REVIEW OF CONTRIBUTIONS REGARDING COANDA EFFECT

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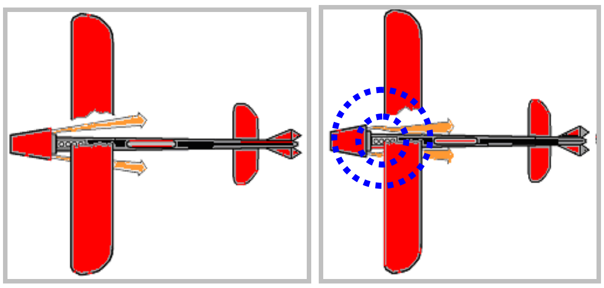
***Abstract**: Coanda effect is the phenomena in which a jet flow attaches itself to a nearby surface and remains attached even when the surface curves away from the initial jet direction.In free surroundings, a jet of fluid entrains and mixes with its surroundings as it flows away from a nozzle. When a surface is brought close to the jet, this restricts the entrainment in that region. As flow accelerates to try balance the momentum transfer, a pressure difference across the jet results and the jet is deflected closer to the surface - eventually attaching to it.*

***Key words**: slot, attached jet, static pressure, centrifugation zone, suction zone.*

1. INTRODUCTION

The Coandă effect or fluid jet deviations closed to curl surfaces was observed by Henri Coandă (1910) during his first flight powered by jet propulsion (Fig.1).



a) b)

Fig. 1 The geometry of Coanda jets

In author's description (Coanda, 1969), this effect is "based on the creation of a depressurized zone in the main air stream along a wall, which permits flows to get the wall direction where the pressure difference was trigged". In fact this is a transformation of a linear jet in a curled jet based on the attachement at a divergent wall. After lengthy research, the engineer obtained the French patent act nr. 792754 of October 8, 1934 and the Romanian one, nr. 24376 of October 4, 1935, entitled *Procedure and device for the deviation of one fluid into another.*

2. THE BASIC ASPECTS OF COANDA EFFECT

The Coandă effect is a natural phenomenon with action on the flow attached to a divergent wall (volet or airfoil) characterized by a high assimmetry. It is posible to remark the following aspects (Fig.2):

1. The depressured zone determines:

a) *flow acceleration upstream in the slot*, without increasing upstream pressure or temperature;

b) *the displacement of the local fluid.*

2. Detaching and re-attaching is caracterized by histerezis (the reattaching is produced at smaller angles than the detaching).

3. The global flow that results from the mixing between the main flow and the displaced one is situated in the depressure zone and is characterized by lower temperature.

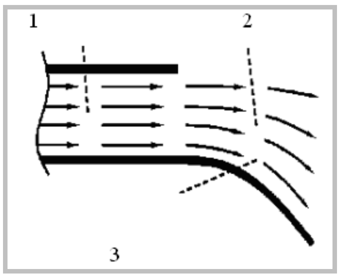
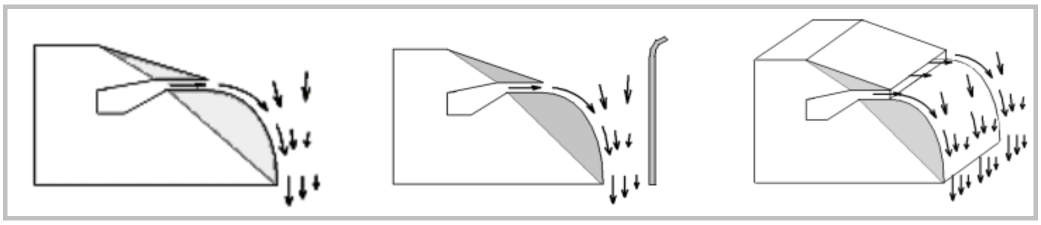


Fig. 2 Coandă flow (2D)

