ELECTRIC MOTOR AS A REPLACEMENT FOR COMBUSTION ENGINE IN PROPULSION SYSTEM OF AIRCRAFT

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Abstract *– Main aim of this paper is to acquaint readers with a new-formed trend in aviation, which is electrification of aircraft propulsion systems. In thesis I target to social-political, econo]mical and technical aspects of this kind of propulsion which have positive or negative tendency in next evolution of electric propulsion. With my mentor we assume that the main problem will be with energy density of Lithium batteries which is sixty time lower than density of comertional jet fuels. This problem we present in examples of three airplanes with different capacity and range. At the end of the thesis we presented the most interesting existing project of electrically-propelled aircraft and analyzethe main advantages of electric propulsion.*

Key words – distributed propulsion, energy density, Li-ion battery life-cycle greenhouse emissions.

I. INTRODUCTION

Last decade of our history global warming in not just hippie phrase but notable fact. This fact motivates still more and more people to action and social-political pressure is still higher. This pressure motivated companies and governments all around the world to look for some more clean and efficient way to carry on aviation business.

An electric motor has lots of advantages, but also one really big disadvantage, which is energy density, the ability of storage amount of energy in one kilogram. The energy density of batteries is main problem of vehicle electrification, modern batteries have still 40 times less energy density than fossil fuels.

Electric propulsion open a new possibilities in aircraft design, this made a space to invite a new aircraft design methodologies and present a pros of electricity in aviation, which reduce drag and are more efficient.

Electric motor as a power plant of airplane is not a new opinion, actually nowadays is few projects which are already in operation. High controllability, light weight and fact that electric motor can work also like a generator open in aviation design new opportunities as boundary layer ingestion, higher aspect ratio or elimination of wingtip vorticies.

II. ELECTRIC MOTOR AS REPLACEMENT OF COMBUSTION ENGINE IN PROPULSION SYSTEM OF AIRCRAFT

FUTURE ENVIRONMENTAL STRATEGIES OF AIR TRANSPORT AUTHORITIES

In the last decade the consequences of human race action on the environment are visible not just for scientists in laboratories but for everyone. Weather extremes, huge wildfires, floods, etc. are still more often and visible for the whole world. The protection of the environment is not just the activity of few "Greenpeacers", is a society-wide mindset. Social-political pressure increasing, "Fridays for future" when young people's lead by Greta Thunberg leaving a school and making climate strikes or United nations Climate change summit in 2019 where politicians all around the world discussed and establish an environmental protective goal for near future.

This social-political pressure has been addressed in Europe by two documents of Advisory council for Aviation Research and Innovation Agenda in Europe (ACARE), Flightpath 2050 [1] and Strategic Research and Innovation Agenda (SRIA) [2], and also in the USA by US National Aeronautics and Space Administration (NASA) by document Aeronautics Strategic Implementation Plan [3].

Table 1: Goals of strategic Research and Innovation Agenda [2]

Technology benefits	**Near term 2015-2025**	**Mid term 2025-2035**	**Far term 2035+**
Noise reduction	10%	11%	15%
No_x emission reduction	81%	84%	80+%

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Aircraft Fuel/Energy Consumption reduction	49%	60%	75%

COMPARISON OF ELECTRIC MOTOR AND COMBUSTION ENGINE

The technical side of the internal combustion engine and electric motor are so different, one works on a combustion and one on electromagnetic principle. An electric motor has lots of advantages, but also one really big disadvantage, which is energy density, the ability of storage amount of energy in one kilogram. The energy density of batteries is main problem of vehicle electrification, modern batteries have still 40 times less energy density than fossil fuels. On the other hands combustion efficiency is three times less than efficiency of electric motors, lots of energy left throw exhaust gases or in to the engine walls. [4]

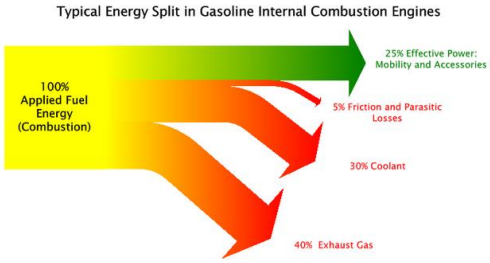

Figure 1: Combustion engine energy lost [5]

HYBRID-ELECTRIC AIRCRAFT

The range of fully electrical aircraft is limited with a specific energy of batteries, and technological predictions are skeptic in this case. Here is opening a hybrid concept, it is a combination of electric and combustion power plant in one aircraft. This concept reaches all positive of electric motors as lightweight, distributed propulsion, good controllability, and eliminated a negative impact of battery's low specific power. As a source of energy used a combustion engine low efficiency but with a high specific energy of jet fuel. Nowadays most common concepts of hybrid-electric aircraft are **Serial-, Parallel-** and **Turboelectric-hybrid**.

