Flying wing with Electric Ducted Fan (EDF) propulsion

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Abstract: EDF propulsion used successfully in UAS domain at all constructive (airplanes, helicopters, airships) positioning possibilities it presents advantages due to compact size and vectored thrust leads to an increase in performance and quality flight. Article wants a review of theoretical and practical ducted propeller (EDF).

Keywords: electric ducted fan, flying wing, aerodinamic analisys, XFLR5

I.Introduction. EDFpropulsion.

EDF propulsion (electric ducted fan) is used successfully in the UAS domain, it presents possible advantages of its compact body positioning and vectored thrust lrads to an increase performance and flying qualities.

EDF propulsion is simple concept and consists of an electric motor that drives a propeller intubated. Exhaust air has sufficient speed to power a UAV. Due to operational requirements (LiPo batteries, constructive simplicity) and the cost price of this type of motor is used increasingly often to power various types of unmanned aircraft is a more accessible option versus small engine jet.

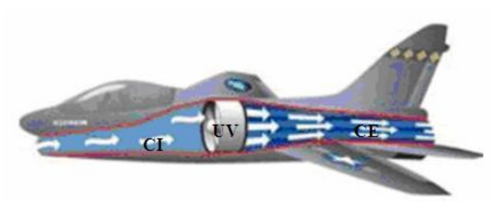


Fig. 1 EDF working principle [1]

EDF of a system parts, see figure 1: the front entrance a sewer (CI) air (which can be profiled or deadlock), in some cases can only be prevailing air inlets in air vector structure; fan unit (cylindrical tube with an electric motor and fan itself) outer diameter which is equal inlet and outlet (UV), the fan blade may have 2-6 according to the embodiment, at the rear of a sewer exhaust of the tapered often lead to an increase in thrust (CE). Compared to conventional jet engines no fuel burned inside the case so EDF and temperatures are much lower and the requirements for materials and systems are reasonable (plastics, composites, dural).

EDF case requires careful design for maximum efficiency with smooth surfaces to prevent turbulent flow. Jet pipe size is essential for optimal functioning of the electric motor blades networks (can lead to underestimating backpressure affecting engine performance). EDF propeller has a number of advantages and drawbacks as follows:

Advantages: EDF unit is compact, it can be mounted inside a fuselage or externally depending on the design of air vector, the EDF unit does not need electricity fuel tanks and ignition systems (pipes, spark plugs, throttle servo), so easier to build, propeller intubations is better than a free propeller (because of loss due to the vortices extreme), the potential benefit to the concept of vectored thrust by diverting the air flow even with smaller angles which results in a high maneuverability of the vector air, multi design versions are easier to build than conventional electric propulsion, achievement aerial maneuvers by differences build from; therefore thrust twin engine and multi-engine versions.

Drawbacks: EDF propulsion produces a traction unit lower than the same engine and the same electric power that drives an air propeller (EDF low diameter: 55/60/70/90/120 mm) to increase the thrust of a propeller EDF is increase the engine power and speed which require additional power to the battery resulting in an increase in the total weight of the propulsion system [1].

EDF propulsion can be used in all types of UAS constructive (airplanes, helicopters, airships), examples in figure 2.

Bae Hawk [1]

Airship Solutions [13]

Air Hogs Elite Helix X4 [14]

iSTAR UAV [15]

Fig. 2 EDF propulsion

3. Theoretical.

3.1. Description EDF thruster. EDF motor type (see figure 3) consists of: outer casing (1) previously cone (2) network of rotor blades (3) mounting flange (4) mounted higher (5), the electric motor (6), speed regulator (7), cables (8) the stator blades (9) the rear cone (10), [2].

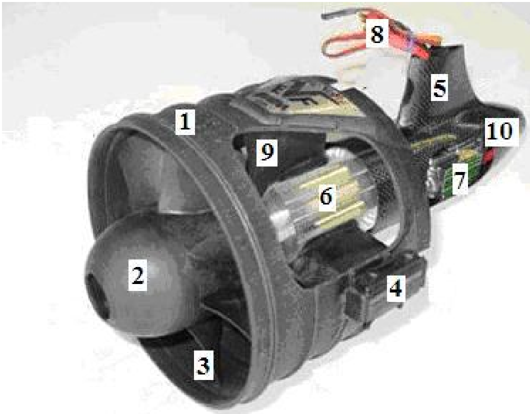


Fig.3 Parts of EDF propulsion

In figure 3 is shown a profile EDF with intakes and the rear nozzle for increased performance.