3. AN ANALYSIS OF THE GEOMETRY OF COANDA EJECTORS

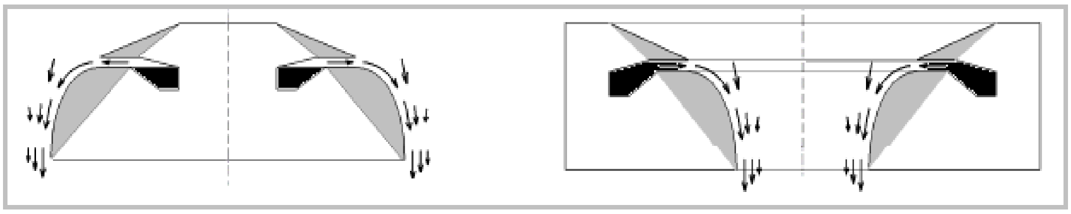
For a 2D attached jet type flow there results a first class of Coanda ejectors with rectangular section (Fig.3), that could function also with limitation wall.

Another type of ejectors is represented by the axial symmetric device (external vs. internal ejectors Fig. 4).



a) b) c)

Fig.3. Rectangular (*2D*) ejectors: a) 2D Coanda flow; b) 2D Ejection device; c) 3D Ejection device with limiting wall



a) b)

Fig. 4 Ejection device: a) Lenticular external ejection device; b) Lenticular internal ejection device

4. A GLOBAL ANALYSIS OF THE MIXING PROCESS IN THE EJECTION DEVICE

Let consider an ejection device that we are going to analyse from the point of view of the mixture between the primary flows, the active one, through which energy is introduced into the system, and the secondary flow.

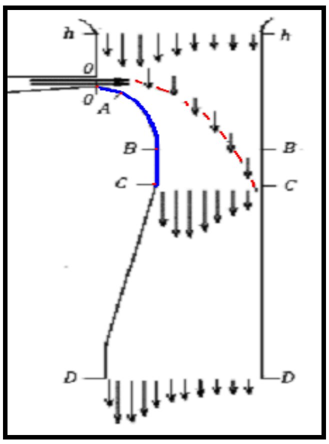


Fig. 5 Coanda ejector with non-uniform speed distribution

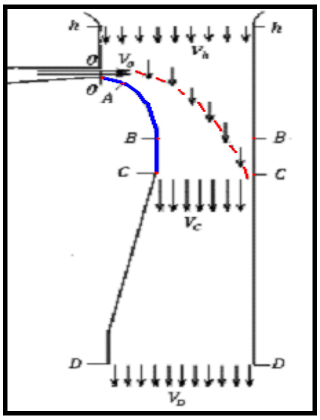


Fig. 6 Coanda ejector with uniform speed distribution

In the inlet (Section 0-0**)**, the primary flow is introduced by compression, acceleration or through absorbtion directly from the environment. The absorbtion section (h-h) through which the resulting inflow moves only and is characterized by the fact that the total enthalpy i* of the flow is the same with that of the environment i_H*. The place around A is supposed to be the spot where the depressurization flow is maximal. Section B-B shows the end of the Coanda profile (line OAB). Section C-C is where the absorption section ends and the thickness of the mixin region equals that of the C-C section. D-D is the exit section from the ejection disposal and is characterized through the fact that the static pressure is equal with that of the environment static pressure p_H. The area h-0-C-B-h is considered to be the absorption area where the total enthalpy i* of the flow is the same as that of the environment i_H*. Area 0-ABC-C-0 is considered to be that of the mixture where the whole quantity of generated flow is received through the permeable surface C0. Area C-D-D-C is the area of acquiring uniformity for aerothermogazodynamic parameters in section C-C and it usually has a divergent form, which contributes to the increase of efficiency of the ejection device. Its existence leads to the increase of the generated flow but it does not necessarily mean an increase of the propulsion force. The research on the force increase will have to take into consideration the entire geometry of the ejection device. The known factors are the geometry of the ejection device in its sections (Ah, A0, AB = AC, AD), the fuel conditions in the slot (p*, P_0), and environmental conditions (p_H, ρ_H, i_H*). Also, for this global analysis of the mixture in the ejection device the values of the energetic performance ηC, ηD on sections 00-CC, 00-DD, are considered as known.

