BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Volumul 63 (67), Numărul 4, 2017
Secţia
CONSTRUCŢII DE MAŞINI

AERODYNAMIC ANALYSIS OF WING'S BEHAVIOUR WITH CONTROLLED FLUID EMISSION ON TRAILING EDGE

BY

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Received: October 16, 2017
Accepted for publication: December 15, 2017

Abstract. The aerodynamic profile is characterized by the carrying capacity, described like the ratio of lift coefficient C_y and drag coefficient C_x. The increase of this parameter can be realized through lift coefficient increasing or drag coefficient decreasing. The work tries to demonstrate, on experimental way, the effect of controlled emission of fluid through the trailing edge of a profile over its carrying capacity. The emission of fluid determines a significant growth of the lift coefficient simultaneously with the considerable diminution of values of the drag coefficient. In these conditions takes place an important growth of carrying capacity's values. The efficiency of fluid emission it is also analyzed from energetically point of view.

Keywords: carrying capacity; lift coefficient; drag coefficient; efficiency; fluid emission.

1. Introduction

The carrying wing is a body with a straight shape, which placed in a real fluid flow with a speed W_∞, generates a lift force F_y and a minimal drag force F_x. According to Newton's relations, established for dynamic action of

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real fluid being in plane motion over an obstacle, the two forces have the following expressions:

$$F_y = \frac{\rho}{2} S C_y W_\infty^2 \tag{1}$$

$$F_x = \frac{\rho}{2} S C_x W_\infty^2 \tag{2}$$

where: ρ is the density of fluid; S – the surface of the carrying wing, $S = b \cdot c$, b the wing's span and c it's chord; W_∞ – the speed of fluid flow, C_y – the lift coefficient and C_x – the drag coefficient.

Referring to these two coefficients, experimental studies make obvious the fact that the main parameter of which depends is incident angle α (Matei and Rădulescu, 1980).

With the help of coefficients C_x and C_y from the Eq. (1) and (2) it can be established a unique parameter, which could help at appreciation of aerodynamic qualities of a carrying wing. This parameter is named carrying capacity ε, definite through the Eq. (3):

$$\varepsilon = \frac{C_y}{C_x} \tag{3}$$

If $C_y = C_y(\alpha)$ and $C_x = C_x(\alpha)$ then, according to Eq. (3), results that $\varepsilon = \varepsilon(\alpha)$. For carrying capacity of the given wing on tries to obtain values as big as possible. The incident angle for which $\varepsilon = \varepsilon_{\max}$ is named optimum incident angle.

According to Eq. (3), the increase of carrying capacity values can be realized through two methods:

– The increase of the lift coefficient C_y, by maintaining constant the values of drag coefficient C_x;

– The decrease of the drag coefficient C_x, by maintaining constant the values of lift coefficient C_y.

By analyzing the characteristically curves $C_y = C_y(\alpha)$ and $C_x = C_x(\alpha)$ of any carrying wing it can establish the following conclusions with general character:

– The increase of lift coefficient values determines also the increase of drag coefficient values C_x;

– The decrease of drag coefficient values C_x, determines the diminution of lift coefficient values C_y.

The work proposes a method of carrying capacity increase by the lift coefficient's increase simultaneously with the decrease of drag coefficient.

The method consists of the launch of a fluid emission with controlled intensity through the trailing edge of a carrying wing - Fig. 1 (Scurtu and Alexandrescu, 2001a).

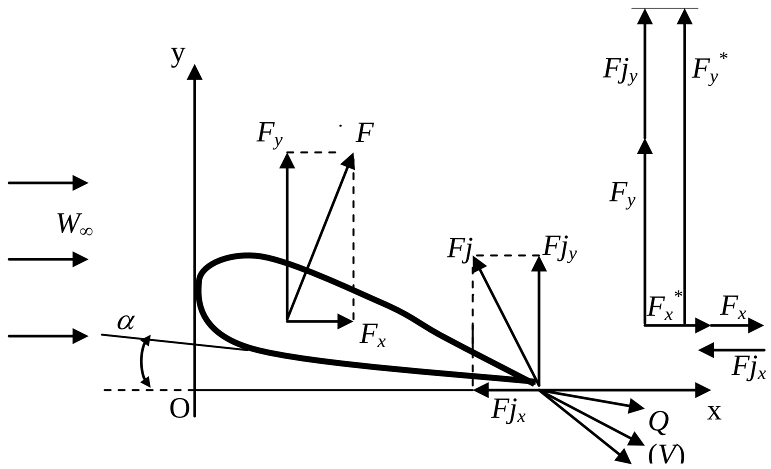

Fig. 1 – Forces on airfoil with fluid emission through trailing edge.

