International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 06 | June - 2023 SJIF Rating: 8.176 ISSN: 2582-3930

Design of an Electric Aircraft by Optimizing ZENITH STOL CH 701 Aircraft

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Abstract - Every automobile industry is shifting towards more electric vehicles. The reason behind is limited availability of fossil fuels and the use of those fuels lead to destruction of the environment. On the other hand, the emission impact of electric vehicles is far less than those of conventionally used vehicles. The aviation industry is responsible for 3% of global carbon dioxide emissions according to the World Economic Forum. If we replace the conventional piston engine aircrafts by electrical engine, then there will be a great reduction in the emissions and compared to conventional aircrafts, electric aircraft require fewer parts, less maintenance and less fuel i.e., the electric planes will be cheaper to operate and the ticket prices will be reduced. Hence electric aircrafts seem to be affordable for the passengers and profitable for the airline businesses. In this project we have replaced the Rotax 912 piston engine of Zenith CH STOL 701 with electric engine and the performance parameters are found.

Key Words: Electric Aircraft, Piston Engine, Fossil fuels, Emission, Electric planes, Less maintenance.

1.INTRODUCTION

The aviation industry is going through a major transformation as new electric propulsion technologies open up new opportunities for cleaner, quieter and more effective aircrafts. Aviation enthusiasts and engineers are increasingly looking into the possibility of switching traditional aircraft engines to electric power as part of this wave of innovation. One such thrilling project entails improving the famed Zenith CH 701 aircraft by swapping out its traditional Rotax 912 engine for an electric motor.

Light sport aircrafts like the Zenith CH 701, which is adaptable for its outstanding short take-off and landing characteristics, great maneuverability, and construction. It is intended to take use of the benefits of electric propulsion, like decreased noise levels, decreased reliance on fossil fuels and improving environmental sustainability by adding an electric motor which provide instantaneous power delivery, less maintenance, and superior torque characteristics, making them a desirable choice for aviation.

This paper aims to maximize the capabilities of the Zenith STOL CH 701 by utilizing the advantages of electric propulsion by substituting the Rotax 912 engine with an electric motor. The resultant aircraft will have better performance, higher dependability, all while emitting less carbon dioxide. The goal of this project is to investigate and answer the numerous technical issues related to the conversion process, such as weight distribution, power storage and management, thermal management, and the integration of electric propulsion elements into the current airframe design

2. Optimization of Aircraft and making it Electric.

The Zenith STOL CH 701 is a piston engine Aircraft. The engine used is Rotax 912 and the fuel used for this engine is 87-octane. to make the aircraft electric we need to replace the Rotax 912 engine with the Electric motor and the fuel should be replaced by the Battery.

The specifications of the Zenith STOL CH 701 Aircraft are as follows-

Length- 20 feet 11 inches
Wingspan 27 feet
Height- 8 feet 7 inches
Wing Area - 122 Square feet
Maximum Takeoff weight - 500kilograms
Engine weight - 60kilograms

Performance parameters
60KW power which is equivalent to 80 horsepower.
Maximum cruise Velocity- 80Mph
Rate of Climb- 1100 feet/min

Now to replace the engine, we need to have an Electric motor which should give equivalent power as of the Rotax 912 engine.

After deep research, the motor found is Emrax 228.

109 Kilowatt = 148 Hp
Maximum voltage 160V
230 Newton meter torque
5500 RPM (Rotations Per minute)
92-98% efficiency
12.3kg weight

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Casing Diameter 228 mm
Axial length 86 mm
mounting-
front 6 × M8 threaded holes
Back 16 × M8 threaded holes

Validation of the motor-

Power (KW)= $(n(RPM) \times mt\ (Nm))/9550$

where,
n is number of rotations
mt is torque in newton meter

from this equation we can select the motor.

Power = $(5500\ \times 230)/(9550\ )$

Power = 132.46 KW

The emrax 228 motor is suitable for our aircraft.

Fig -1: Emrax 228 Electric Motor

2.1 Selection of the Battery-

The motor has power output of 109 KW. To provide the required power, we have selected the following battery-

48V 100Ah LiFePO4 Lithium iron phosphate deep cycle battery.

