Dynamic Switching of Wall-Reattachment Fluidic Device

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Synopsis

Effect of the geometrical configuration of wall-reattachment fluidic device on the switching dynamics, the switching time, and its dispersion, was investigated experimentally by using a large scale model.

The results obtained can be summarized as follows:

1) The switching time, its dispersion, and switching probability depend upon the connection of the input to the control port.

2) Effect of the vent and splitter on the jet in dynamic switching is explained commonly by using the margin of a given control flow rate to the switching control flow rate.

3) The switching time decreases as input increases, whereas its dispersion remains constant except for small input.

1. Introduction

Designing fluidics circuits by using the wall-reattachment fluidic device, it

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is important to grasp the dynamics of the device. Many investigations have been

performed on the dynamics experimentally and theoretically [1], [2], [3], [4]. Most of

them present comprehensive results on the measurement of switching time and the

theoretical analysis based on the assumption of quasi-steady process. However

few paper investigated systematically on the effects of the geometrical configura-

tion of the device on the switching time and its dispersion [5], [6]. Thus, it is

necessary to make clear these effects for designing the reliable device.

In this paper, therefore, the effects of the geometrical configuration on the

switching dynamics, especially the switching time and its dispersion are experi-

mentally made clear.

Then, it is shown that these effects can be commonly explained by using the

margin of a given control flow rate to the statical switching control flow rate.

2. Experimental Setup and Procedure

Fig.1 shows the large scale model of wall-reattachment fluidic device used for

experiments. Main nozzle width was 8 mm, and aspect ratio was 5.9. All experiments

were carried out using the air. Reynolds number of the jet was 1.36×10^4 based on

the main nozzle width as the characteristic length. The model was the symmetrical

bistable type, the offset $D/b_s = 1$ and the inclined wall angle $\alpha = 15°$. Wall length

or vent distance, and splitter distance
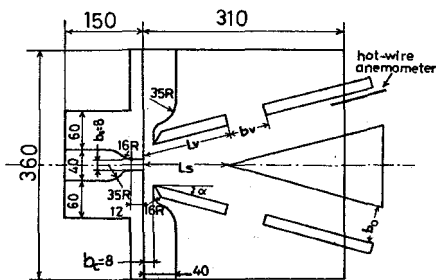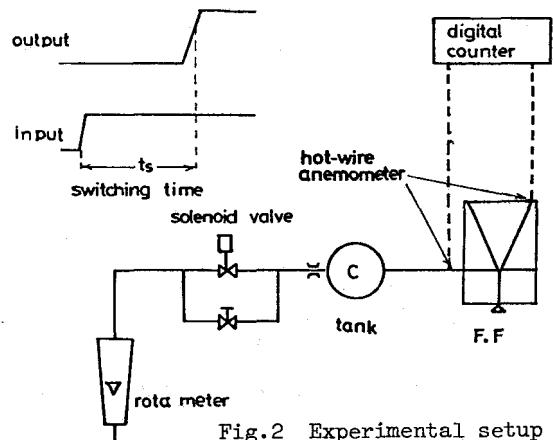
were variable.

Fig.1 Large scale model

Fig.2 Experimental setup

For simplicity, the width of the side wall vent was the same as the output duct width, and the vent distance along main nozzle axis was equal to the splitter distance.

The experimental setup is shown in Fig.2. A stepwise input was generated by the solenoid 3-way valve, and supplied to the control port through the small tank (volume = 2500 cm^3). The switching time, defined as the time required from 10 % of input velocity change to 90 % of output, was measured with the electronic digital counter, and the velocity by the hot-wire anemometer. Input pulse duration was 5 seconds, which was about 30 times the average switching time. From twenty data measured for each input, the average of switching time and its dispersion were evaluated. The dispersion was represented by the range (the difference between the maximum switching time and the minimum).

3. Results and Discussion

3.1 Input Pressure

Fig.3 (a) and (b) show the shapes and amplitudes of the input pressure and velocity in two cases; (a) the input is applied directly and (b) through the tank. The velocity changes at the control nozzle exit u_c are similar in two cases. While, the pressure chnges in the control port p_c are quite different; the pressure change in case (a) shows the large overshoot. For each input, the switching time, its histogram, and switching probability are shown in Fig.4 (a) and (b). In Fig.4 (a), the control flow rate was chosen as input magnitude. In the statical switching, it is not a serious problem which is chosen contrl flow rate or control pressure as an input magnitude. But in dynamic switching, the switching can occur
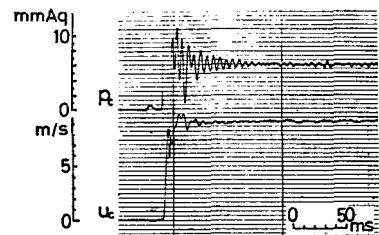
(a) without tank
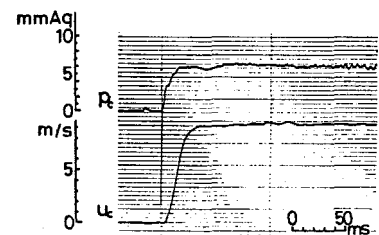
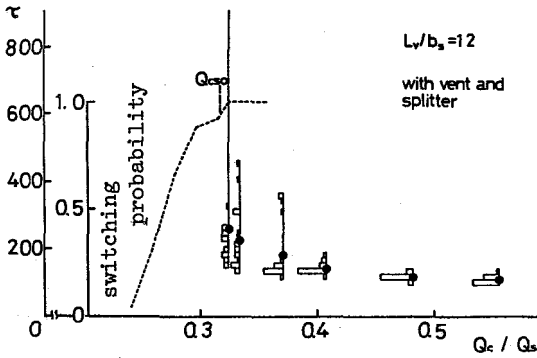(b) with tank

