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Performance comparison between ducted fan driven by ICE and electric motor

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1. Introduction

Today's drive towards zero-emission operation is evident in all areas of passenger and freight transport. The origins of electrically powered aircraft can be traced back to the 1960s, when the first radio-controlled model aircraft appeared. Electricity storage technologies have made great strides in recent decades, and today's lithium based-batteries have many times the energy density. The technology of electric motors and control electronics has also advanced significantly, allowing for increased performance, downsizing and lightweighting. All of these factors have brought the use of electric power to power aircraft in all modes of transportation closer. But despite progress, the specific energy of fossil fuels remains 30–40 times greater, which is first and most important reason why the widespread application of electric propulsion in this sector will be complicated.

This paper describes a comparison of the flight performance of an ultralight aircraft with ducted fan propulsion. The author aims to find and describe the differences in performance of the UL39 ALBI II aircraft, where the fan will be driven by a piston internal combustion engine in the first case and an electric motor in the second.

2. Methods

Design point is taken from [3] and can be found in Table 1. A compressible fluid model is used because the flight velocity range is 0–100 $\mathrm{m\,s^{-1}}$ and the upper limit is on the border between incompressible and compressible flow. And also this method could be used for faster aircraft than the ultralight category.

2.1 Fan characteristics

The aim of the first step is to find compressor characteristics [1] for what was used Numerical Propulsion System Simulation Code described in [2]. Computed characteristics can be found

Table 1. Fan design point

Fan pressure ratio Π	1.062
Fan diameter D	660 mm
Motor RPM	7 800
Fan air mass flow $\dot{m}$	33.46 $\mathrm{kg\,s^{-1}}$
Fan efficiency η_{fan}	0.85

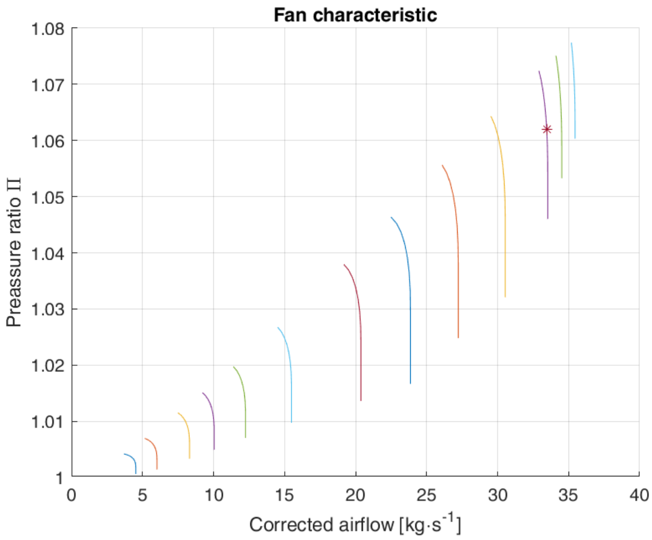


Fig. 1. Fan characteristics

in Fig. 1. The values deducted from the characteristic will be used to calculate the thrust for different values of speed and airflow.

2.2 Thrust

The values of the state variables at the inlet to the compressor channel corresponded to the values of 0m ISA and can be found in Table 2. According to the equations for compressible flow were determined values in front and behind of fan thanks to which the velocity values at the nozzle outlet v_3 could be determined. The thrust of the propulsion system is determined from the momentum conservation law

$$T = \dot{m} \cdot (v_3 - v_0), \tag{1}$$

where the air mass flow is taken from fan characteristics.

2.3 Propulsion efficiency

Propulsion efficiency is defined by the following standard formula:

$$\eta_{prop} = \frac{T \cdot v_0}{P}, \tag{2}$$

where P is engine power taken from ICE and electric motor characteristics.

