Study on the Equation of the Theoretical and Experimental Attachment Current Line for a Bistable Fluidic Element with Jets of Different Physical Nature

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Abstract: *This paper presents the possibility of determination of the experimental attachment flow line for the wall – attachment digital device and its equation. The function of this element is based on the controlled attachment of the main jet at a curved wall through the Coanda Effect. For this purpose, it was used the method of image analysis and then, taking over points was processed with soft program aid. The experimental obtained flow line was compared with theoretical curve. The bistable element which was examined is a special device with an incompressible fluid as supply jet and compressible fluid as command jet*

Keywords: *attachment flow line, bistable element, Coanda Effect*

1 INTRODUCTION

The current economic environment, strongly competitive, has determined the creation and promotion of new equipment and fluid systems of automation. Between the 1950 and 1960 many efforts have been made by researchers worldwide in order to control the fluid jets and to obtain the change of directions without acting on them with moving parts or other devices. The solution was the use of Coanda Effect, and the results start to be achieved.

Many applications were developed using the Coanda Effect **[2],** especially concerning aviation engine devices for thrust reversal, silencers for noise reductions of the reactive jets, ventilation and exhaust devices and many others technical procedures.

The main idea was to use fluidic elements to control systems and devices in all technologies involving the use of fluids. The elements were simple in construction, had fixed parts, the manufacture price was attractive and they could be powered by almost any source of the fluid under pressure. An essential advantage was that the fluidic components were capable to work a lot of time under extreme environmental conditions (in the presence of electromagnetic, nuclear radiations, dusty fields, and explosive environment) and having motionless parts the changes in time of the operation were not important.

The fluidics elements start to be promoted, in specific applications when the electrical devices can be replaced in terms of price and working conditions. The main applications of fluidic elements are as specific elements and systems in aircraft systems, missiles and spacecrafts or nuclear field, mining industry **[5, 6, 7].**

Generally, the classification of the fluidic elements is done after the functions performed and based on the function phenomena mainly used. Based on function the two main categories of fluidic elements are: analog and digital **[10].**

The digital elements or logical elements operate on digital logic and the state at the output of the elements is „0„ or „1„.

In the analog fluidic elements, the fluid flowing from the pressure supply can be controlled proportionally in some limits by varying the characteristics of the fluidic input and thus a continuously correlation between the input and the output is obtained.

The classification after the function includes analog devices like:

- fluidic amplifiers in which low value of input pressures or flows can control higher output pressures or flows.
- fluidic oscillators in which jet pressure or air quantities at different frequencies can be obtained by varying an input.

The classification after the function includes logic or digital devices like:

- fluidic bistable elements
- monostable elements.

The classification after the principles of operation divides the fluidic elements in three categories **[3]:**

- elements based on the jet interaction.
- attachment elements based on Coanda Effect.
- vortex element based on the commanded transition of jet from a laminar regime to a turbulent regime.

The Coanda Effect is in a simple description the tendency of a fluid to adhere to a curved surface because of the reduced pressure caused by the flow acceleration around the surface. This effect of attachment can be controlled either by injecting a thin jet of fluid tangential to the curved surface, or by acting with a control jet forcing the main jet to attach at the wall.

In conclusion, the sensitive flows at amplifications, meaning the fluid flow which changes flow direction, velocity profile and nature of flow, with the help of the secondary or lateral jets, they are mostly used in automatics.

Many investigations and research performed in the fluid field proved that the achievement of the amplification effect at the fluidic devices it is similar with the electronic magnification (electronic valves, transistors).

2. ABOUT THE DETERMINATION OF THE THEORETICAL ATTACHED FLOW LINE

The target of this paper is the analytical determination of equation of attachment flow line on the wall, then determination of the equation of the experimental line of attachment flow line and finally, comparison between theoretical and experimental results. It was used the method of image analysis and taking over points was processed with soft program aid.

The analyzed fluidic device with discrete action operates in a discontinued manner, a characteristic of relay type non-linearity with hysteretic and insensitivity area. It is represented by the fluidic amplifier of the symmetrical bistable element type. The bistable and monostable fluidic element, which is a special case of the bistable fluidic device, are two types of fluidic amplifiers, basing in their work, on the principle of jet attachment to solid walls – the Coanda Effect.