In Fig. 7 is presented the distribution of speed in a section of the Coanda ejection device with two different regions, an asymmetrical one (d width), and a uniform one (D-d width) where the length of the boundary layer at the wall being s.

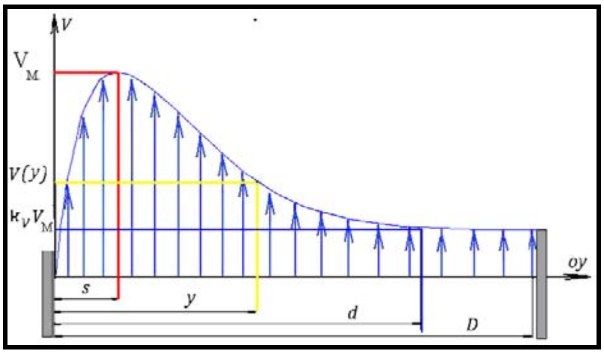


Fig. 7 Distribution of speed in a section

5. CASE STUDY: COANDA EJECTION DEVICE WITH UNEVEN SPEED

Let a Coanda ejector with non-uniform and variable speed distribution. In the D exit section, the static pressure p_D equals the environment pressure p_H. The power transferred to the fluid in D section is:

$$P_0 = \eta P_D = \int_{A_D} \rho_H V_D(y)\left(i_D^* - i_H^*\right) dA_D$$

$$= \frac{\rho_H V^3_{MD} A_D \chi_{3D}}{2} \tag{1}$$

The gain force is given by the difference between the two force distributions, with a maximal value corresponding to A:

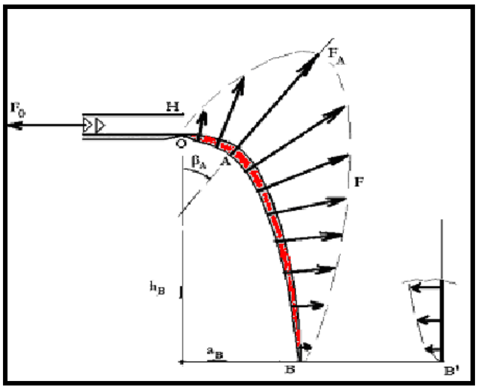


Fig. 8 Force distributions on Coanda airfoil

Let detail Coanda flow by using two zones with special properties, the centrifugation zone and the suction zone.

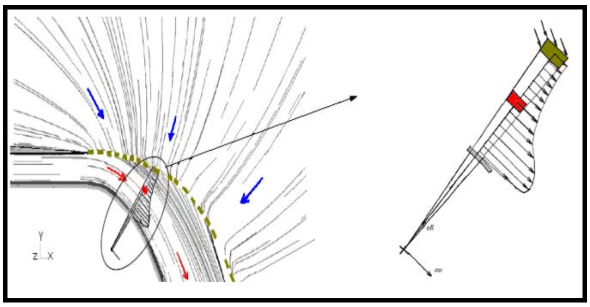


Fig. 9 Detailed analysis of Coandă flow

The equations for the centrifugation zone that is associated to the mixing region 0-ABC-C-0 with C0 permeable are:

$$\frac{1}{r} \cdot \frac{\partial(\rho \cdot u_\omega)}{\partial \omega} = 0 \tag{2}$$

$$-\frac{u_\omega^2}{r} = -\frac{1}{\rho}\frac{\partial p}{\partial r} \tag{3}$$

$$u_\omega \frac{\partial u_\omega}{\partial \omega} = -\frac{1}{\rho}\frac{\partial p}{\partial \omega} \tag{4}$$

$$i^* = i_H^*\left(\frac{p}{p_H}\right)^{\frac{k-1}{k}} + \frac{u_\omega{}^2}{2} \tag{5}$$