Fig. 3 EDF with paneling profile

3.2. Theoretical

The choice of the motor-driven intubations was made in terms of performance, although the pressure drop is present due to the friction at low speeds and standing.

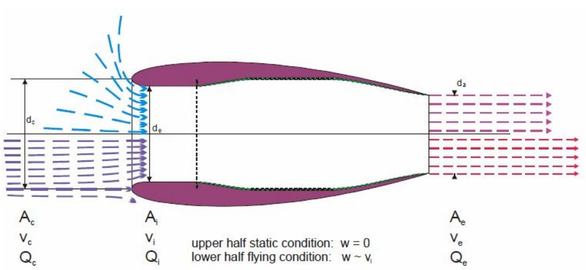


Fig.4 Air flow in EDF [3]

In figure 4 we have represented in principle a fan EDF having to stand in the upper half (w = 0), then the power lines from the power inlet (d_a) and exhaust nozzle (d_e). In the case of the lower half have one speed $w \approx vi$, in which case the power lines are parallel, both intake and exhaust, and the exhaust velocity is higher than in the case of w = 0.

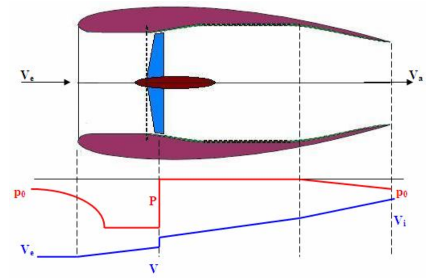


Fig. 5 Changes parameters in EDF

In figure 5 we have represented the variation engine parameters EDF [4]. According to Bernoulli's law, we have:

$$Q_i = Q_e \qquad 1$$

$$Q = S \cdot v = d^2 \cdot \frac{\pi}{4} \cdot v \qquad 2$$

according to 1 and 2 have:

$$v_e = v_i \cdot \frac{d_i^2}{d_e^2} \qquad 3$$

where the Q-air flow, S-section, v-speed, d-diameter. For a flight speed v_i = 10 m/s, a 70 mm nozzle, according to equation 3 have an exhaust velocity of 13.6 m / s We measure a thrust Newton's principle [1]:

$$T = M \cdot \Delta v \qquad 4$$

where T-traction, M-air mass, Δv-speed diference.

$$\Delta v = v_e - v_i$$

And flight power required is:

$$P = T \cdot v_i \qquad 5$$

And air mass is:

$$M = \rho \cdot Q_i \qquad 6$$

Efficiency (E) is defined as:

$$E = \frac{P_{fan}}{P_{mot}} \approx 0{,}85 \qquad 8$$

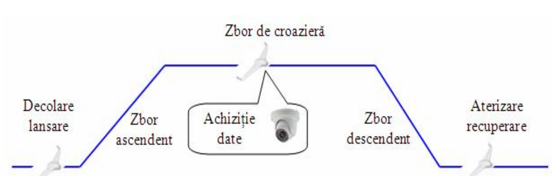
Following [5] we have input to the propeller thrust free:

$$\frac{T_T}{T_L} = \sqrt[3]{2} \qquad T_T = 1.26 \cdot T_L \qquad 7$$

4. Flying wing with EDF propulsion.

4.1.Concept. Mission.

For the model in figure 4 missions suggest flying wing geometry in figure 5, [6].



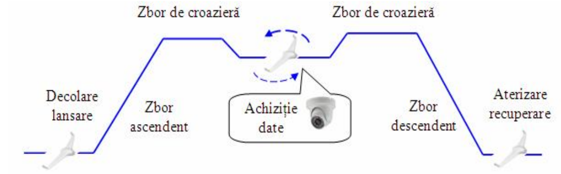


Fig. 4 Mission with data aquisition

Air vectors missions of flying wing type developments that involves 3D fly with structural morphing application elements and vectored thrust with a power consumption of electrical power. Evolutions accuracy 3D airspace depends on the skills to perform the tasks the human operator and adjusting the parameters of the system of command and control with a minimum consumption of resources (energy, time) [7, 8].

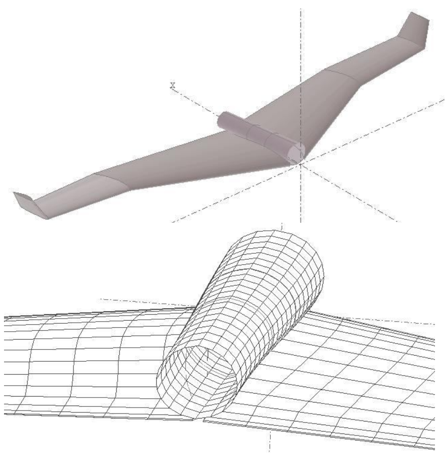


Fig. 5 Flying wing with EDF propulsion

According to figure 5 mission profiles proposed flying wing can achieve 3D developments with EDF propulsion (table 1).

