Regenerative Braking System on HAWK I Aircraft

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Abstract- *In the present work, the simulation of electromechanical regenerative braking system was developed through modeling in Hawk aircraft landing gears to power generation for the alternative source. By considering aircraft's mass, speed and the energy wasted by an aircraft while braking, a simulation for regenerative braking system is developed. With the help of the theoretical values determined by the specified formula, the selection for electric motors and the storage devices are selected and then this model is simulated to evaluate and characterize the energy and the power requirements for the regenerative braking system. Power harnessed from this regenerative braking is 90kw.*

Keywords- Electromechanical, Regenerative Braking system, HAWK I Aircraft

I. INTRODUCTION

The word 'Braking" means when the body in motion, the application of brake to reduce the speed and make the body come to rest. All automobiles and aircrafts require brake to control its speed. Usually by depressing the pedal. In a moving vehicle the vehicle momentum is counteract by friction in brakes. In friction brakes the pads will rub against the disc or wheel which is connected to axle. Excessive heat will be reduced du rot friction. This heat energy will be dissipates to air. Almost 25% of energy for vehicle operation could be generated .And also fuel efficiency will be reduced by this. Usually braking is applied to wheel of aircraft only on runway. Mainly landing and taxing. During landing the vehicle will be on 60-90 m/s of velocity. The brake applied won't make the wheel to get stationary at once. There will be stop and go movement. Here the energy is losted by braking. As we know by a law says that energy can be created nor destroyed. So the energy which is wasted by heat during braking could be harnessed by system called regenerative braking system. So when aircraft moving, wheel will be on forward direction. When brake applied wheel kinetic energy could be harnessed by electromechanical arrangement. The heat energy could be converted to mechanical energy and convert to electrical energy.

II. CONVERSION OF KINETIC ENERGY TO ELECTRIC ENERGY USING ELECTRIC MOTOR

The Regenerative braking system commonly has a electric motor for generating electricity. From the principle of electric motor the regenerative braking system works. The motor gets actuated when electric flows through it. When any force externally given to a motor then it becomes generator and produces electricity as shown in Fig 1.

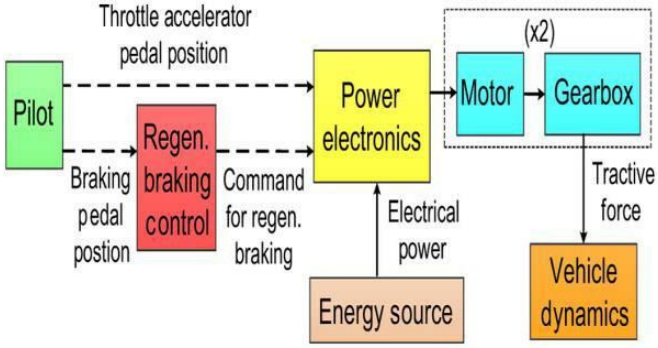

Fig.1: Energy flow diagram of a Regenerative braking system[4]

Whenever the motor starts to rotate in single direction, the supplied electrical energy is converted to mechanical energy. This mechanical energy will be used to run the generator which in turn produces electric current and gets stored in a battery. And used for applications of electrical gadgets. Similarly the aircraft speed also reduced by electric motor friction.

III. WRITE DOWN YOUR STUDIES AND FINDINGS

In this paper regenerative braking system concept is made by the type of electromechanical type. In landing gear of an aircraft i.e. rear one. Here a two motor of YASA P400 series motor is place in behind the wheel place on the supporting frame. From the belt and pulley the energy is transferred from wheel to generator during braking as well as motor to wheel during taxing. This is shown in Fig.2.

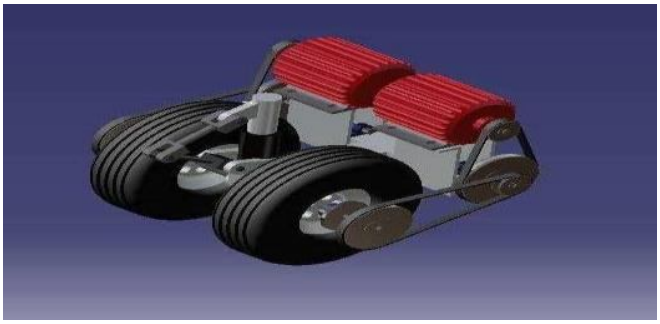

Fig.2. CAD model of Regenerative braking system of electromechanical type

Then calculation of braking force, regenerative braking force, dynamic load, friction force and mean power that can be harnessed by braking is calculated by considering aircrafts velocity, mass, acceleration.

