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THEORETICAL STUDY: FLOW CONTROL MONO AND BI-STABLE FLUIDIC DEVICE FOR MICRO-INJECTION SYSTEM

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ABSTRACT

This paper is focused on the modeling of a micro-injection systems composed of passive amplifier without mechanical part. The micro-system modeling is based on geometrical oscillators form. An asymmetric micro-oscillator design based on a monostable fluidic amplifier is proposed [1, 2]. Several configuration of associate device are simulating to found adequate logical signal form. The characteristic size of the channels is generally about **a** few hundred of microns

NOMENCLATURE

f: frequency (Hz)

t_s : switching time (s)

t_t : transmission time (s)

l_b : loop length (m)

L_O : outlet length (m)

γ : constant of gas 1.4 of air

r :gas constant (j/K.mole)

T: temperature (K)

q: mass flow (kg/s/m)

Δt: time steep (s)

Re: Reynolds number

INTRODUCTION

Within the last decade the world of the "bio" micro technology has growth up, more to many university and private groups which have been developing micro systems for biomedical and chemical applications. Fluidic elements with no moving parts, able to realize logic (yes, no, and, or...) or proportional (signal amplification) functions,

Were widely studied in the 1960s [1] the characteristic size of the channels is generally about a few tens of microns. This miniaturization involves series of fundamental problems related to the fluid mechanic. Indeed, at these scales, the fluidic flows are laminar [1].

The working principle of this device consists in disturbing the flow of jets moving along the principal channel by flow oscillations generated by three pairs of lateral canals. The device is called micro injector.

In these cases, the oscillators use special designed geometric configurations, identified by the absence of moving parts, to create an environment where self-induced, sustained oscillations will occur [2, 3], they can be used as flow meters. A novel fluidic oscillator has been developed and tested by V.Tesar, make these oscillators attractive as micro reactor injection application.

DEIGN AND OPERATION OF THE OSCILLATOR DESCRIPTION

Micro oscillator were obtained from wall attachment micro fluidic amplifiers using a feedback loop from the outputs to the control input, figure 1, [2, 3, 4]
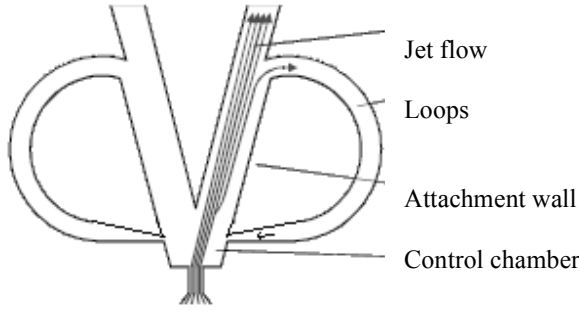
Figure 1 bistable oscillator

The principle of oscillators is based on a fluid jet, which injected into the oscillator, bends due to small fluctuations towards one of the attachment walls. Some examples of systems and processes that might employ this technology include inkjet printers, blood-cell-separation equipment, chemical synthesis, genetic analysis, drug delivery, electro chromatography, micro-scaled cooling systems of electronic devices which generate high power. The fluid flow on the bent side of the jet is restricted and a low-pressure regime is created, which causes the jet to attach to the wall (Coanda effect) [7]

APROXIMATION OF THE OSCILATION FREQUENCY

The period of oscillations is determined by the switching time from the attachment wall to another and the transmission time through the feedback channel [3, 4, 5]; the frequency is determined by expression (1)

$$f = \frac{1}{2.(t_s + t_t)} \qquad (1)$$

For liquids flow, generally the frequency of oscillation is strongly dependent on the switching time [4], is given in expression (2)

$$f = \frac{1}{2.(t_t)} \qquad (2)$$

For gases, the frequency of a bistable feedback oscillator is function of the jet travel time, of the jet switching time, and the acoustic travel time [5]. In a rough approximation is given by expression (3).