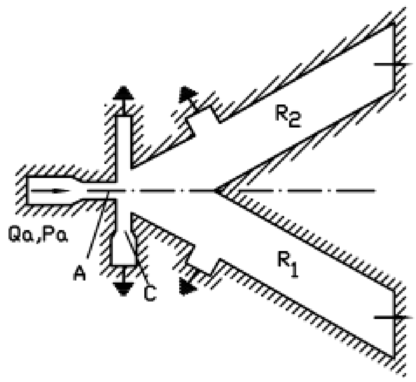

Fig. 1 *Monostable fluidic amplifier*

Its geometrical structure is inspired by an amplifier design for supersonic fluids, studied by Bavagnoli **[1],** with linear dimensions ranging within the limits of the value field recommended by technical literature. Its particularity stands in fact that it uses a liquid supply jet and air control jets in its operation.

At the exit of the supply nozzle, the power jet meets an auspicious geometrical structure for his attachment to the solid wall. So, in the corresponding receiving canal (*R*2) it obtains a pressure signal and a flow signal. Their values are established by the supply pressure (*pa*) level and by the geometrical structure. In subtend receiving canal (*R*1) the achieve flow is null. We achieve the first stable state. If we apply a command jet in the control nozzle that determine the switch of the power jet in subtend receiving canal (*R*2) **[1, 5]**

The power jet returns in the receiving canal (*R*2) if the geometrical structure is asymmetrical (Figure 1) and the command jet disappears. We obtain again the initial stable state. So, a command jet, with a lower energy level, is able to modulate a supply jet with a high energy level in a large band of frequency. The bistable fluidic device and its particular case monostable fluidic device is a decision element.

The process of the jet attachment is not so simple and the methods to switch the main jets are studied in many papers **[4, 5, 9,10].**

As the jet attaches to the wall, a portion of fluid is directed downstream along the wall, and a small amount of fluid is directed upstream along the wall. This represents the return flow Q_r. The point on the wall, where the flow splitting takes place, represents the attachment point, and the current line that contains it is the attachment current line **[5].**

The theoretical determination of equation of attachment flow line on the wall is possible using the continuity equation for the jet's attachment area.

The presence of the control flow causes a change in the position of the attachment point, the line of attachment of the jet being displaced by its action.

The continuity equation applied in jet's attachment area gives the following relation:

$$\boldsymbol{Q_c + Q_r = Q_{ant},} \tag{1}$$

where: Q_c is command debit; Q_r is return debit and Q_{ant} – is trained flow.

Considering the continuity equation and the expression of the normalized flow rate for half of jet w_{ant}, **[5]:**

$$\boldsymbol{w_{ant} = \frac{Q_{ant}}{Q_a} = \frac{1}{2}\left(\sqrt{1+\frac{x}{x_0}} - 1\right)} \tag{2}$$

and the normalized return debit for half of jet w_r , **[5]:**

$$\boldsymbol{w_r = \frac{1}{2}\sqrt{1+\frac{x_c}{x_0}}\left[1 - th\frac{\sigma_y(x_c)}{x_c + x_0}\right]} \tag{3}$$

will obtain the normalized control debit $w_c = w_{ant} - w_r$; so,

$$\boldsymbol{w_c = \frac{1}{2}\left[\sqrt{1+\frac{x_c}{x_0}}\, th\frac{\sigma_y(x_c)}{x_c + x_0} - 1\right]}, \tag{4}$$

or for a certain distance *x*, the expression of the normalized control debit w_c is:

$$\boldsymbol{\sqrt{1+\frac{x}{x_0}}\, th\frac{\sigma_y(x)}{x + x_0} = 2\frac{Q_C}{Q_a} + 1} \tag{5}$$

Equation (5) is the theoretical attach flow-line considering the command debit Q_c reported on the supply debit Q_a. Based on relation (5), using MathCAD, it was designed the attach flowline, for different values of the power nozzle width, for a jet dispersion coefficient σ=8 and a ratio Qc/Qa=0,05. This is presented in Figure 2.

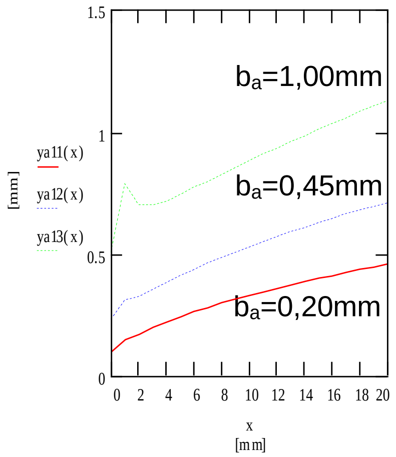

Fig.2 *Curve of the theoretical attachment current line*

3. DETERMINATION OF THE EXPERIMENTAL ATTACHED FLOW LINE

Starting from theoretical models and based on some tested configuration in order to obtain power jet attachments on walls, the author developed in the papers **[5]**, **[6]**, **[7]**, an original configuration for a fluidic element based on the Coanda Effect. The general design of this element is presented in Figure 3 where the best metal model is photographically presented.