BRAKING FORCE

Braking force is the force exerted on the aircraft wheels both ear and front on the time of braking operation. The brake system composed of combined friction and electromechanical braking system.so the force acting on the declaration of speed of aircraft can be calculated by using braking force.

$Fb=M- Mgfr - ½\rho aCdAfV^2$

Where, M is the mass of the vehicle (kg), g is the acceleration due to gravity (m/s^2), fr is the rolling resistance coefficient, ρa is the density of air (kg/m^3), Cd is the coefficient of aerodynamic drag, Af is the frontal area of the vehicle (m^2) V is the average velocity of the vehicle (m/s)

REAR BRAKING FORCE

It is the force exerted at the rear wheel of aircraft during braking. The braking force will be distributed between rear and front wheels. Here it is mainly concentrated on rear as braking system is present in rear wheel. So the rear braking force can be calculated by using.

Fbr=μWr (dynamic)…..N

Where, μ is co efficient of friction between road and tyre for bit-uminous concrete is 0.54 and Wr is the dynamic load acting on rear wheels.

DYNAMIC LOAD ACTING ON REAR WHEELS

The dynamic load will be the load i.e. been acting on a wheel and the runway. The dynamic load on rear wheels can be written as

Wr (dynamic) =Mg/L (Lb– ha/g) +Fa h/L…..kg

Where, g is the acceleration due to gravity (m/s^2), L is the Wheel base (m),Lb is the distance of the rear axle from the centre of gravity his the height of centre of gravity from the ground(m).

AERODYNAMIC FORCE

It is the force exerted on the body of aircraft by the air in which the body is immersed due to the relative motion between body and the air. The aerodynamic force is calculated by using…

$Fa= Cd\times\rho a\times Af\times v^2$…..N

RATIO OF BRAKING FORCE ACTING ON REAR WHEEL AXLE TO THE TOAL BRAKING FORCE

β = Fbr/Fb

Where, Fbr rear braking force and Fb braking force.

FRICTIONAL FORCE

The frictional force is the force created by the frictional brakes. This friction causes the generation of kinetic energy getting harnessed here to achieve the motive of the project. The frictional force is calculated by using…

Ffriction= Fbr / β…

Where, Fbr is the rear braking force and β is ratio of braking force acting on rear wheel axle to the total braking force.

REGENERATIVE BRAKING FORCE

I n the constant power operating region, the regenerative braking force that the electric motor can generate at any instant by considering frictional and rear braking force, can be calculate by using…

Freg = Fbr - (1-β) Ffriction…..N

Where, Fbr is rear braking force and Ffriction is frictional force.

BRAKING POWER OF MOTOR

The braking power of motor is the power could be harnessed by wasted energy and power capacity of motor/generator. It is the theoretical power generation.

$Pm = Freg \times Vi$……

Where, Vi is initial velocity of aircraft during landing

Table 1. Experimental Aircraft parameters

Mass M	4239.83 kg
Acceleration due to gravity g	9.81 m/s^2
Rolling resistance co efficient f_r	0.014
Density of air ρ_a	1.29 kg/m^3
Co efficient of aerodynamic drag C_d	0.023
Frontal area of aircraft A_f	13. 82 m^2
Velocity of aircraft V	60-90 m/s
Wheel base L	4.664m
Dist of rear axle from C.G L_b	0.852m
Height of C.G from the ground h	1.954 m
Acceleration a	1.51 m/s^2
Initial velocity of aircraft V_i	90 m/s

Table 2. Theoretical results

Velocity m/s	F_{reg} N	Regenerative Power kw
60	572.2	51.5
70	677.59	60.97
80	1169.90	105.2
90	1650.07	148.5

The above values are calculated by the formulas and considering the aircraft parameters theoretically.

IV. SIMULATIONS

To evaluate the proposed regenerative braking of electromechanical type and to compare with the theoretical values calculated by considering the aircraft parameters. The simulation and analysis of CAD model is done in CATIA software. The first CAD model will be designed with rear landing gear placed with motor and pulley attachment. Then by defining the speed, time, mass and battery, super capacitor specification. The simulation of a model is done as shown in Fig.3 and results with values and graphs are obtained.