Table 1. Stages of flight missions

Stages	Details
Start, take off	-
Flight climb	altitude 0-500 m
Cruise	altitude 100-500 m,
Data aquisition	range 2000 m,
Cruise	autonomy 0,5 h
Descent flight	altitude 0-300 m
Landing, stop	Distance to landing 0m

4.2. Propulsion system performance analysis. The propulsion system consists of a brushless electric motor type EDF HK2836 (feature in table 1), equipped with a controller, the motor drives the blade intubation 5-reinforced plastic (see tigure 4) [8, 9].

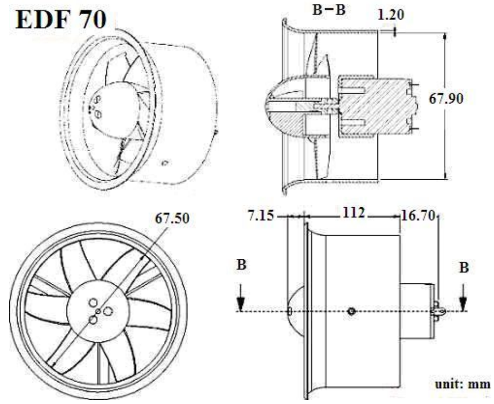


Fig. 5 Dimensions of EDF 70

Table 2 EDF features

Dimensions	D28 x L75
Max thrust	1200 g
Enghine weight	97 g
EDF weight	180g
Power	520 W
RPM	3500 rpm/V
Max current	35 A / 14.8 V
Propeller EDF, 5 blades	2,51x1 2,6x1

Selected drive variant is analyzed using computer program Drive v. 3.4 [10] gives curves in Figures 6 and 7 after settings in figure 8.

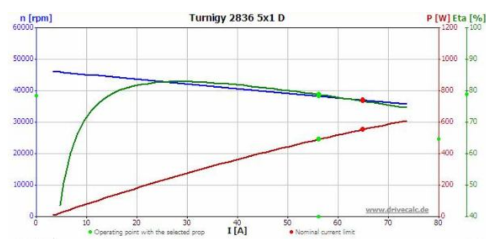


Fig. 6 The propulsion system curves

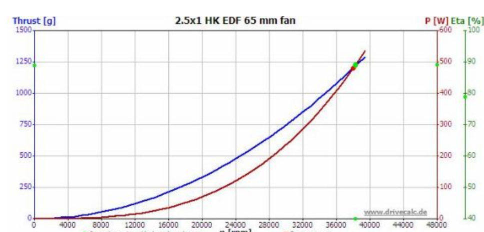


Fig. 7 The propulsion system curves

In figure 9 is shown the diameter variation of static traction motor EDF. EDF system chosen at 70 mm diameter have a thrust of T0 = 12 N (1.22 kgf), see Figure 6 and Table 2.

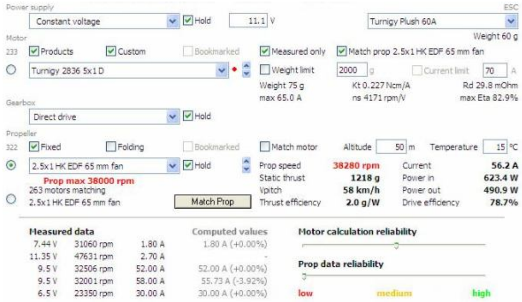


Fig. 8 Settings EDF propulsion

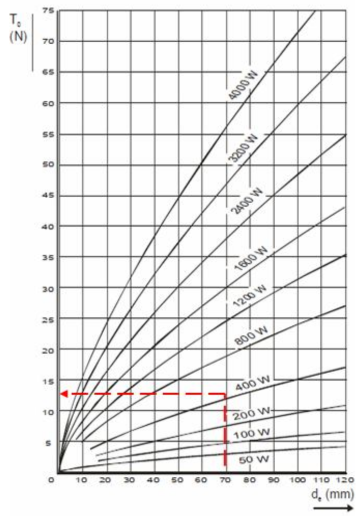


Fig.9 The graphic static thrust [3]

For tensile test to manufacture a test stand, we used a radio control and LiPo batteries and values are read using an electronic scale (0-40 kg) and reported in Table 2. (figure 10).

