All Electric Airplanes

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ABSTRACT

This report aims to give a brief overview of the concept, the development and the performances of electric planes. First, an introduction looks back to the first steps of electric aircrafts. Then, some important technical aspects of electric aircraft design are explained. In the following section, a comparison between the electric aircraft and the traditional aircrafts is made. Finally, a short conclusion highlights the future trends in the sector of electric aircrafts.

I. Introduction

Airplanes release about 700 million metric tons of CO_2 into the atmosphere [1], and it should be increasing considerably in a near future. Indeed, the International Air Transport Aviation [2] expects 7.2 billion passengers by 2035 (a near doubling of the 3.8 billion travelers in 2016) due to an increasing demand from the Asia-Pacific Market. Due to a diminution of fuel resources and a significant contribution to global warming, alternatives to fuel aircrafts such as electric aircrafts are being studied.
An electric aircraft is powered by electric motor using energy from different possible methods: battery, fuel cells, solar cells and others. This type of aircrafts can be considered as locally zero-emission (depending on how the electricity is produced), and are thus cleaner than classical aircrafts. The first prototype, a Brditschka HB-3 motor glider converted to an electric aircraft, the Militky MB-E1, has been developed in 1973 after the apparition of the NiCad batteries. Due to the lack of better batteries, only a few electric aircrafts have been developed until 2003 where the Lange Antares 20E, a self-launching 20-meter glider equipped with Li-ion batteries, was designed. From this point, the development of electric aircraft has started and lot of planes have been created. As for the automotive industry, the development and the performance of electric aircrafts is really influenced by the battery technologies.

II. Technical Aspects

II.a Battery

The fundamental element of an electric propulsion system is the energy storage and the conversion of chemical energy to electrical energy, and finally to mechanical energy. As a good indicator of efficiency, the specific energy density E^* can be used, which is expressed in $[\frac{Wh}{kg}]$.

Nowadays, the most used batteries for electrical aircrafts are **Lithium-Ion** type. Such batteries can be produced relatively cheap and can be scaled to build larger systems of several hundred kWh energy capacity.

The batteries are the main limitation when talking about electrical aircraft. Other technologies such as **Zn-Air**, **Li-S** and **Li-O_2** are in development and should gain in specific energy density in the next few years [3].

II.b Range

The range of an aircraft is an important characteristic. In this section, the calculation of the range is made, taking into account that the energy sources are batteries. The range can be expressed as

$$R = v \cdot t \tag{1}$$

where t, the time needed to drain all the batteries, is

$$t = \frac{m_{battery} \cdot E^*}{P_{battery}} \tag{2}$$

with the battery power $P_{battery} = \frac{P_{aircraft}}{\eta}$. Assuming a cruise flight, the thrust compensates for the drag and the lift for the weight. This gives

$$P_{aircraft} = \frac{W \cdot v}{L/D} \tag{3}$$

Using Eq.1, 2 and 3, the range can finally be expressed as

$$R = \frac{m_{battery} \cdot E^* \cdot \eta \cdot L/D}{W} \tag{4}$$

II.c Electric Motor

Today the studies of new electric motors for aircraft are focused on two configurations which are distributed engines and Brushless DC Motors. The most efficient engine available on the market, Siemens SP260D [4], has a power output of 260kW and weights 50 kg. That gives a high Power-to-Weight ratio of 5. The result is obtained from an accurate study on material of the end-shield, decreasing the aluminum part by a factor of 2. The rotor is composed by permanent magnet, where the stator is a cobalt-iron alloy. This technology will enable to develop larger electric aircrafts in the future (with a maximum 2 tons MTOW) .

III. Technologies comparison

III.a Advantages and disadvantages

In Table 1, the main advantages and disadvantages of classical and electrical aircrafts are shown.

Classical aircrafts	
Pros	**Cons**
Low to long range Decreasing weight Low to high PAX	High fuel consumption High flight costs High CO_2 emissions
Electrical aircrafts	
Pros	**Cons**
High power to weight ratio Low flight costs High efficiency Low CO_2 emissions Less noise	Low range Constant weight Battery limitations Low PAX Battery charging time

Table 1. Comparison between classical and electrical aircrafts

III.b Energy conversion and efficiency

The conversion from the energy source to the actual propulsion involves several steps. In Fig.1, three different technologies are compared, respectively batteries, turboprop and turbofan. For each step of the conversion, a typical efficiency η has been assumed, regarding the current trends the battery system shows an efficiency of more than 70 %, whereas classical kerosene based technologies have a lower efficiency of around 30%. The main reason for this difference is the conversion from fuel to electricity in the classical fuel combustion systems, which exhibits a low efficiency of 50%

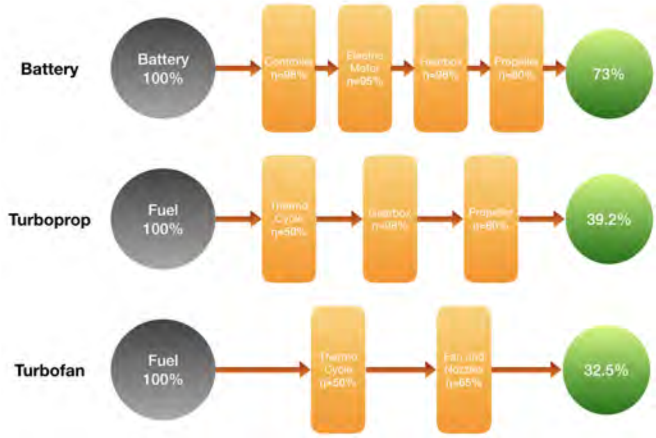

Fig. 1 . Conversion chains for different technologies. Figured inspired from the document [3]

III.c Power to weight ratio

Traditional piston and turbine engines can reach higher output powers but are also heavier, which reduces their power to weight ratio.

IV. Conclusion and future trends

The development of electric airplanes is still limited at the stage of small aircrafts and small ranges by the batteries. Hybrid aircrafts which combine both advantages of classical aircrafts and electric aircrafts seems more realistic in a near future. Elon Musk[1] [5] said that commercial electric airplanes will be possible once the battery energy density will be over 400 Wh/kg. Indeed, with this capacity, the technology could be power 150-seats planes with a maximum range of 300 miles (30 percents of the flights) and using electric aircrafts should be interesting for airlines since the flight cost is low. This is the reason why important airlines such as Easyjet have signed collaboration with research companies in electric aviation.

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[1] CEO of **Tesla**