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Vertical (VTOL) & short (STOL) takeoff and landing for modern jet powered aircraft: a Problem to carry heavy payload & its solution

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ABSTRACT
A vertical (VTOL) & short (STOL) takeoff and landing (V/STOL) aircraft is an airplane which is able to vertically takeoff or can takeoff with in a very short runway even in a paddy field. Vertical takeoff and landing (VTOL) aircraft is a subset of V/STOL aircraft that does not require any runways at all. A V/STOL aircraft needs to be able to hover. Vertical takeoff and landing (VTOL) or short (STOL) are desirable characteristics for any type of aircraft. Even VTOL aircrafts have too many advantages, but still there is only one drawback which has prevented them to be at the top of fighting aircraft i.e. the problem with payload. The VTOL aircraft can only carry very little payload, while taking off vertically due together power plant design which does not support heavy payloads. In this paper we will discuss how to increase their payload capability by using electromagnetic flux which will provide an extra bit of thrust during takeoff. Hence, increase the payload capability of aircraft.

Keywords: Keywords: Takeoff, landing, payload, aircraft

1. Introduction

Though vertical takeoff and landing (VTOL) or Short take off and landing (STOL) are most desirable characteristics for any type of aircraft but until the introduction of the gas turbine engine, the low disc loading rotor, as on the helicopter was only system capable of VTOL .For a pure jet engine, this V/STOL concept was developed by the principle that was proposed by M. Wibault. During 1960s, many countries around the world wanted to design an aircraft that will be able to take off and land easily from the aircraft career by reducing the cost of making large aircraft career and runways for therm. After that the Harrier, Mirage-IIIV, YAK-38, F-35, V-22 etc were developed and designed according to the desired mission and requirement of V/STOL aircrafts. Though there are different/STOL aircrafts now-a-days, but still now all of these V/STOL aircraft allow a very little amount of payload during takeoff. Here we will try to improve their payload capacity by using electro-magnetic flux. Though our research may not solve this problem fully but it will open a new horizon for new generation researchers.

2. Power plant-a historical view

Different types of power plants were used to make the operation of V/STOL aircraft smooth and successful as much as possible it was. But Rolls Pegasus –a turbofan engine was unique in this field. It was considered as a blessing for V/STOL aircraft during that time.

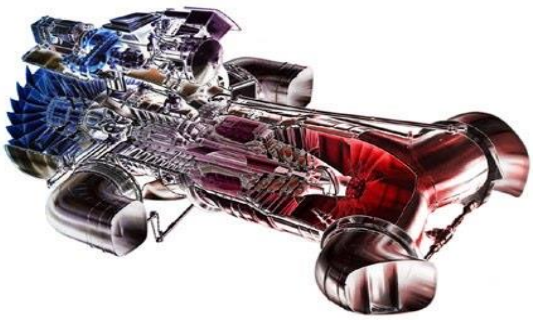

Fig.1 The Rolls-Royce Pegasus V/STOL Engine

This engine also provides the thrust vectoring system for the V/STOL aircraft of that period. This eradicated the necessity of traditional long runway and opened a new horizon for that aircraft which were responsible to take off and land from variety of ships at sea. This Rolls Royce Pegasus turbofan engine featured three low pressure and eight high pressure compressor stages which were driven by two low pressure and two high pressure turbine engine respectively. This Pegasus was first turbofan engine which had the initial compressor fan ahead of from bearing. But unfortunately at higher ambient temperature the maximum takeoff thrust provided by the Pegasus engine was limited. To overcome this problem and to increase the thrust during takeoff, water was sprayed into combustion chamber

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and turbine to keep the blade temperature down let and to enable to engine to its optimum speed.

3. Power plant thrust equations

Let us consider a propulsive duct in which air of mass $\dot{m}_i$ enters the intake with velocity c_i and pressure. During the combustion process acceleration of air happens and it leaves through the nozzle with pressure p_j and velocity c_j. The flow is assumed to be steady and reversible outside the duct .A_j and A_i are considered as the exhaust area and intake area respectively.

So, thrust due to the rate of change of momentum = $\dot{m}_j c_j - \dot{m}_i c_i$

And pressure Thrust = $(p_j-p_a)A_j - (p_i-p_a)A_i$

Net Thrust = $(\dot{m}_j c_j-\dot{m}_i c_i)+(p_j-p_a)A_j-(p_i-p_a)A_i$

We have by mass balance,

$\dot{m}_j=\dot{m}_i+\dot{m}_f$

Where $\dot{m}_j$, $\dot{m}_i$ and $\dot{m}_f$ are the mass flow rates of exhaust gases, air and fuel respectively.