Fig. 10 EDF propulsion and test stand

Table 3. Test EDF 70

Nr. crt.	Battery (V)	Thrust (kgf)
1	7,4	0,45
2	9,4	0,61
3	11,1	0,80
4	14,8	1,18

Choosing the EDF propulsion air flying wing type involve many aspects of flight mass line (due to battery use, see table 3) and final balance affecting the autonomy and range. [14]

Tabel 4 Features LiPo battery

Battery	Current	Power	Weight
2S Gens	2500 mA	7,4 V	150 g
3S Gens		11,1V	220g
4S Gens		14,8	280g

4.3. Aerodinamic analysis

XFLR5 aerodynamic analysis performed using v. 6.06 at a speed of 10 m / s footprints reveal the total resistance (figure 11) and induced resistance (figure 12) of the flying wing equipped with a drive arranged on the axis of symmetry of the EDF.

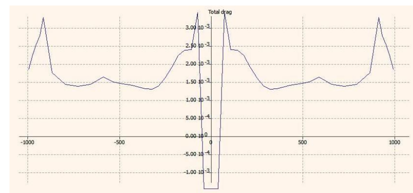


Fig. 11 Total resistance

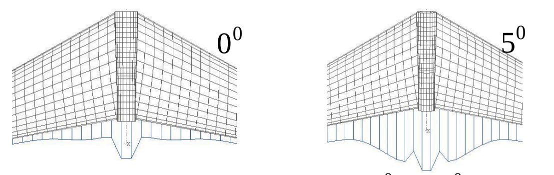


Fig. 12 Induced resistance mark for 0^0 and 5^0 incidence

According to figure 12 is observed increasing influence on the resistance induced EDF propulsion fairing with increasing angle of incidence.

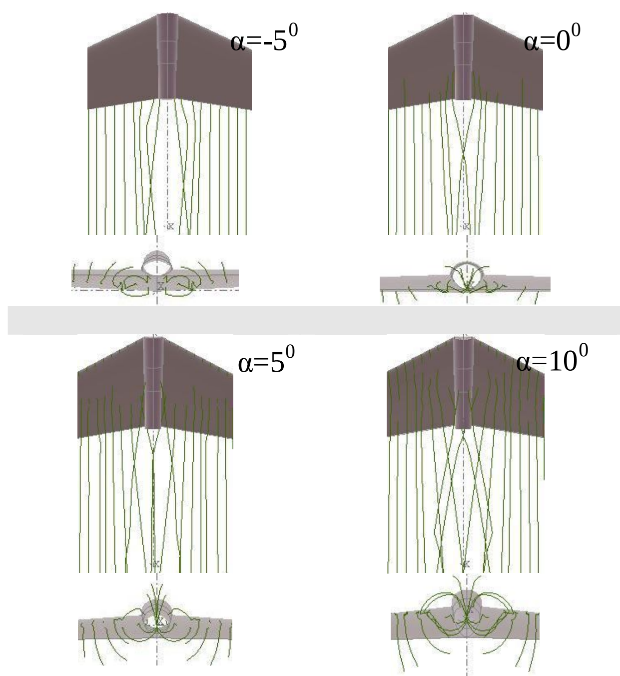


Fig. 12 Stream lines according to the incidence

With 3D Panels XFLR 5-VLM1 method and Dirichlet boundary conditions, in figure 13 we evidenced the influence of hull EDF on power lines depending on the angle of incidence.

Table 5 Aerodinamics features

Propulsie/Incidență	Alpha = 0.00°	Alpha = 5.00°	Alpha = 10.00°
fără EDF	XCP = 298.534 mm CL = 0.18211 CD = 0.00138 CX = 0.00275 Cm = -0.20374	XCP = 279.800 mm CL = 0.56850 CD = 0.01315 CX = 0.02631 Cm = -0.59940	XCP = 278.682 mm CL = 0.94213 CD = 0.03628 CX = 0.07255 Cm = -0.98741
cu EDF	XCP = 319.927 mm CL = 0.16365 CD = 0.00206 CX = 0.00413 Cm = -0.19620	XCP = 300.125 mm CL = 0.51689 CD = 0.01862 CX = 0.03723 Cm = -0.58043	XCP = 297.261 mm CL = 0.86368 CD = 0.05150 CX = 0.10300 Cm = -0.95162

In table 5 along with the displacement of the center of pressure (X_{CP}) resistance coefficient (C_D) is higher and the coefficient of lift (C_L) lower in the presence of the extrados wing fairing flying EDF are observed and a decrease in the coefficient of time (C_m).

Conclusions

EDF propulsion may be a viable alternative when flying wing type air delivery under reasonable maneuverability at low altitudes developments.

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