superconducting magnets and electromagnets are used for levitation and propulsion during take-off respectively, speed and position sync technology by modulating Vehicular Ad-hoc Network (VANET) for landing purpose. An unmanned Air vehicle of 100cm span with T-Tail have been designed and manufactured as per standards of ASME. Due to the levitation of aircraft by superconducting magnets Gross weight of the vehicle reduced approximately 6% was recorded. A Magnetic Panel Runway of length 3m have been designed and tested for 10m/s as take-off velocity. We conjectured that this concept will reduce fuel consumption during take-off, accidents during landing, further a shorter runway length can be achieved.**

Keywords: **Magnetic levitation, VANET, electromagnet, superconducting magnets.**

I. INTRODUCTION

Air transport is the fastest mode of transport in the era which we are living, but being safe and efficient is most important than being fast. A survey between 2004-2013 in aircraft accidents stated that nearly 50-57% of air accidents are in the phase of take-off and landing, predominantly in landing. Thus, to achieve a safer transport electronics should help the aviation. In this project, the concept of magnetic levitation is being employed for take-off or to launch the aircraft that has zero or minimal friction and there is no direct application of magnets to the aircraft body to eliminate the electromagnetic interference. The vehicular ad hoc system (VANET) is applied for speed sync during landing. The effect of eliminating the landing gear on the flight performances, the fuel economy change due to assisted take-off and landing is also discussed. The magnet types, levitation pattern, sync technologies and their advantages and disadvantages are also explained.

II. DESIGN OF RC AIRCRAFT

The Mass of the aircraft has to be estimated to a higher value for being on the safer side. For this design iteration, the mass can be estimated as *750g*. keeping in mind the structural constraints, the wing loading selected should not exceed $0.53\ g/cm^2$.

$$\text{Wing loading} = \text{Mass of the aircraft} / S_{wing}$$

From which the wing area can be calculated. To find the span of the wing aspect ratio is needed, for powered aircraft AR should be *6*.

$$\text{Wing Span, } (b_{wing}) = \sqrt{(AR_{wing} + S_{wing}}$$

Hence, the wingspan is calculated. To have a complete wing geometry next, we have to calculate the wing chord,

$$\text{Wing Chord } (C_w) = \frac{S_{wing}}{b_{wing}} \text{ (for rectangular wing)}$$

Now we have the entire wing geometry in ASME standards. Coming to the performance of the wing, to find the lift produced, assuming steady level flight, (L=W)

$$0.5 \times \rho \times V^2 \times CL_{3D} \times \text{Swing} = \text{m} \times \text{g}$$

By knowing the lift produced by the wing the angle of attack(α) can be found as *3 to* 5^0 (α) keeps the aircraft away from the stall angle providing a safer flight. Therefore, the angle of attack $(\alpha) = 4.^0$

Next to wing the main and stability producing part is the emphanage section, Choose the tail area (S_t) to be around *15-16%* of the wing area. (for better stability of the aircraft). And following the same procedure of the wing parameter calculation, the tail parameters are calculated. Since the tail is tapered the taper ratio comes into account,

Taper ratio of tail (λ_{tail}) = *0.45* (for elliptical distribution of lift)

$$\text{Tail root chord } C_{root} = \frac{2S_t}{b_t\,(1+\lambda_{tail})}$$

$$\text{Tail tip chord } C_{tip} = \lambda_{tail} \text{ x } C_{root}$$

To ensure the stability of the aircraft by placing the tail, is found by the CG calculation "x" is the distance of your center of gravity from the aerodynamic center of the wing. Aerodynamic center is at *25%* of the chord length of your wing from the leading edge.

$$X_{cd} - X_{ac} = X$$

TABLE I: SPECIFICATIONS OF RC AIRCRAFT

Sl. No	**Parameter**	**Values**
1	Wing Span	100 cm
2	Wing Chord	15 cm
3	Co-efficient of lift	0.43
4	Angle of attack	4^0
5	Tail span	30 cm
6	Tail root chord	10 cm
7	Tail tip chord	4.5 cm
8	Position of CG	6 cm
9	Position of tail	41 cm
10	Airfoil shape	NACA 0015

From the final specifications the 2D and 3D drawings are being made with *CADD* and *CATIA* software respectively and the results are validated.