Fuel air ratio = $f=\dot{m}_f/\dot{m}_i$

So, $\dot{m}_j=\dot{m}_i(1+f)$

So, Net Thrust = $\dot{m}_i\{(1+f)c_j-c_i\}+(p_j-p_a)A_j-(p_i-p_a)A_i$

For subsonic aircraft $(p_i \approx p_a)$& $(p_j \approx p_a)$,

Neglecting small value of pressure thrust,

$T=\dot{m}_i\{(1+f)c_j-c_i\}$

4. Electromagnetic flux

A stationary charge produces an electric field in the surrounding space .When the charged particle is in motion it also creates a magnetic field around it .Electromagnetic Flux (EMF or EM Flux) is a spatial distribution of influence of charged particles around them while they are in motion .Because of mutual interaction of electric and magnetic fields created by the charged particles; an electromagnetic flux is generated.
From a classical perspective, the EMF can be regarded as a smooth, continuous field, propagated in a wavelike manner; whereas from the perspective of quantum field theory, the field is seen as quantized, being composed of individual particles.

4.1 Nature of electromagnetic field

Electromagnetic Field is produced due to combined interaction of electric field and magnetic field. Electric Flux is a property of electric field which can be defined as the number of electric lines of force that pass through

$\boldsymbol{E=F/Q}$

a given area. The mathematical relation between electric flux and enclosed charge is known as Gauss's law for the electric field, one of the fundamental laws of electromagnetism which is,

$\Phi_E=\oiint_S E.dA=\frac{q}{\varepsilon}$------ - - - - - - - - - (i)

$\Phi_B=\oiint_S B.dS=0$------ - - - - - - - - - (ii)

When the electric charges are in motion, magnetic and electric fields are generated which produce forces on electric charges .These forces and their effects are described by Lorentz force law which is,

$\vec{F}=q\vec{E}+q\vec{V}\times\vec{B}$

Faraday's Induction Law states that induced electromotive force in any closed circuit is equal to the rate of change of the magnetic flux through the circuit. Mathematically,

$\oiint_S \vec{E}.dl=-d\Phi_B/dt$------ - - - - - - - - ($iii$)

Faraday's Induction Law refers to changing magnetic field induces (negative) vortex of electric field.
Ampere's Law relates the net magnetic field along a closed loop to the electric current passing through the loop.
Mathematically,

$\oiint_S \vec{B}.dl=\mu_0 i+\frac{1}{c^2}\frac{d}{dt}(\Phi_E)$------ - - - - ($iv$)

These Laws[(i) to (iv)] are the mathematical way of defining an electromagnetic field .These four laws are known as Maxwell's Equations which are the fundamental postulates of classical electromagnetic. All classical electromagnetic phenomena are explained by these equations. These equations are used to explain the behavior of an electromagnetic field.

4.2 Electro-magnetic field & its reciprocal behavior

A very practical feature of the electro-magnetic field is illustrated by maxwell's equation, Faraday's law and the ampere-maxwell law. At first, we will think about the faraday's law. According to this law, a changing magnetic field creates an electric field and it is the principle behind the electric generator. Ampere's law relates magnetic fields to electric current to produce them, It relates a magnetic field to its electric current source. It states that," a changing electric field creates a magnetic field.".Thus we can apply this law to generate a electric field and run an electric motor. Lovents force between two point charges is

$\boldsymbol{F_{12}=(Q_1Q_2/4\pi\epsilon_0\epsilon_r r^2)l_r}$

We can verified it with the help of coulombs law and Biot-savart law also-

$F_L = Q(v \times B)$

$d\mathbf{B}/p = (\mu_0 I/4\pi r^2) dl \times l_r$

This is also known as the law of laplace.

5. Multi-frequency flux generator

Ultrasonic generators with multiple frequency technology are specially designed units that convert electrical energy into ultrasonic signals. Connected with immersible transducers, ultrasonic signals from the generator will be converted into corresponding mechanical vibrations able to "scrub off" surfaces immersed in liquid.