The fluid emission through a slit practiced in the trailing edge determines the appearance in the fluid jet of resultant force Fj; this force is decomposing in following components Fj_y and Fj_x (Scurtu and Alexandrescu, 2001b).

The vertical component Fj_y has a direct effect over the lift force F_y, determining its increase, and the horizontal component Fj_x has the same direction but contrary to the drag force F_x, determining the decrease of its value.

So for the carrying wing with fluid emission, we have:

$$F_y^* = F_y + Fj_y \tag{4}$$

$$F_x^* = F_x + Fj_x \tag{5}$$

If xpression (4) of the lift force don't presume discussions, the relation (5) of drag force allows the following observations:

a) If $F_x > Fj_x$, then the force F_x^* has the role of a classic drag force, but lower comparatively to the one established for the classic profile;

b) If $F_x = Fj_x$, the force F_x^* is null, the carrying wing become like an ideal wing. The only force which act over it is the lift force F_y^*;

c) If $F_x < Fj_x$, the force F_x^* becomes negative. The carrying wing gets a propulsive character. In this case the notion of carrying capacity is not available any more; it needs to be replaced with a new notion. It is proposed the naming carrying-propulsive capacity.

The energetic analysis of the efficiency of fluid emission through the trailing edge of portative wing has in view the balance of the power developed by the aerodynamic force F^* and emission. If resultant aerodynamic force F^* for the wing with fluid emission is:

$$F^* = \sqrt{F_y^{*2} + F_x^{*2}}$$

where F_x^* and F_y^* are given through the Eq. (1) and (2) result:

$$F^* = \frac{\rho}{2} bcW_\infty^2 \sqrt{\left(C_y^*\right)^2 + \left(C_x^*\right)^2} \tag{6}$$

As a result, the power P_p^* developed by the resultant aerodynamic force F^* is:

$$P_p^* = \frac{\rho}{2} bcW_\infty^3 \sqrt{\left(C_y^*\right)^2 + \left(C_x^*\right)^2} \tag{7}$$

For the classic wing without fluid emission, the resultant force F is:

$$F = \sqrt{F_y^2 + F_x^2} = \frac{\rho}{2} bcW_\infty^2 \sqrt{\left(C_y\right)^2 + \left(C_x\right)^2} \tag{8}$$

The power developed by the aerodynamic force F for the classic wing is:

$$P_p = \frac{\rho}{2} bcW_\infty^3 \sqrt{\left(C_y\right)^2 + \left(C_x\right)^2} \tag{9}$$

The power variation ΔP it is defined through the relation:

$$\Delta P = P_p^* - P_p = \frac{\rho}{2} bcW_\infty^3 \left[\sqrt{\left(C_y^*\right)^2 + \left(C_x^*\right)^2} - \sqrt{\left(C_y\right)^2 + \left(C_x\right)^2}\right] \tag{10}$$

The Eq. (11) gives the reactive force developed by the fluid emission through the trailing edge, being a force of impulse:

$$Fj = \rho A V^2 \tag{11}$$

where *A* is the area of slit's section of fluid emission and *V* – the medium speed of fluid emission at the exit from the slit.

The power developed by this force is:

$$P_F = Fj \cdot V = \rho A V^3 \tag{12}$$

With the Eqs. (10) and (12) on defines the efficiency θ of fluid emission through the relation:

$$\theta = \Delta P / P_F \tag{13}$$

2. Experimental Considerations

The portative wing on which we made the experimental tries is built on the base of an aerodynamic profile like *Gottingen 593*. It is realized from a plate of 0.3 mm thick, being obtained by taking adequate shape as a pattern. So it results that the wing is empty inside, the extremities, which limit the span, being obtruded. In the trailing edge the whole length of the span, it is practiced the fluid evacuation slit with height h = 0.001 m. The wing chord is c = 0.15 m and the span is b = 0.1 m.