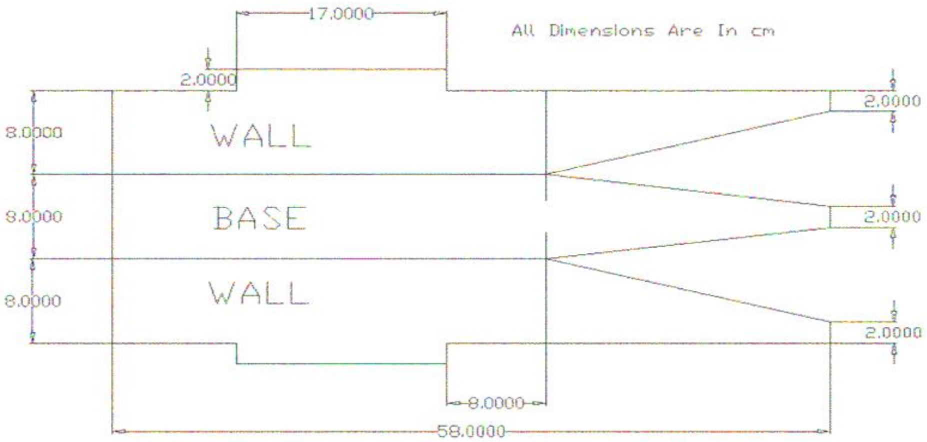

Fig.1 RC body design sheet

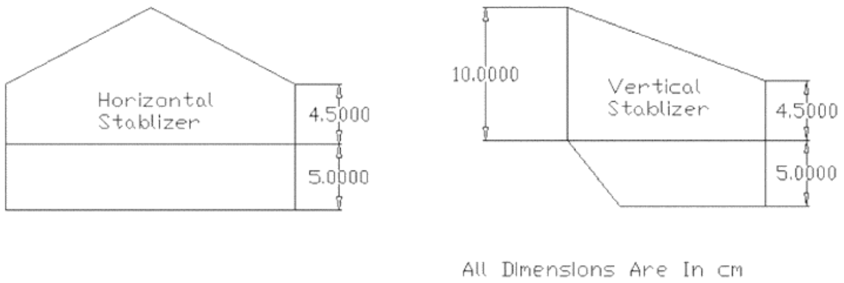

Fig.2 RC stabilizers design sheet

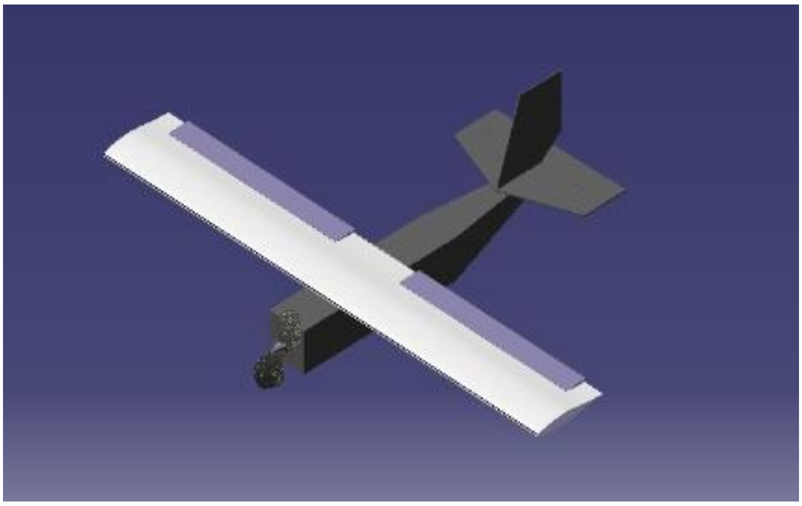

Fig.3 RC 3D model

The materials used for RC manufacturing are,

- Coroplast And Styrofoam
- ESC – Engine Speed Controller
- BLDCM – Brush Less DC Motor
- Servo motors
- Propeller
- LI-PO Battery
- Transmitter and receiver

Thus, an unmanned Air vehicle that weighs 700g having the 100cm span with T-Tail have been designed and manufactured as per standards of ASME.