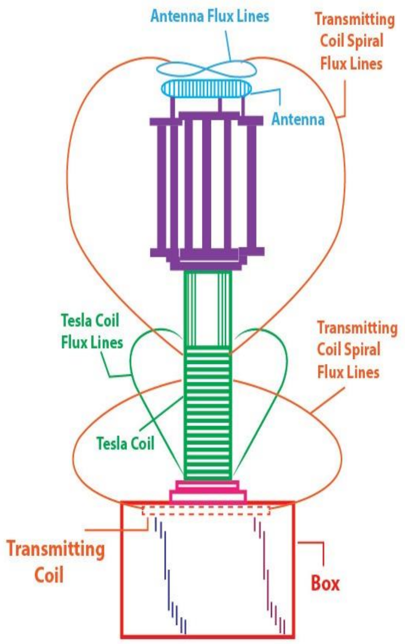

Fig.2 A typical flux generator

5.1 Features

1. Robust unit - Material in contact with cleaning solution is made of stainless steel
2. Thermostatic adjustable heating and timer function
3. Designed for use with water-based as well as solvent-based cleaning chemicals
4. Convenient drainage option
5. Mounted on stainless steel frame for secure fastening to the deck
6. Ideal partner for cleaning fuel and lube oil filters

5.2 Benefits

1. Allows usage of chemicals with less hazard
2. Flexible solution & low audible sound

6. Result and Calculation

By using different types of generator electromagnetic flux can be generated. We are interested here to use the generator shown in fig.2 for our calculation purpose. To increase the thrust produced by the aircraft, we can use this flux which is being generated by this flux generator.

Fig.3 A self conceptual designed V/STOL aircraft

Let us consider 127 KN is the maximum weight that can be carried by our considered aircraft (conceptual). Now by using electromagnetic flux we can provide an extra bit of thrust to the aircraft. We have done this by using the following calculations of table 1 and derived our result. Generally, here we have taken the radius of our coil of the flux is 0.02 m which we kept fixed. We changed the number of turns and varied the current with a view to increase the magnetic flux .By doing this experiment for several iteration and using 12000 turns of the coil we produced 23212.98 N of magnetic flux that is around 23.212 KN (shown in table-1). So, from here, we can summarized that around 23.212 KN force can be managed by using magnetic flux to assist the aircraft in vertical or short take off and certainly this 23.212 KN force is around 18% of this gross force required for this aircraft to perform this.

6.1 Calculation

(1) Number of turns (n) =100
Radius = 0.02 m
Magnetic flux B=$\frac{\mu o n i}{2r}$ =0.0314
Force generated, F=2πIRBcosθ=0.039

(2) Number of turns(n)=1200
Radius (m) = 0.02
Magnetic flux B=$\frac{\mu o n i}{2r}$ = 1.257
Force generated, F=2πIRBcosθ=6.314

(3) Number of turns(n)=1500
Radius (m) = 0.02
Magnetic flux B=$\frac{\mu o n i}{2r}$ = 2.827
Force generated, F=2πIRBcosθ=21.3151

(4) Number of turns(n)=2000
Radius (m) = 0.02
Magnetic flux B=$\frac{\mu o n i}{2r}$ = 6.283
Force generated, F=2πIRBcosθ=78.955

(5) Number of turns(n)= 2500
Radius (m) = 0.02
Magnetic flux B=$\frac{\mu oni}{2r}$ = 11.78
Force generated, F=2πIRBcosθ=222.05

(6) Number of turns(n)=5000
Radius (m) = 0.02
Magnetic flux B=$\frac{\mu oni}{2r}$ = 31.41
Force generated, F=2πIRBcosθ=789.42

(7) Number of turns(n)=10000
Radius (m) = 0.02
Magnetic flux B=$\frac{\mu oni}{2r}$ = 141.37
Force generated, F=2πIRBcosθ=7994.298

(8) Number of turns(n)=12000
Radius (m) = 0.02
Magnetic flux B=$\frac{\mu oni}{2r}$ = 263.89
Force generated, F=2πIRBcosθ=23212.98

Table 1 Calculation for force generated by flux

Serial no	Number of turns(n)	Radius (m)	Current (I)	Magnetic flux B=$\frac{\mu oni}{2r}$	Force generated, F=2πIRBcosθ
1	100	0.02	10	0.0314	0.039
2	1000	0.02	40	1.257	6.314
3	1500	0.02	60	2.827	21.3151
4	2000	0.02	100	6.283	78.955
5	2500	0.02	150	11.78	222.05
6	5000	0.02	200	31.41	789.42
7	10000	0.02	450	141.37	7994.298
8	12000	0.02	700	263.89	23212.98

Conclusion

From this study, we can see that V/STOL thrust can be increased around 18% by using electro-magnetic flux generator. We can easily increase this capability of generated thrust by increasing the number of turns of the coil and the current passing through it according to the mission requirement. Different types of fluxes i.e spiral ,horizontal can be used in this purpose. But there are some problems for the implementation of this as the flux generated by this can harm the aircraft instrument and structure ,so special care should be taken during the time of airframe manufacture. Therefore, no others only specially designed V/STOL aircraft can use this which are capable of withstanding the hazard produced by the flux.

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