$$f = \frac{\sqrt{\gamma.r}}{2.(l_b + 2.L_o)}\sqrt{T} \qquad (3)$$

VALVE MODELLING

The valves are characterized by their flow evolution versus pressure [6]. Two main advantages of micro-fluidic can be highlighted: very small analysis devices reduce the time of analysis and volume of components needed.
.
Tesla diode
A Tesla diode [7] is similar to a valvular conduit. Its profile is presented in Figure 2.
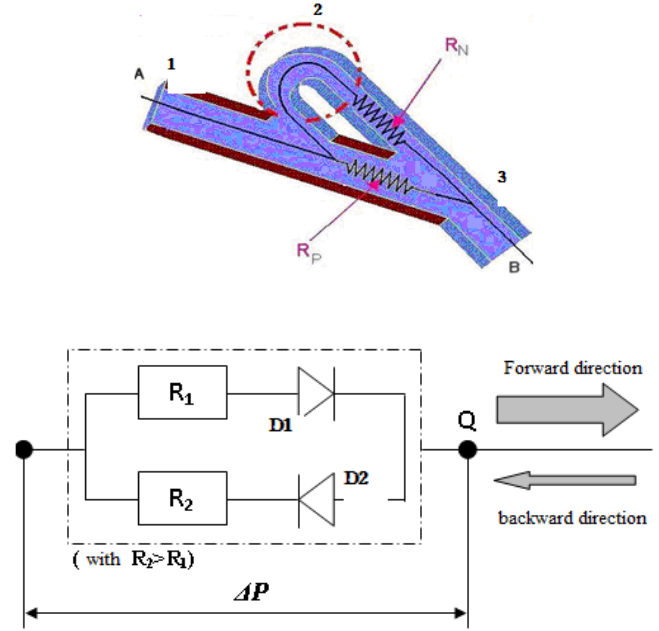

Figure 2 principle schema of Tesla diode [7]

The basic structure of the diode of Tesla was invented by NIKOLA TESLA 1920. The flow in this diode is similar to two electric impedances in parallel figure 2. She allows a quasi-free flow of A towards B, but resisting in the sense (direction) set with a total equivalent electric resistance (RP + RN).
The geometry of the valve can be separated into three regions. In the region 1 and 3 the friction losses can be neglected and only acceleration losses have to be considered. For the flow, two analytic equations are implemented in order to take into account the asymmetric behavior of the micro-valve [7].

DESCRIPTION OF THE SIMULATE GEOMETRIES.

We simulate the air flow in an oscillator geometry without feedback, it is a configuration with two injectors only with

events for every injector, that dimension is $(13 \times 4.4)\,cm$. The output orifice size equal 0.067 cm
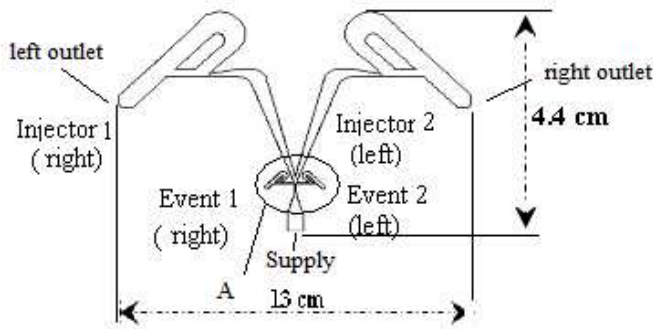

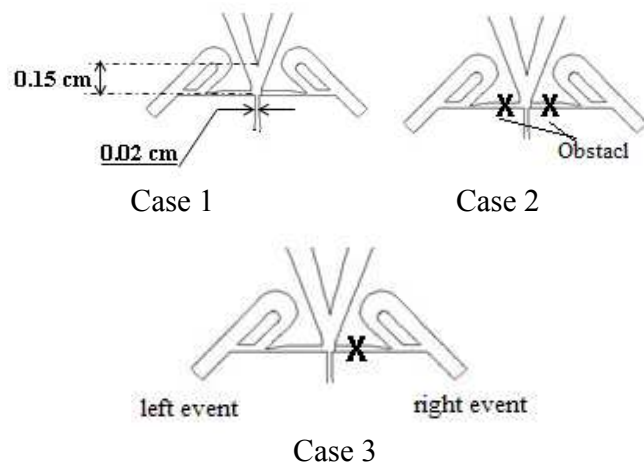Figure 3: Fluidic oscillator injection system initial configuration first case

Figure 4: Configuration A (region) simulate oscillator injection system

The pressure applied on the valve supply is supposed to be positive. A jet issuing from a nozzle and expanding between two inclined walls will attach to the less inclined one or to the wall which is closer from the jet axis figure 4. The jet will oscillate, and the element will behave as a fluidic oscillator.