The battery has following specifications

Model	ALF-04100A
Battery type	ABS Sealed
Battery chemistry	Lithium Iron Phosphate LiFePo4
Cell type method	Cylindrical cells/welded
Voltage (V)	48V
Capacity (Ah)	100Ah
Energy stored (Wh)	4800 Watt-Hours
weight	40kg
Dimensions (L × W × H)	52cm × 26cm × 22cm
Normal charge current	6 Amps.
Normal continuous discharge	50 Amps.
Maximum continuous discharge	100 Amps.
Maximum peak discharge	200 Amps.
Charge temperature	0^0 C to 45^0 C
Discharge temperature	-20^0 C to 60^0 C

Table -1: Battery specifications

Fig -2 Battery

2.2 Battery Packs-

To find the number of battery packs needed, we need to find the requirements i.e., what should be the endurance.
For our paper we have kept the endurance of 1 hour. To find the number of batteries for 1 hour endurance we find mathematically.

If we multiply voltage with capacity, we get watt.
Here, we multiply the voltage with ampere hour to find watt hours.
The specifications of the battery determine the volts and capacity.

Mathematically –

Voltage × Ampere hour h= Watt hour

By putting the values, we get

48V × 100 Ah = 4800 Wh.

Now the value we got is 4800Wh and we convert it into KWh by simply dividing it by 1000.

4800/1000 = 4.8 KWh

Therefore, a single battery will give us 4.8 KWh.

As per our electric motor, the required energy is 109 KW.

And the endurance we decided is 1 hr.

To find batteries needed to provide 1 hour of endurance we simply divide the required energy with battery KWh.

109KWh / 4.8KWh = 22 batteries.

We need 22 batteries each with 4.8 KWh to provide 109 KWh power for electric motor for 1 hour of endurance.

2.3 WEIGHT ESTIMATION

WEIGHT OF EXISTING AIRCRAFT (ROTAX 912 ENGINE)

Gross weight = 500kg.

Empty weight = 263 kg.

Engine weight = 60 kg.

WEIGHT ESTIMATION FOR NEW AIRCRAFT(ELECTRIC)

First of all, we consider the gross weight of the existing aircraft.

500kg

Now we find what is the fuel weight for the existing aircraft.

To find the weight of the fuel, we find the density of the fuel.

Fuel used is 76 liters.

The density of the 87-octane fuel is 0.73g/ml

We convert it into g/L to simplify and find the end result in kg/L

Conversion-

76000 × 0.73 = 55480 g/L

55480g/L /1000 = **55.48 kg/ L**

Therefore, we found the weight of fuel used.

Now we add the engine weight and fuel weight of the existing aircraft.

60kg + 55.48kg = **115.48kg**

We subtract the weight of fuel and engine from the gross weight.

The reason is simple, we are just removing the fuel and engine from the aircraft and placing the electric motor and batteries.

Therefore,

500kg – 115.48kg

The new gross weight of the aircraft without engine and fuel is

348.52kg

Now we add electric motor weight and battery weight into the new gross weight.

We know the weight of battery i.e., one 48V LiFePO4 battery weighs 40kg

we have used 22 batteries,

22×40kg = **880kg.**

The weight of total batteries is 880kg.

The weight of the electric motor is 12.3kg.

Now we add total battery weight and electric motor weight.

880+12.3 = **892.3kg**

We found the weight of battery and electric motor. Now we add it to the newly found gross weight without engine and fuel

384.52kg+892.3kg = **1276.82kg.**

The new gross weight of our electric aircraft is **1276.82kg**

2.4 Thrust estimation

Thrust estimation of existing Aircraft

To find the thrust we need to know the various factors which will affect the thrust. Such as engine power, efficiency of the propeller and the velocity of the aircraft.

The formula to find thrust is

$$\text{Thrust} = \frac{\textbf{engine power} \times \textbf{efficiency}}{\textbf{velocity}}$$

Blade pitch	Efficiency
20^0	NON
25^0	0.816
30^0	0.836

Table -2 Blade pitch angles and their efficiencies

30^0 produces best efficiency.