The creation and the supplying of fluid emission through the trailing edge are made from an outside compressed air source, through a compressor *2E.C.S* type.

The adjustment and measurement of fluid discharge evacuated through slit, is realized with the help of a flow meter. The fluid discharges have the following values: Q_1 = 0 m^3/s; Q_2 = 1·10^{-3} m^3/s; Q_3 = 2•10^{-3} m^3/s; Q_4 = 3•10^{-3} m^3/s; Q_5 = 4•10^{-3} m^3/s; Q_6 = 5•10^{-3} m^3/s; Q_7 = 6•10^{-3} m^3/s.

Corresponding to these discharges, the medium speed v in the fluid emission has the following values: V_1 = 0 m/s; V_2 = 10 m/s; V_3 = 20 m/s; V_4 = 30 m/s; V_5 = 40 m/s; V_6 = 50 m/s; V_7 = 60 m/s.

The experimental tries were made on the wind tunnel from the "Fluid Mechanics" laboratory from "Gheorghe Asachi" Technical University of Iași. In the experience room it was created a speed, W_∞ = 20 m/s, for the general current of fluid. Corresponding to this speed, the Reynolds number is Re = 1.3•10^5.

The measuring balance allows the determination, on gravimetrical way, of both the lift force and the drag force for a domain of incident angles $\alpha = \pm 45°$. The incident angles "α" for which was made the experimental determinations has the following values: 0°; 2°; 4°; 6°; 8°; 10°; 12°; 14°; 16°; 18°; 20°; 22°; 24°; 26°.

Figs. 2 and 3 show the influence of fluid emission through the trailing edge of the airfoil on lift coefficient (Fig. 2) and drag coefficient (Fig. 3).

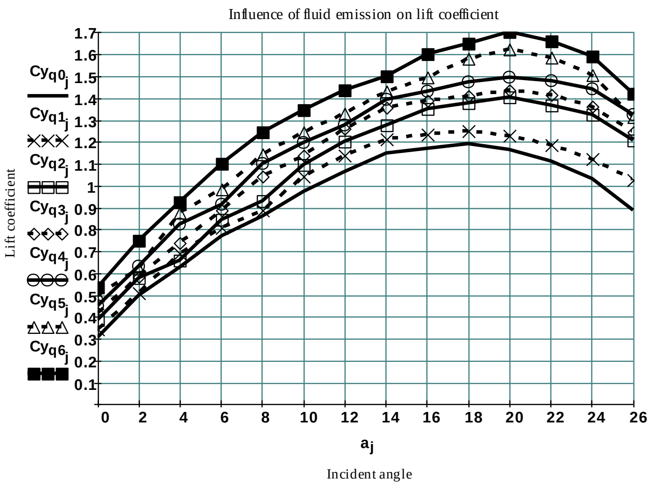

Fig. 2 – Influence of fluid emission on lift coefficient.

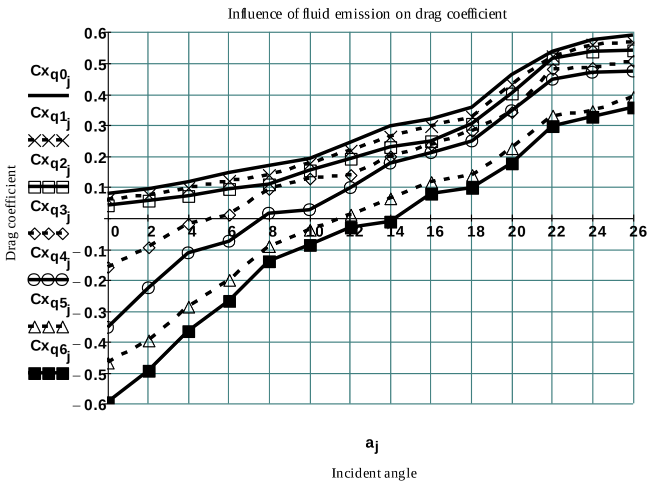

Fig. 3 – Influence of fluid emission on drag coefficient.

In conformity with the experimental determinations, it was calculated the portative capacity ε for the classic wing, respectively ε^* for the wing with fluid emission where is possible. The efficiency of fluid emission, over the characteristics of portative wing is established with Eq. (13).