All following results are obtained for monostable oscillator. The relationship f (1/V) is linear [8]; the injector form is supposed the Volume layout. This linear relationship for a given supply pressure, the switching of the jet from the stable position towards the unstable position occurs as soon as an upper threshold pressure is reached inside the volume V.

MODEL SIMULATION

With a plane oscillator of constant depth made with a square tube. Such plane oscillators are simulated by a fully CFD approach.

Hypotheses

The simulation of the micro-injection systems is obtained with several hypotheses:

1- air and turbulent regime
2- Incompressible ideal gas flow.
3- Inlet pressure 2×10^5 Pa
4- Next results are presented for the Reynolds number at the nozzle is around Re = 5632

RESULTS FIRST CASE INJECTION SYSTEM

On the first case geometry figure 3, we present the following results.
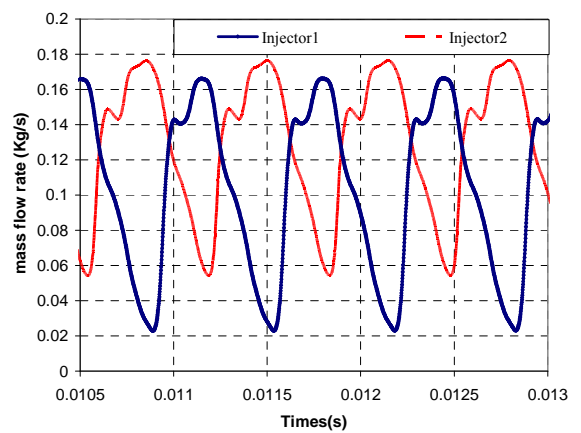

Figure 5: masse flow output injection system signal

The spectral analyses with Fourier transformation FFT describe the frequency oscillation of injection system for three cases studied, figures 6, 7, 8.
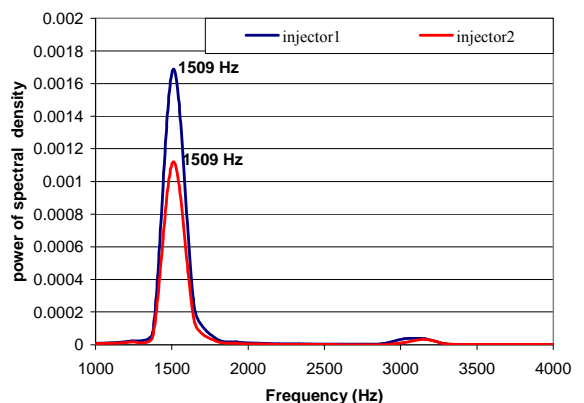

Figure 6: Spectral power of flow signal
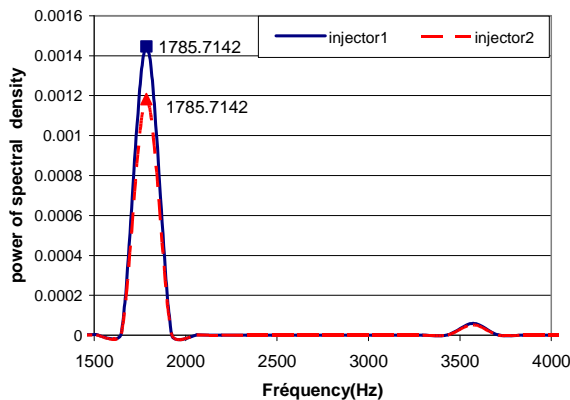
case 1: two event open