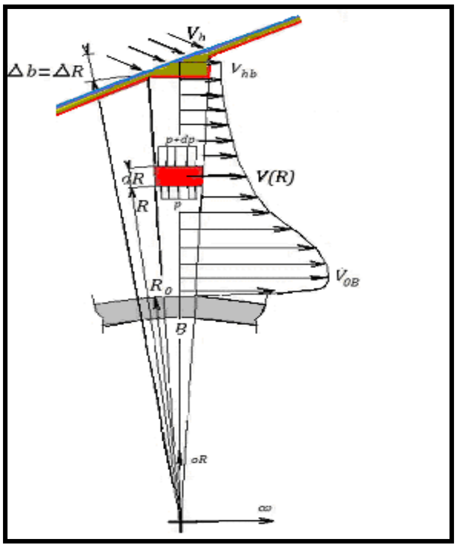


Fig. 10 Element of jet

For a small element of jet flow, the radial movement equation is:

$$\frac{dR}{R} = \frac{dp}{\rho u_\omega^2} \tag{6}$$

For B_i on the profile:

$$u_\omega = u_{\omega 0} f_u(R) \qquad u_{\omega 0} = u_0 f_{u0} \tag{7}$$

and the total enthalpy is conserved:

$$i^*(R) = \frac{[u_\omega(R)]^2}{2} + \int \frac{[u_\omega(R)]^2}{R} dR|_R + i_c^* \tag{8}$$

The static pressure is expressed by:

$$p(R) = p_H\left(1+\frac{1}{i_H^*}\int\frac{[u_\omega(R)]^2}{R}dR|_R\right)^{\frac{k}{k-1}} \tag{9}$$

and the static density ad static temperature are:

$$\rho(R) = \rho_H\left(1+\frac{1}{i_H^*}\int\frac{[u_\omega(R)]^2}{R}dR|_R\right)^{\frac{k}{k-1}} \tag{10}$$

$$T(R) = T_H\left(1+\frac{1}{i_H^*}\int\frac{[u_\omega(R)]^2}{R}dR|_R\right)^{\frac{k}{k-1}} \tag{11}$$

The gain in force at B_i:

$$\phi_{Bi} = \frac{1}{b_0}\int_{R1}^{R2}\left(1+\frac{1}{i_H^*}\int\frac{[u_\omega(R)]^2}{R}dR|_R\right)^{\frac{k}{k-1}} f_{u0}^2 f_u^2(R)dR \tag{12}$$

and the corresponding efficiency is:

$$\eta_{Bi} = \frac{1}{b_0}\int_{R1}^{R2}\left(1+\frac{1}{i_H^*}\int\frac{[u_\omega(R)]^2}{R}dR|_R\right)^{\frac{k}{k-1}} f_{u0}^3 f_u^3(R)dR \tag{13}$$

We note that the flow attached is situated in the depressure zone defined by the exit from slot, 0-0, B-B section and D-D exit with a maximal value in A.

6. CONCLUSIONS

In the conclusion we can state that for the same energy available P_0, the D_f force gain can be obtained by decreasing the speed $V_D < V_M$, similarly to an increase by ejection of the mass flow evacuated.

In order to obtain the highest force possible for an available used energy it is preferable to put into motion the highest amount of fluid possible with the lowest speed possible instead of a small amount of fluid put into motion with a high speed.

REFERENCES

1. Berbente, C., Constantinescu, N.V, *Dinamica gazelor şi Dinamica fluidelor vâscoase*, Aerotermochimie, UPB, Bucuresti, 1985;
2. Carafolie, E., Constantinescu, N.V., *Dinamica fluidelor compresibile*, Ed. Academiei RSR, Bucuresti, 1984;
3. Coandă, H., *Air - source du progress*, Book - [s.l.], qqq, aprox. 1961;
4. Coandă, H., *Fluid propulsion system* Patent US3337121, 1967;
5. Coandă, H., *Programme d'etude et de realisation d'un aerodyne actionne par un systeme thermosouflant*, 1960;
6. Constantinescu, N.V., Galetuse, S., *Mecanica fluidelor şi elemente de aerodinamică*, Ed. didactică şi pedagogică, Bucureşti, 1983.