NEW INITIAL SIZING METHODOLOGIES

Next interesting change which comes with electric propulsion is ability to change aircraft design, actual design of commercial aircraft is used for decades without any big change, but different technical character of electric motors opens new design methodologies, throw which we can change a look of wings and reduce a drag. [6,7]

NEW DESIGN OPPORTUNITIES

The low weight and controllability with fast response is a big advantage of electric propulsion. For decades conventional aircraft design change just in few details. Back swept wings mounted in the centre of the fuselage, tail with stabilizers and jet engines on a tailor obviously on wings. If we change the source of propulsion we have a lot of new design choices as **distributed propulsion, higher aspect ratio of wings, elimination of wingtip vortices, boundary layer ingestion or regenerative breaking.** [8]

III. CONCLUSION

In the beginning we can see a strong social-political pressure on any kind of "dirty" industry (industry with high carbon emissions), and aviation is one of them. Social movements have strong impact on political authorities as European Commision or NASA, and authorities has power to affect companies. Flightpath 2050 and SRIA presented a brave goals which have affect to companies to invest money into new greener way of aviation, to electric propulsion.

Technical differentials between combustion engine and electric motor are big and almost in every case electric motor have advantage, is more controllable, almost noiseless and maintenance-free. Almost perfect, but the low energy density of batteries are a huge problem, and also the reason why the electric motors are not nowadays in the air.

Problem with heavy batteries is possible to solve by using a combination of combustion engine and electric motor, using hybrid-electric configuration. This configuration helps to reduce maximum take-off weight and make possible to flight with bigger aircraft as 4-seat general aviation aircraft.

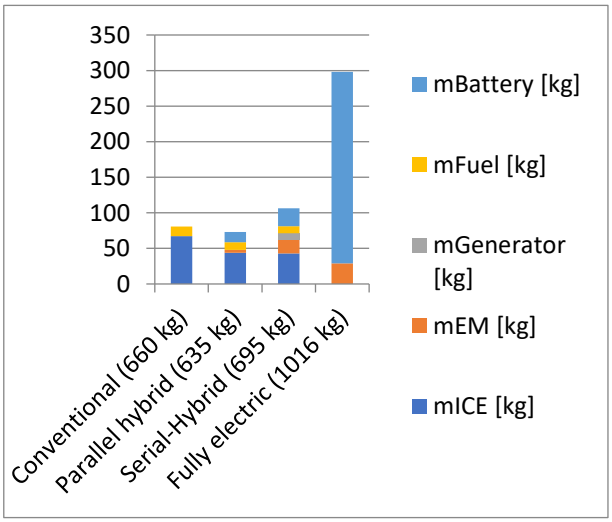

Figure 2: MTOW of general aviation aircraft with different configurations (150 km mission) [6]

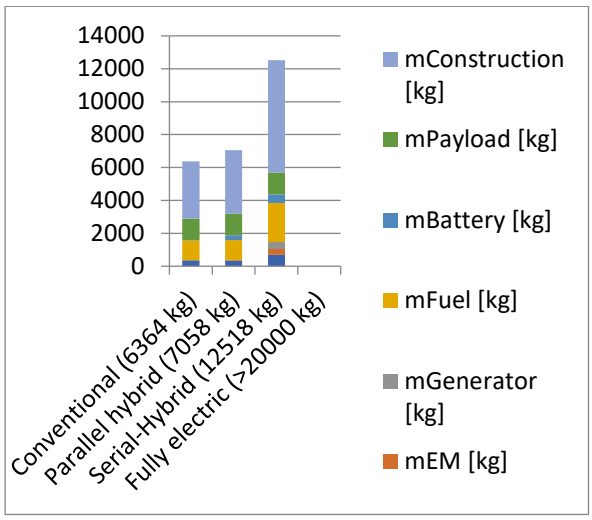

Figure 3:MTOW of regional aircraft with different configurations (1280km mission) [7]

Already few projects of electric aviation are existed and are in service. This project from one side show a possibility of this brave ideas and also show a benefits of electric aviation.

Distributed propulsion, high aspect ratio, boundary layer ingestion or regenerative breaking are big pros of light weight, good controllability and fact that electric motor can work also like a generator.

The future looks bright, standard of living in whole world increasing, and health differences are slowly disappearing. Everything is moving forward and also in a field of aviation we still must looking how to by more efficient, environmental friendly and more available to everyone.

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