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TRAPPED VORTEX RING

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Abstract: *Paper discusses an almost unknown and yet interesting operating principle of fluidic no-moving-part devices for flow control. The principle is based on the properties of vortex rings. A standing vortex ring is kept in a semi-toroidal recession positioned opposite to an annular nozzle from which issues an annular fluid jet. The ring can exist in the recession with two alternative senses of rotation so that the annular jet is led to either the central exit through the centre of the vortex, or to the outer space past the outer vortex circumference.*

Keywords: ***Fluidics, vortex ring, fluid flow control.***

1. Introduction

Fluid flow control valves are indispensable components in innumerable systems. There are situations in which the mechanical motions bring problems or disadvantages. The solution provide no-moving-part fluidic valves with flow control by phenomena taking place inside solid, constant-geometry cavities. A branch of these valves operates in a switching regime, with bistability (or monostability) achieved by the Coanda-effect attachment of the jet to attachment walls (Perera and Syred, 1983). Another fluidic flow control principle described here is an even less known idea (Tesař and Reisenberger, 1999). It is based on the special properties of a vortex ring which is "trapped" - held stationary inside a semi-toroidal recession. The two different stable regimes differ in the sense of the rotation of the vortex ring in its cavity. The incoming flow, in the form of an annular jet directed against the vortex ring collides with it and — unable to continue in its original flow direction — is deformed and forced to divert as shown in Figs. 1 and 2. When used in a valve, there is also a control of the rotation direction of the vortex ring. The most obvious arrangement is the use of small control flows entering the semi-toroidal recession through nozzles directed tangentially to the poloidal motion.

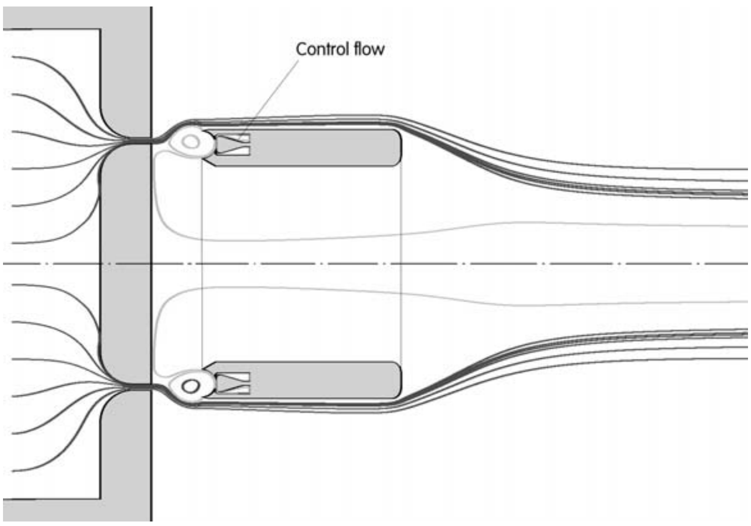

Fig. 1 Computed pathlines of the of the flow after a very small control fed into the outer control. All the flow from the annular nozzle at left continues past the outer surface of the annular body.

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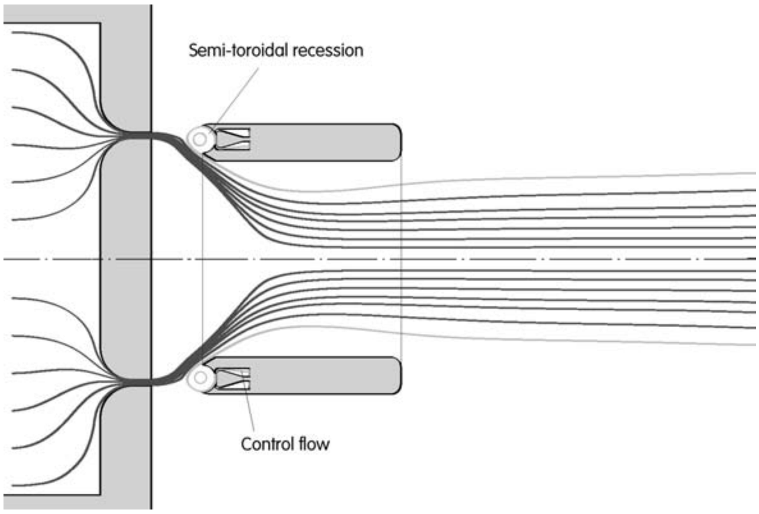

Fig. 2 Computed pathlines after a control flow into the inner nozzle. All fluid flow passes through the central hole in the annular body.

The character of the two alternative flows operating under the same boundary conditions may be demonstrated here in Figs. 1 and 2 on the results of numerical flowfield computations. Also described in the paper is demonstration of the control by suction signals. Then the paper provides several examples of the application of the idea – in particular a control of heating by the pulse width modulation of the switching and a use (in combination with radially switched Coanda-effect monostability – Tesař, 1995) in an automobile catalytic converter for aftertreatment processing of engine exhaust gas (Tesař et al., 1996). The main factor in the latter application was the spatial compactness (available space in an engine compartment of contemporary car is scarce), resistance to extremely high temperatures (the valve can operate while actually glowing hot above 700 °C), and robustness securing long-time life without maintenance.

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