III. RC PERFORMANCE ANALYSIS

The main performance characteristics of the aircraft performance are its stalling speed, to find the stall speed the main parameter needed is the maximum lift coefficient and maximum drag coefficient the airfoil that we are using is NACA0015, from UIUC web portal for airfoil characteristics at 16^0 of attack is being calculated as, $C_{CLmax} = 0.75$, For flap deflection of 45^0, $(\Delta C_{L\ max}) = 0.40$, $C_{CDmax} = 0.15$. Therefore, the average maximum coefficient of lift is $(\mathbf{C}_{\mathbf{L\ max}}) = 1.15$

For aspect ratio >5 from *Raymer* book,

$$C_{L\ max} = (0.9)\ (c_{clmax})$$

$C_{L\,max} = 1.03$

Now we have the corresponding maximum C_L of our aircraft, so from which the stalling speed can be calculated using some additional information from the design calculation,

$$V_{stall} = \sqrt{\frac{2}{\rho}\frac{W}{S}\frac{1}{\text{CLmax}}}$$

Hence the stalling speed of the RC aircraft is being found as approximately *10m/s***,** from which the take-off and landing characteristics can be found. So that based on them the runway distance can be calculated. calculation of the landing distance starts with the assumption of approach angle since it is assumed as $\theta_a = 3^o$.

The average velocity during flare is given by the ratio with the stalling velocity as,

$$V_f = 1.23\, v_{stall}$$

$$V_f = 11.15 \text{ m/s}$$

The flight path radius during flare is equated with the flare velocity and acceleration due to gravity as,

$$R = \frac{{V_f}^2}{0.2g}$$

$$R = 63.36\text{m}$$

The flare height is found as,

$$h_{hf} = R\,(1 - \cos\theta_a)$$

$$h_{hf} = 0.086 \text{ m}$$

The approach distance to clear the 50ft/15.24m obstacle to overcome the initial drag is,

$$S_a = \frac{15.24 - h_f}{\tan\theta_a}$$

$$S_a = 289.139 \text{ m}$$

Then, the flare distance is given as,

$$S_f = R \sin\theta_a$$

$$S_f = 3.31 \text{ m}$$

From these values, the ground roll distance can be approximated as follows,

$$S_g = j\,N\sqrt{\frac{2}{\rho}\frac{W}{S}\frac{1}{\text{CLmax}}} + \frac{j^2(W/S)}{g\rho_\infty\,\text{CLmax}\,\mu_r}$$

$$S_g = 45.23\text{m}$$

The total landing distance is given as,

$$S_a + S_f + S_g = 340\text{m}$$

The first phase of take-off is the ground roll, and it can be calculated by using the formula,

$$S_g = \frac{1.21(W/S)}{g\rho_\infty\, C_{L_{max}}(T/W)}$$

The average value of T/W during take-off is that value at $V\infty = 0.7\, V_{LO,}$ where, $V_{LO} = 1.1\, V_{stall,}$ therefore, $V\infty = 6.98$ m/s.

Since the thrust available, $T_A = \frac{\eta_{pr} P}{V\infty}$

$$\left(\frac{T}{W}\right)_{0.7VLO} = 7.026$$

therefore, the ground roll distance is calculated as, $S_g = 9.25$ m.

To obtain the distance covered while airborne to clear an obstacle, we first calculate the flight path radius,

$$R = \frac{6.69\,(V_{stall})^2}{g}$$

$$R = 58.36\text{m}$$

The included flight path angle is

$$\Theta_{oB} = \cos^{-1}\left(1 - \frac{h_{DB}}{R}\right)$$

$$\Theta_{oB} = 42^{o}$$

The airborne distance is

$$S_a = R \sin \Theta_{oB}$$

$$S_a = 39 \text{ m}$$

The total take-off distance is, $S_g + S_a = 50$ m.

Touch down velocity,

$$V_{TD} = 1.15\, V_{stall}$$

$$V_{TD} = 10.43\text{m/s}$$

Lift off velocity,

$$V_{LO} = 1.1\, V_{stall}$$

$$V_{LO} = 9.97 \text{ m/s}$$

All of these performance calculations and the velocity predictions are done with reference to the Aircraft Performance and Design by John D. Anderson, Jr (chapter 8.8.4, 8.8.5, 8.8.6).

IV. MAGNETIC RUNWAY

According to the International Civil Aviation Organization (ICAO), *"a runway is a defined rectangular area on a land aerodrome prepared for the landing and takeoff of aircraft".* Runways may be a man-made surface (often asphalt, concrete, or a mixture of both) or a natural surface (grass, dirt, gravel, ice, or salt).