Table 2. Input parameters for the propulsion system

Flight velocity range v_0	0-100 m s^{-1}
Air density ρ	1.225 kg m^3
Atmospheric pressure p_{s0}	101 325 Pa
Air temperature T_{s0}	288.15 K
Air specific heat at constant pressure c_p	1004.5 J kg^{-1} K^{-1}
Air ratio of specific heats κ	1.4
Air specific gas constant r	287.1 J kg^{-1} K^{-1}

3. Results

The results of this study are thrust curves (i.e., dependence of the thrust on the flight velocity) and propulsion efficiency for different mass air flows, RPM, and different power unit of fan, see Figs. 2–5.

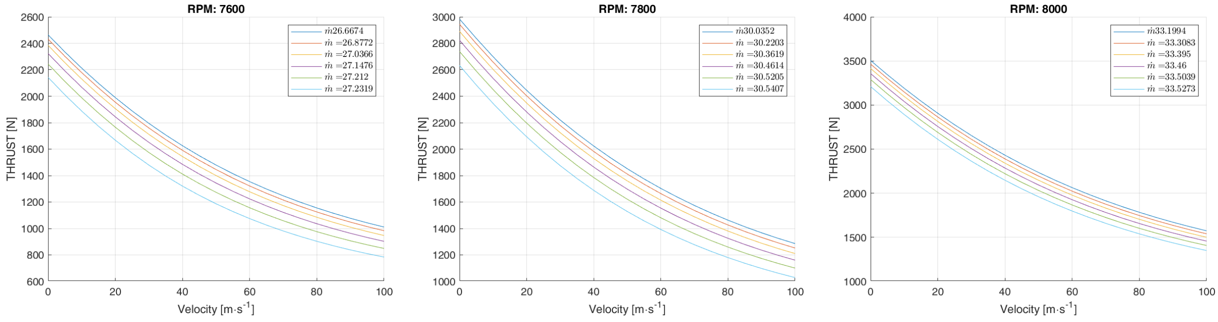


Fig. 2. Thrust curve on different RPM and airflow

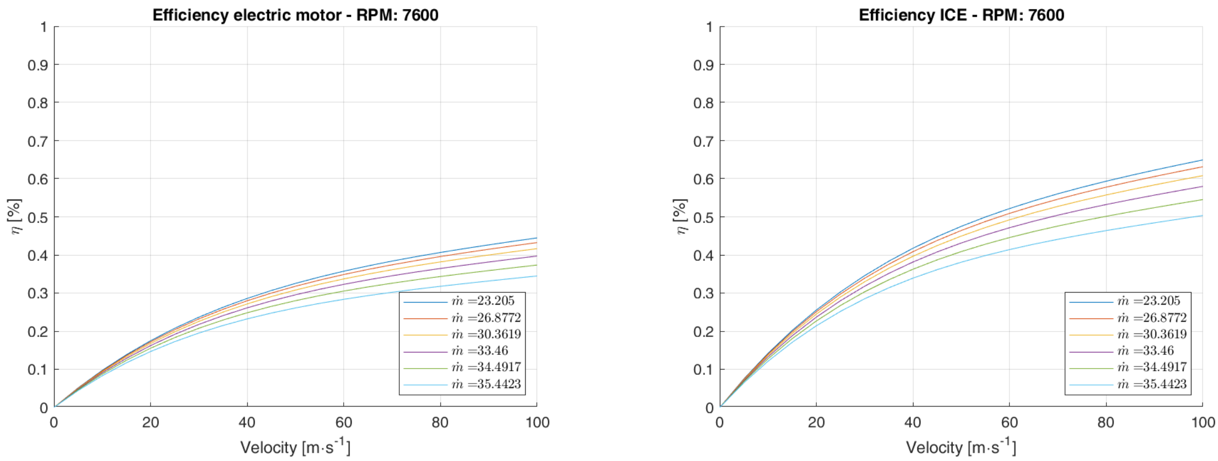