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Figure 7: Spectral power case 2: two event close
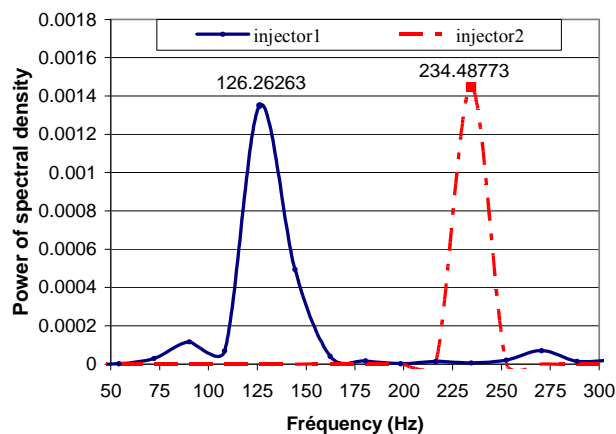
Figure 8: Spectral power of flow signal
(cas3: one event close)

	case 1	case 2	case 3	
	Inject 1&2	Inject 1&2	Inject 1	Inject 2
F (Hz)	1509	1785.71	126.26	234.48

Table 1: frequency of three case of first configuration

The frequency of second injector third case is approximately double of the first injector, table 1.

RESULTS SECOND CASE INJECTION SYSTEM

The principal objective of our study is oriented to control injection system for several applications. In this context we chose the following configuration figure 9. This geometry constituted by four injector with TESLA diode are assembled to obtain (1-3; 2-4) order control.
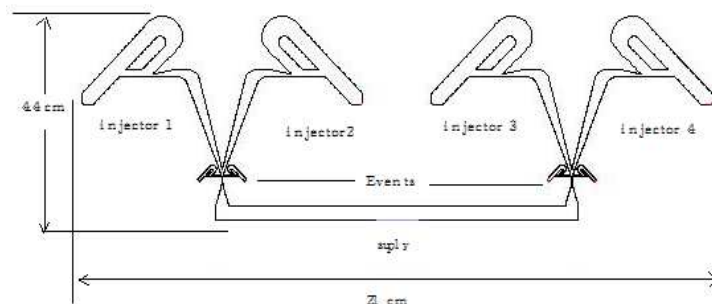

Figure 9: fluidic oscillator injection system initial configuration second case

This configuration is allowed for injection system with four injectors. The orders of injection are more important a many filed application an engineering, for examples: fuel injection, or printer injection. Buts the principal problem is reversed flow, however many solutions with moved parts are possible, In this case we propose the fluidic diode, figure 2, without feedback and needles we can obtain injection jet and reduced reversed flow.

The mass flow signal output for second case injection system is presented at below figure 10.
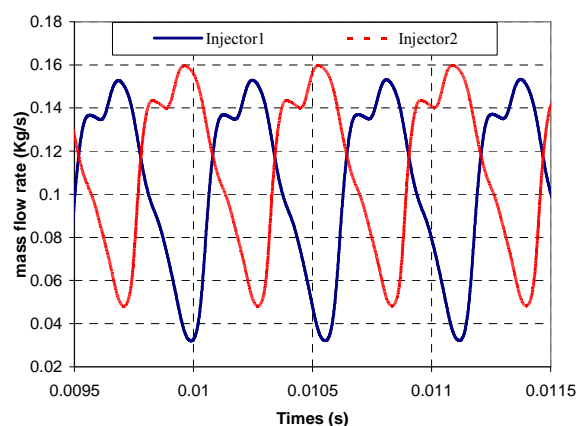

Figure 10: masse flow output injection signal

Second case injection system

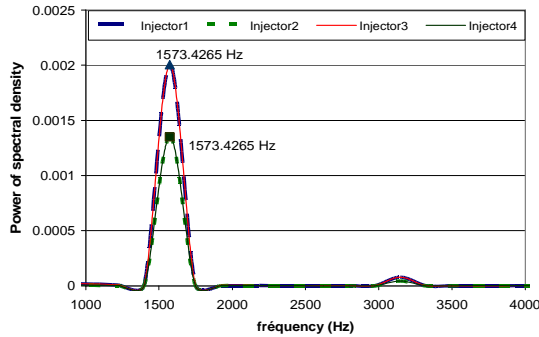The spectral form of signal output mass flow for four injector design principal frequency equal to 1.5 kHz.