A magnet is simply an object which produces a magnetic field. North and South are the designations made to describe the two opposite poles. North is attracted to South and repelled by North. South is attracted to North and repelled by South. "The principle is that two similar poles (e.g., two north's) repel, and two different poles attract, with forces that are stronger when the poles are closer. There are four magnetic forces on the top: on its north pole, repulsion from the base's north and attraction from the base's south, and on its south pole, attraction from the base's north and repulsion from the base's south. Because of the way the forces depend on distance, the north-north repulsion dominates, and the top is magnetically repelled. It hangs where this upward repulsion balances the downward force of gravity, that is, at the point of equilibrium where the total force is zero."

Maglev Technology: This technology uses monorail track with linear motors, these aircrafts move on special tracks rather than the mainstream conventional runways. they use very powerful electromagnets to reach higher velocities, they float about 1- 10 cm above the guideway on a magnetic field. These aircrafts are propelled by the guideways. once the aircraft is pulled into the next section the magnetism switches so that the aircraft is pulled on again. The electromagnets run the length of the guideway.

The electromagnetic suspension is the most efficient way to achieve maximum speed and proper stability. Hence, EMS is chosen for levitating magnetic panel. In this design, the runway is made as an I-section to carry more load when the aircraft is off from its levitation**.**

TABLE II: RUNWAY SPECIFICATIONS

DIMENSION	VALUE
Length	300 cm
Width	15 cm
Height	15 cm
Number of magnets per meter	86 no.

Since the required length of the runway is reduced by the ratio of 1:10 the 50m normal transmission runway needed for this particular RC aircraft to land and take-off is being reduced to 5m. The type of suspension technique suggested is an electromagnetic suspension, since it needs less amount of energy discharge to produce high speed in a shorter distance. Which is the main purpose, it is also safer than any other techniques, the installation and maintenance cost is far less than other techniques. The design is done using CATIA.

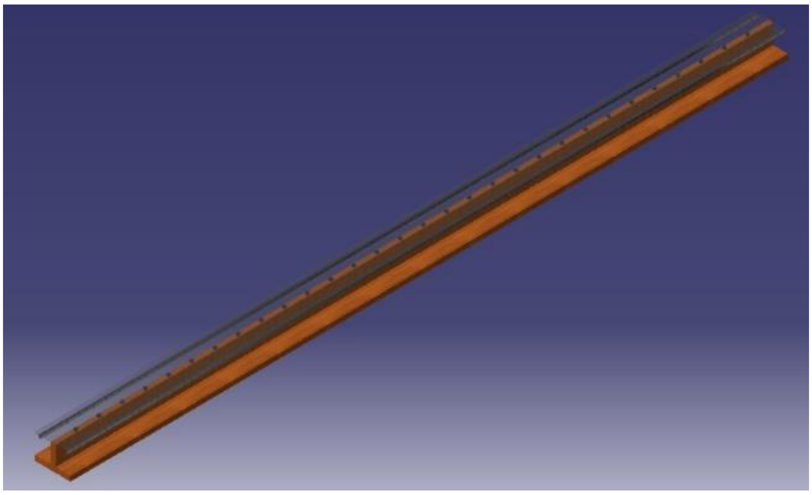

Fig.4 Base of the runway.

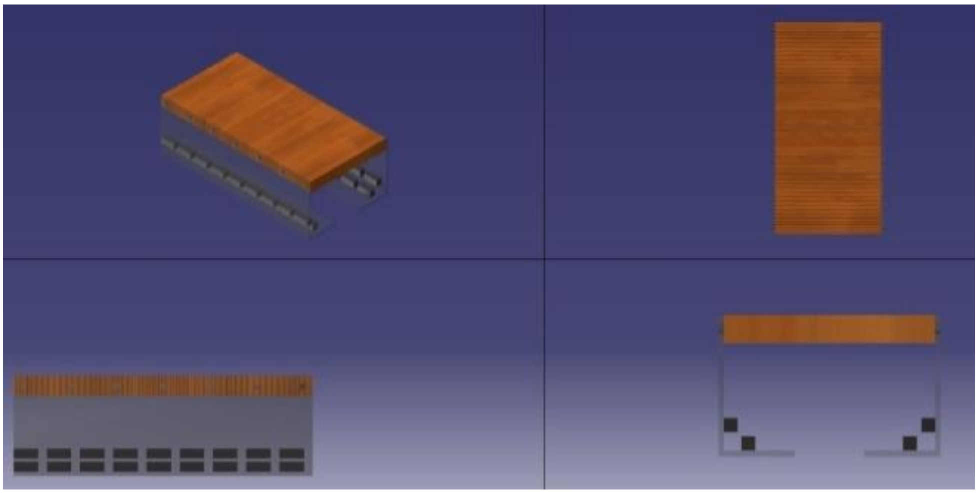

Fig.5 Mag-Lev panel

Neodymium Magnets: A neodymium magnet (also known as NdFeB, NIB or Neo magnet), the most widely used type of rare-earth magnet, is a permanent magnet made from an alloy of neodymium, iron, and boron to form the Nd2Fe14B tetragonal crystalline structure.