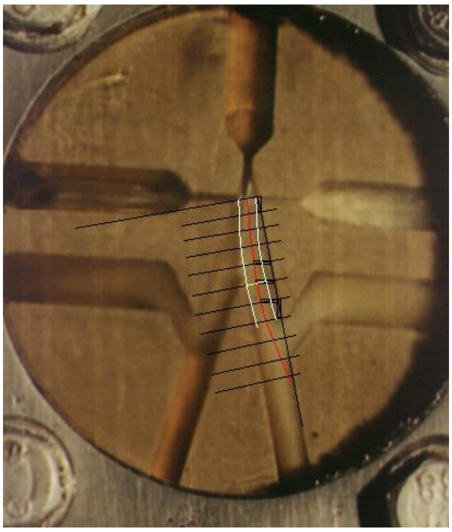

Fig. 3 *Digitizing the attachment current line*

For the experimental control of the theoretical results and for a mathematical modelling we must determinate the experimental attach flow-line equation using the image analysis (Figure 3). We made this for a supply pressure $8{,}7\times10^5$Pa, right command, and for a command pressure $p_c=2{,}2\times10^5$Pa.

After coordinating of the attached flow-line points was obtained, all the date was processed with TC WIN. So it's obtained the experimental attach flow-line **[5]:**

$$\ln y = a + bx + cx^2 + dx^3 \qquad (6)$$

where: a = 0,1722; b = 0,1145; c=-,0046; d = -0,0001, and its representation (Figure 4).

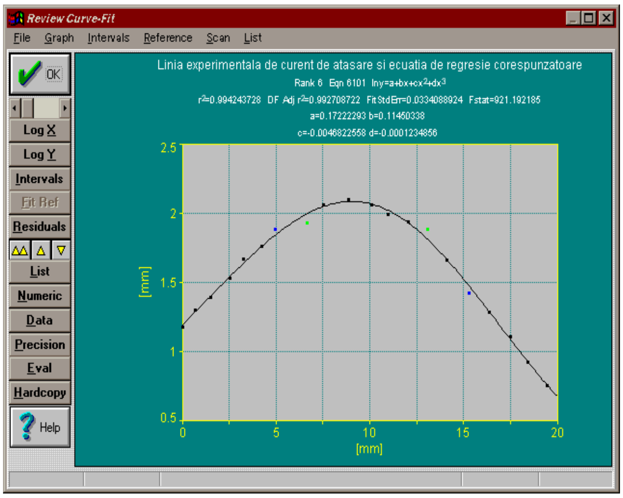

Fig. 4 *Experimental attach flow-line*

4. CONCLUSIONS

- The obtained curves verified jet's progressive attach theory (Coanda Effect) [2], [3];
- We can see the same increasing allure on the analyzed domain. The experimental curve shows the jet attach tendency, but also the tendency to detach the jet. The experimental curve has a maximum near x = 8.25mm due to the presence of the separation bubble, while the theoretical curve has a continuously increasing tendency up to x = 20mm, the upper limit of the analyzed interval.
- The difference between the theoretical and experimental curves is due for the approximation at the thin jets' experiment, the attach flow experimental line is the symmetry jet's axe. On the other hand, in the experimental tests it wasn't possible to respect exactly the value of the ratio Q_c/Q_a=0,05.
- The proposed mathematical model for describing the operation of the analyzed fluidic amplifier [], can be supplemented with this experimental curve equation.
- The solution of fluidic elements using the Coanda Effect even for execution elements is possible and presents superior advantages over the existing solutions by his safety in operation in hostile environments.
- The direction to develop the fluidic element using Coanda Effect is not abandoned, some recent papers **[8], [11]** is the proof of a growing interest in this field.
- Now, after many years the fluidics start again to be promoted, this time in specific applications when the

electrical devices can be replaced in terms of price and working conditions. This technology is used in applications when the main agent is a liquid or other fluid under pressure and in case when the systems work with air the technology is called some time pneumonic. The main applications of fluidic are in use as specific elements and systems in aircraft systems, missiles and spacecrafts or nuclear field.

- The actual orientation of the research in this field of study, aims to achieve fluidic elements and systems with a minimal energy consumption, a great speed of response, high reliability, safety in operation, a higher level of compatibility with the conventional automation systems, a lower price and many other performances that justify their usage.

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