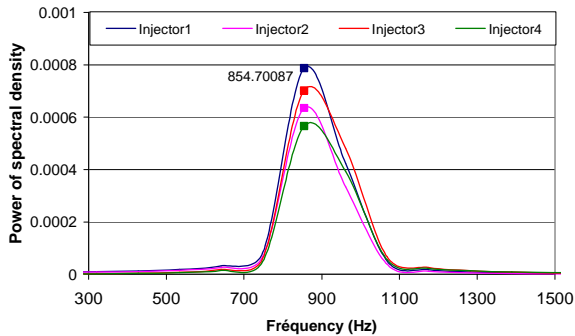Figure 11: Spectral power of flow signal

(cas1: four events open

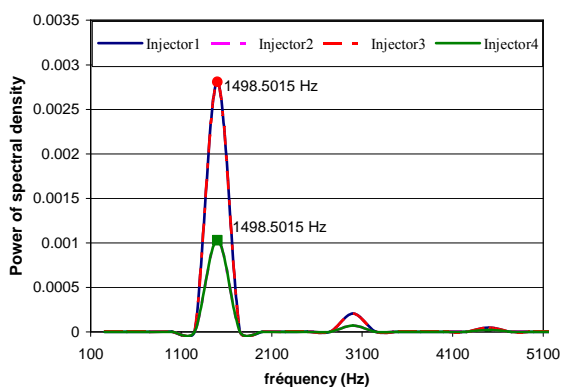Figure 12: spectral power of flow signal (cas2: four event close)

Figure 13 spectral power of flow signal (cas3: two events close)

The principal problematic in many engineering applications is residual reversed flow. Our objectives are minimizing reversed flow and control it with passive actuator
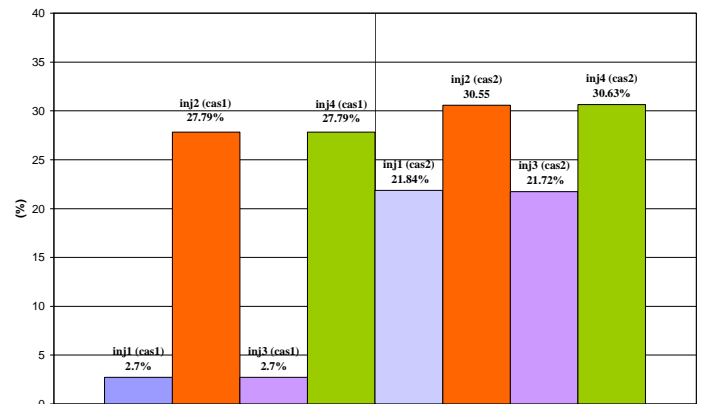

Figure 14: Masse flow rate at closed injector in % for case 1 and case 2 second configuration

CONCLUSION

In this paper, a global modeling of a micro-injection system has been purposed in order to normalize its behavior. The reversed flow exist at down pressure with oscillation frequency between 0.1 kHz and 1.8 kHz
The performance of oscillating injection system mill metric size was simulated. The first results of theses numerical calculations indicate evaluation oscillating frequency of fluidic monostable oscillator, the next one consist of oscillating controlled injection system with four injectors.

Further simulations are currently underway for studying mixing capabilities for injection system.
A numerical study that the oscillation frequency is essentially controlled by a capacitive effect and that a secondary oscillation, due to the propagation of sound waves, disturbs the pressure signal without causing the jet switching [8]

All results, presents the response of monostable oscillator injection system. The oscillations exist for bistable oscillator if the feedbacks are connected at the system figure 1. The principal cause of these phenomena is, in the nozzle control the flow disturb the principal jet, and destabilize it. In the monostable oscillator the existence of one stable position and the capacitive effect create the oscillations.
In perspectives we propose the experimental study to confirm our results and optimize the geometrical

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injection system form principally the injection orifice and the nozzle splitter size.

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