Magnetic properties: *Remanence (Br)* which measures the strength of the magnetic field, *Coercivity (H ci)* the material's resistance to becoming demagnetized, *Energy product (BH max)* the density of magnetic energy, *Curie temperature (T ^{o} C)* the temperature at which the material loses its magnetism.

TABLE III: MAGNETIC PROPERTIES

PROPERTY	NEODYMIUM
Remanence (T)	1–1.3
Coercivity (MA/m)	0.875–1.99
Relative permeability	1.05
Temperature coefficient of remanence (%/K)	−0.12
Temperature coefficient of coercivity (%/K)	−0.55–0.65
Curie temperature (°C)	320
Density (g/cm^3)	7.3–7.5
CTE, magnetizing direction (1/K)	5.2×10^{-6}
CTE, normal to magnetizing direction (1/K)	-0.8×10^{-6}
Flexural strength (N/mm^2)	250
Compressive strength (N/mm^2)	1100
Tensile strength (N/mm^2)	75

The variation in the magnetic properties due to different arrangements used in the runway and panel are calculated by using the software called "*vizimag"* with corresponding magnetic flux diagrams, flux density plots, magnetic force plots.

V. SYNCHRONISATION TECHNOLOGY

Principle: *VANET* (vehicular ad-hock network) technology can create an interface between two moving bodies through high-speed signal transmission and can find the position and speed values using GPS (Global positioning system) and DSRC (Dedicated short-range communication).

Working: Ground controller (signal transducer), which is capable of producing signals and gathering signals simultaneously from both aircraft and the moving panel. These signals are processed by and master computer and the parameters needed to locate and synchronize the panel to the aircraft like altitude, speed, acceleration, touch down velocity are calculated. The calculated values of speed, acceleration, the position of the aircraft is being set on the panel thus is can synchronize with it. The logic of safe landing is being calculated through statistical and analytical approaches and the landing will take place safely. If the conditions are not good for landing the main controller will alert the aircraft and insist it not to land and make a loiter. When the panel is all set landing will be initiated again. So, accidents are merely possible by using this mag-lev panel concept.

Material Used: *A High-speed signal transmitter and receiver setup***,** for creating a continuous data uplink between them and the computer to which they are connected. *Programming software (Arduino software),* to imprint our logic into the transmitters and receivers to convert inputs readable by the computer and outputs understandable by the user. *High processor pc,* to constantly analyze the data and predict whether the landing is possible or not.

VI. RESULTS

Since the required length of the runway is reduced by the ratio of 1:10, the 50m of normal transmission runway needed for this particular RC aircraft to land and take-off is being reduced to 5m.

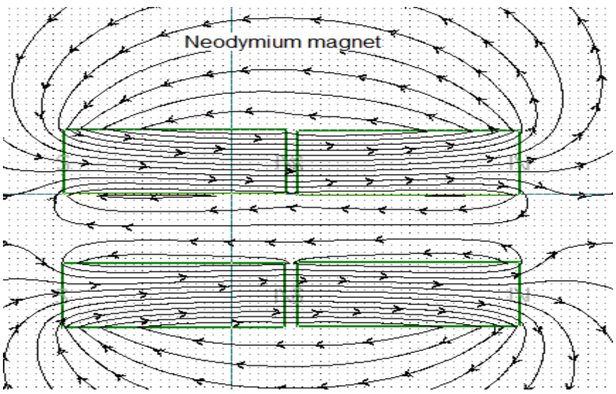

Fig.7 Magnetic flux of propelling magnets

take-off velocity is nearly achieved and the RC does fly properly.