Fig. 3. Propulsion efficiency on 7 600 RPM: (left) electric motor, (right) ICE

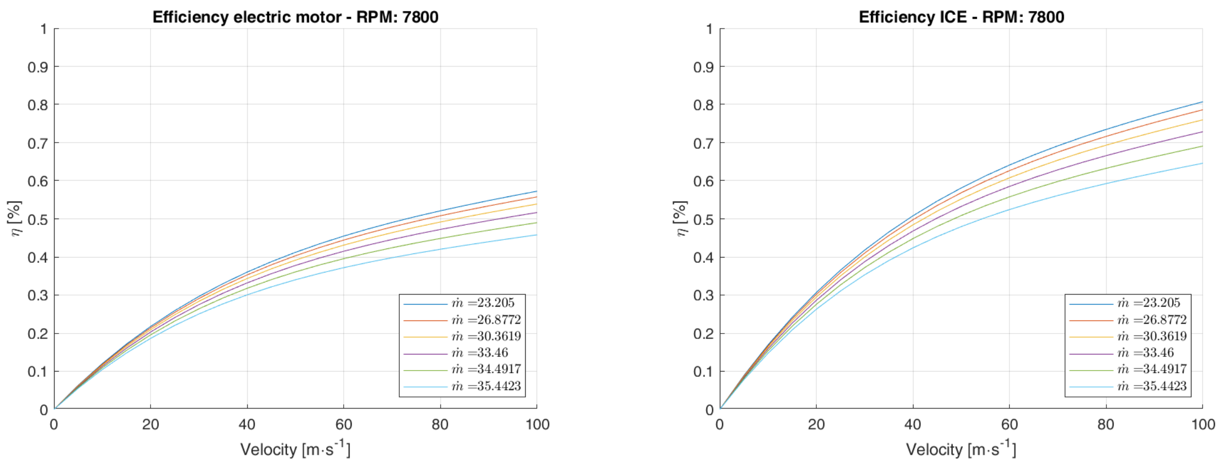
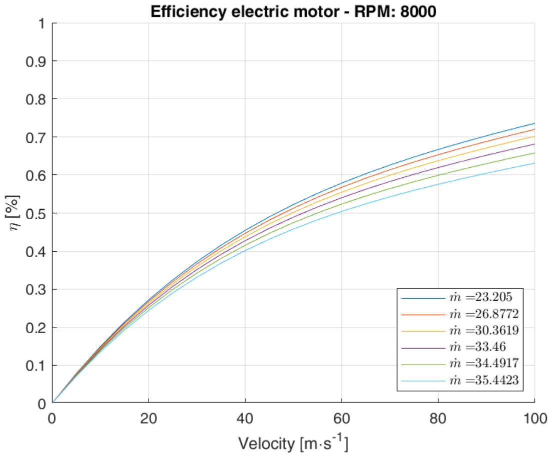


Fig. 4. Propulsion efficiency on 7 800 RPM: (left) electric motor, (right) ICE



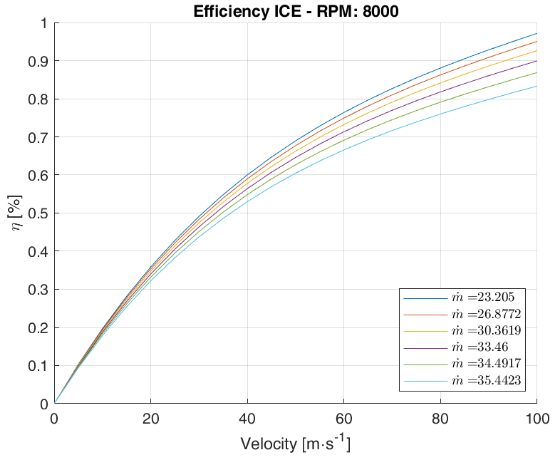


Fig. 5. Propulsion efficiency on 8 000 RPM: (left) electric motor, (right) ICE

4. Conclusion

The results show that ICE reaches higher propulsion efficiency because the power of ICE grows gradually with RPM. Whereabouts power of electric engine reaches their peak in low RPM and very slowly declining.

Acknowledgement

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