The result is plotted in the graph which shows the difference between practical and theoretical regenerative power. The theoretical power obtained by calculation is more than the practically achieved by simulation is shown in Fig 4.

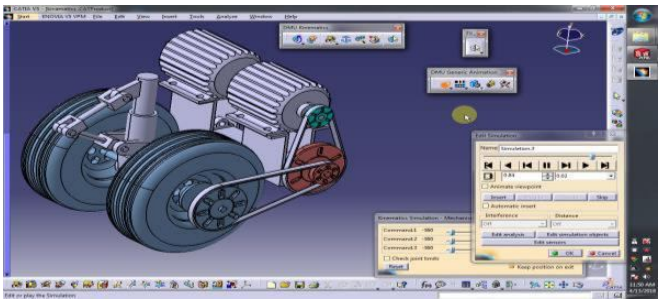

Fig.3 simulation of CAD model of regenerative braking system

The CATIA software used to simulate the model. Firstly the assembled model will be brought to simulation workbench. Then in digital mock up the DMU generic animation is selected. Here predefined mechanism is selected. Then rotation of wheel is set for required rotation of +/- 360. And distance and time is selected.

V. SPECIFICATIOS

Aircraft's Battery:

Type	Lithium ion
Voltage	400V
I (current hour)	150Ah
Weight	30kg

Super capacitors:

Model	JD screw terminal type
Voltage	400V
Units	10 units of 100F
Internal resistance	8mΩ
Capacity	5F
Weight	15kg

Electric Motor/Generator:

Model	YASA P400 SERIES
Voltage	336-360V
Torque	370Nm
Power	160kw
Max Speed	8000rpm
Efficiency	93%
Weight	24kg

Table 3. Simulation Results

Velocity m/s	Practical Regenerative power KW	Deceleration m/s^2	Efficiency %
60	41.3	0.83	89.8
70	48.56	1.13	87.5
80	84.16	1.49	78.96
90	118.56	1.88	70.06

The result is plotted in the graph which shows the difference between practical and theoretical regenerative power. The theoretical power obtained by calculation is more than the practically achieved by simulation is shown in Fig 4.

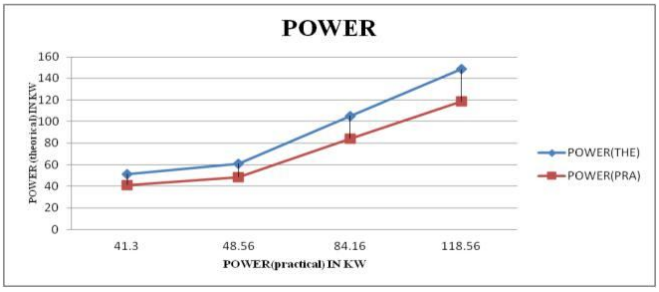

Fig 4. Graph practical power v/s theoretical power

The regenerative force obtained as per the deceleration of aircraft's speed is plotted on graph as shown in Fig 5. The speed goes down as per the braking. The regenerative force is achieved.

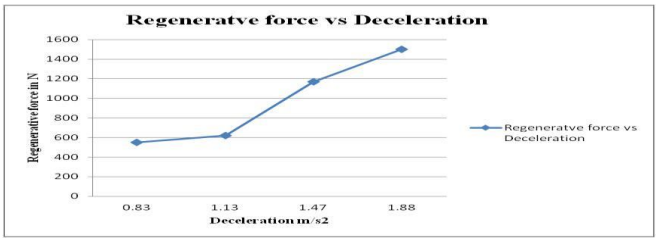

Fig 5. Graph Regenerative force v/s Deceleration

VI. CONCLUSION

This project proposes an electromechanical type of energy braking model for HAWK I aircraft. By considering its mass, speed, landing distance and braking capability. The energy being wasted during braking activity of an aircraft is found By considering the forces like braking force at rear mainly due to the presence of braking system at rear landing gear. Then to simulate the model the 3D model of a electromechanical regenerative braking model was assembled in CATIA software, analyzed and simulated. Then the results of the practical and theoretical were compared and concluded that an average of 72% of energy i.e., wasted in friction braking can be recovered by installing thus system. And also the taxing of aircraft can be done and fuel consumption also reduced due to the use of electric taxing. Further research can be made on taxing.

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