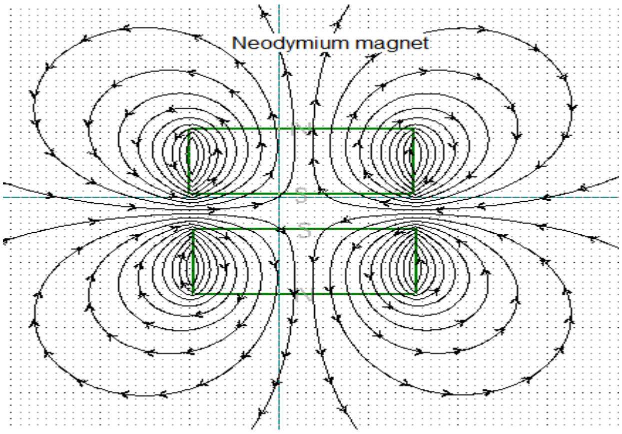

Fig.8 Magnetic flux of levitating magnets

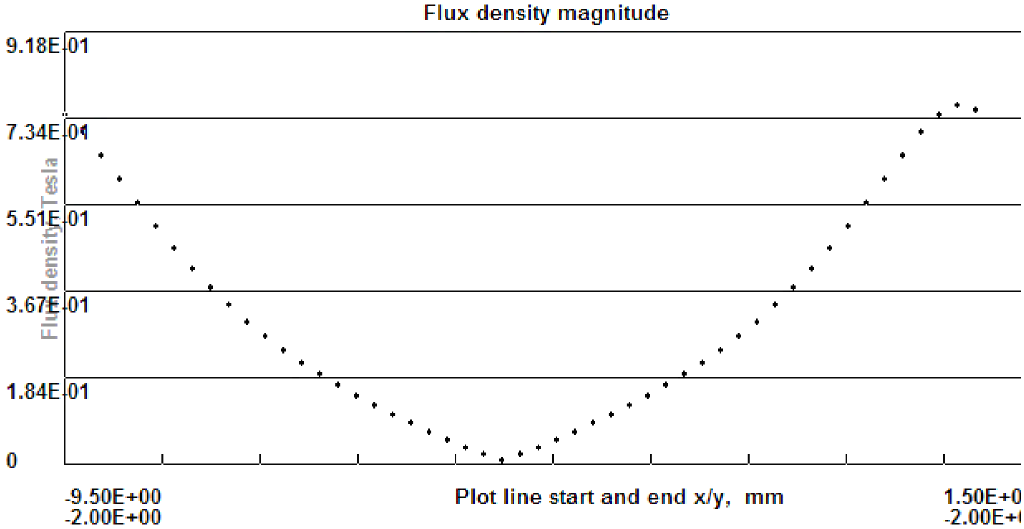

Fig.9 Magnetic flux density plot

TABLE IV: OVERALL RESULTS

SL NO	PROPERTIES	VALUES
1.	Magnetic force of one neodymium magnet	1.06e0 tesla
2.	Maximum magnetic flux density	7.35e1 tesla
3.	Minimum magnetic flux density	0 tesla
	Magnetic force of levitating neodymium magnet	1.08e2
4.	Air gap produced	1.5 cm
5.	Velocity achieved	10m/s

VII. CONCLUSION

The landing gear of the aircraft is being removed and the take-off and landing are assisted by the mag-lev panel for acceleration on take-off phase and deceleration on landing phase. RC aircraft is made without landing gear, testing of magnetic levitation runway is done which proves there is very small runway is needed to take-off the aircraft using mag-lev technology. The take-off speed achieved in 3m runway is 10m/s using strong neodymium magnets. If electromagnets are used the results can be enhanced. The need for strong data transfer is the main key to land the aircraft, which is possible nowadays, if that combines with the effective piloting this will the safest way of landing an aircraft. Due to minimal friction in the take-off phase with results from rule-of-thumb is that a reduction in fuel consumption of about 0.75% results from each 1% reduction in weight is verified.

ACKNOWLEDGEMENT

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REFERENCES

[1] Conceptual Design of An Aircraft with Mag-Lev Landing System *Nishanth Murugan, Mohammed Niyasdeen Nejaamtheen, S. Sounder Ranjan, 2013.*

[2] Design of Magnetic Levitation Assisted Landing and Take-Off Mechanism of Aircraft Using Hammock Concept *Kumar Poudel, April-May 2014.*

[3] Magnetic Levitation System for Take-Off and Landing Airplane *Gabriel, 2013.*

[4] Aircraft Design: Conceptual Approach by *Daniel P. Raymer*

[5] Aircraft Performance and Design by *John D. Anderson, Jr*

[6] Introduction to electrodynamics, *D.J. Griffiths.*

[7] General Aviation, Accidents and Fatalities, Recent Studies of Causal Factors.