Given values

Engine power = 60 KW

Velocity = 80mph

Efficiency = 0.836

Engine power should be converted from KW to W.

The velocity should be converted to m/s.

The values become

Engine power = 60 x 1000 N = 60000 N

Velocity = 49.174 m/s

$$F = \frac{60000 \times 0.816}{49.174}$$

The Thrust we got for existing aircraft is **995.64 N**

Thrust estimation for Electric Aircraft

We use the same formula to find the Thrust.

The values are as follows

Power = 109 KW

Efficiency = 0.816

Velocity = 49.816

After converting to the required standards, the values, we get

Power = 109 x 1000 = 109000 W

$$F = \frac{109000 \times 0.816}{49.81}$$

The Thrust we got for Electric Aircraft is **1808 N**

2.5 Thrust to Weight ratio

It is the ratio of the thrust of the aircraft to the weight of the aircraft. It is a dimensionless ratio.

The thrust produced and the weight both should be in the terms of newton.

The Thrust to weight ratio for our existing aircraft is as follows-

Thrust produced = 995 N
Weight of the aircraft = 500 kg = 4903 N

T/W = 995/4903

T/W=**0.20**

The thrust to weight ratio for newly designed electric aircraft is as follows-

Thrust produced = 1808 N
Weight of the aircraft = 1276.82 kg = 12521.32 N

T/W = 1808/12521.32

T/W= **0.14**

2.6 Rate of climb

Rate of climb is the aircrafts vertical velocity. It is the velocity with which the aircraft climbs
The rate of climb for given aircraft is 1100ft/min

$$ROC = \frac{T \times V - D \times V}{W}$$

Where, T is Thrust, V is Velocity, D is Drag, W is Weight of Aircraft.

Thrust = 995 N Velocity = 35 m/s Weight = 4903 N

We find Drag

$D = W \times C_D / C_L$
C_L =3.3
C_D =0.15
D = 4903N x 0.15 x 3.3

D = 222 N

By putting all the values in the formula

$$ROC = \frac{995 \times 35 - 222 \times 35}{4903}$$

ROC = 5.51 m/s

Convert the m/s to feet/min

5.51 m/s = **1084 ft/min**

Therefore, the given value of ROC in the handbook is 1100 ft/min. we calculated the value and obtained 1084 ft/min.
The percentage of error is just 1.45 %

Similarly, we will calculate ROC for new Aircraft,
The given values are

T = 1808N
Velocity = 49 m/s
Weight = 10110 N

We find drag induced

D = 10110 X 0.15/3.3

D = 459.57N

$$ROC = \frac{1808 \times 49 - 459.57 \times 49}{10110}$$

ROC = 6.52 m/s

ROC = 1283 ft/min

The ROC of newly found aircraft is greater than the existing aircraft.

3. CONCLUSIONS

The newly designed aircraft has ability to produce thrust of 1808 N

The Thrust/weight ratio for the aircraft is 0.14

The efficiency of Propeller is 0.816

The rate of climb ROC is 1283ft/min

It has Endurance of 1 hour

The project's main goal was to improve the Zenith STOL CH 701 by switching out its Rotax 912 engine with an electric motor. Several significant results were acquired via extensive testing and analysis, proving the effective use of the electric propulsion system and its impact on the performance of the aircraft.

The Magnix 228 electric motor was used in place of the Rotax 912 engine, and numerous important modifications were made.

One of the project's noteworthy accomplishments was the optimized aircraft's greater rate of climb in comparison to the Zenith STOL CH 701 original. This improvement can be ascribed to elements like the electric motor's greater power output and perhaps superior aerodynamics brought on by the adjustments made during the installation of the electric propulsion system.

It is important to remember that further study, development, and testing could be necessary to completely optimize and perfect the electric propulsion system for use in actual aircraft. But the initiative also makes a significant contribution to the area and sets a solid platform for future improvements in electric aircraft technology.

ACKNOWLEDGEMENT

The heading should be treated as a 3rd level heading and should not be assigned a number.

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