The variation $\varepsilon(\alpha)$, $\varepsilon^*(\alpha)$ is presented in Fig. 4 and the variation $\theta = \theta(\alpha)$ in Fig. 5.

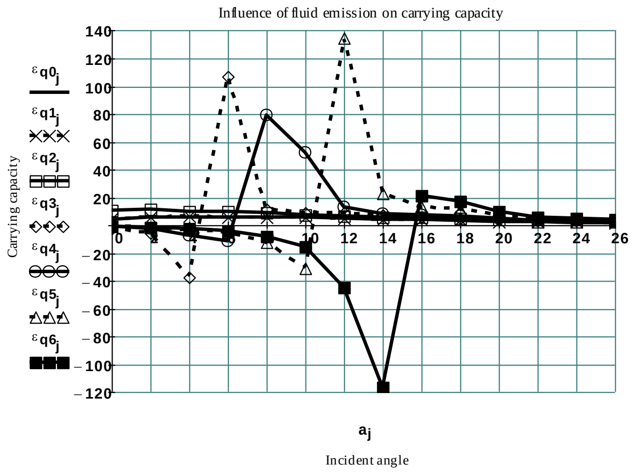

Fig. 4 – Influence of fluid emission on carrying capacity.

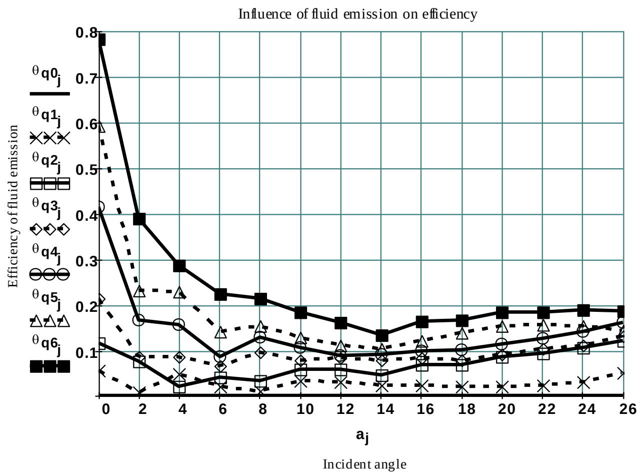

Fig. 5 – Influence of fluid emission on efficiency.

3. Conclusions

The analysis of Fig. 4 allows the following conclusions:

1. At constant intensity Q of fluid emission through the trailing edge, the carrying capacity $\varepsilon^{*}>\varepsilon$, no matter what incident angle value will be $\alpha\in[0°\div26°]$.

2. At constant values of incident angle α, the carrying capacity ε^{*} grow in the same time with the growth of fluid emission intensity through the trailing edge.

3. For incident angle $\alpha\in[0°\div10°]$ and for discharges $Q \geq 2*10^{-5}$ m^3/s, the drag coefficient $C_x^* < 0$. The carrying wing gets propulsive character. As a result, the notion of carrying capacity loses its signification.

The analysis of Fig. 5 allows the following conclusions:

4. The efficiency θ is positive, fact which demonstrates that the aerodynamic power developed by the wing with fluid emission is bigger than the aerodynamic power developed by the classic wing.

5. With a constant discharge, emitted through the slit from the trailing edge, the efficiency θ decrease until the half of the incident domain α considered and then it starts to grow.

6. For a constant incident angle, the efficiently grows at the same time with the growth of fluid emission through the trailing edge.

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ANALIZA ARIPII AERODINAMICE CU EMISIE CONTROLATĂ DE FLUID PRIN BORDUL DE FUGĂ

(Rezumat)

Lucrarea propune o metodă de mărire a capacității portante a aripilor aerodinamice. Metoda constă din lansarea unei emisii controlate de fluid printr-o fantă plasată pe toată lungimea bordului de fugă. Se constată pentru noul tip de aripă o creștere considerabilă a capacității sale portante. Analiza energetică privitoare la consumul suplimentar de putere pentru întreținerea emisiei fluide arată că, această putere consumată este mai mică decât efectul pe care îl produce asupra puterii forței aerodinamice rezultante.