Fig.3 Input pressure and velocity

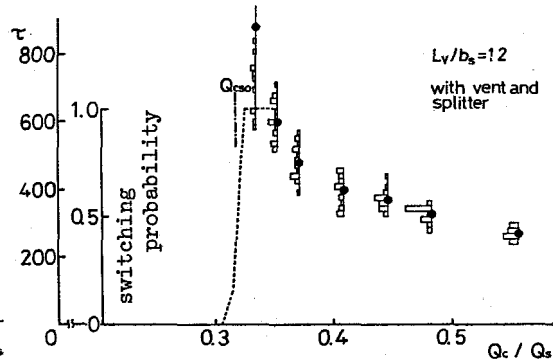Fig.4(a) Switching time vs. control
          flow rate without tank

Fig.4(b) Switching time vs. control
          flow rate with tank

even when the applied control flow rate
is less than the statical one as shown
in Fig.4 (a) when the input pressure
has large overshoot. It must be notic-
ed that the effect of the control flow
rate on the switching time is small in
compared with the no overshoot case.
This fact is explained as follows: the
actual resultant input is very large due

Fig.5 Switching probability.

to the overshoot, so the switching is not almost affected by the control flow rate.
Fig.5 shows the switching probability for the various inactive offset D_N/b_S. Thus,
when the impedance is mismatched in control port, it is difficult to estimate the
dynamic switching from the statical one. This mismatching may cause the hazard in
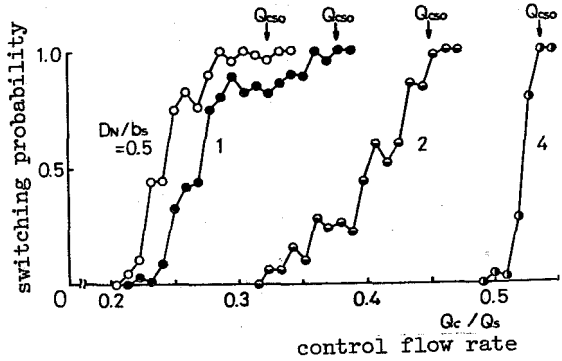the fluidics circuits.

     In following experiments such an overshoot was removed with the tank.

3.2 Effects of Initial Control Flow

     In the practical fluidic device, the control pressure in no input state is the
ambient pressure due to the control or output vents of the preceeding element. This
induces the inflow into the control port before the input is applied. In this
section, the switching dynamics in such a situation is discussed.

Fig.6 shows the switching time and its disper-
sion for some initial control flow rates. The switch-
ing time and its dispersion are not affected by the
initial control flow rate.

3.3 Effects of the Splitter

The statical switching control flow rates are
plotted for each geometrical configuration in Fig.7.
Here, the device with the splitter only was investi-
gated to make clear the effect of splitter. Fig.8
shows the relationships between the splitter distance
L_s/b_s and the switching time and its dispersion. The
switching time and its dispersion vary with the splitter distance. This is due to
the shrinkage effect [7] of the splitter in statical switching. The shrinkage effect
has been explained as follows; when the jet begins to interact the splitter, the
pressure lowering in the flow passage formed by the splitter and the side wall makes
the pressure in reattaching bubble decrease and the reattachment point of the jet
moves upstream in compared with the case where the splitter is faraway. That is,
the bubble shrinks. But when the splitter is located extremely upstream, such a
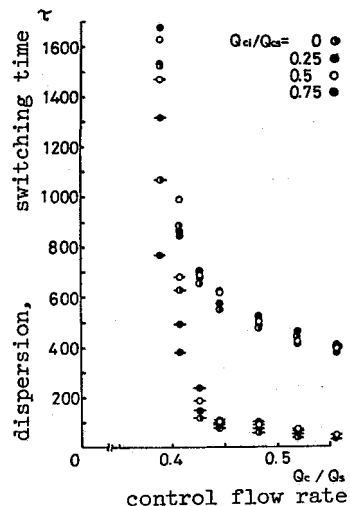shrinkage has a limit because the jet flows separately.

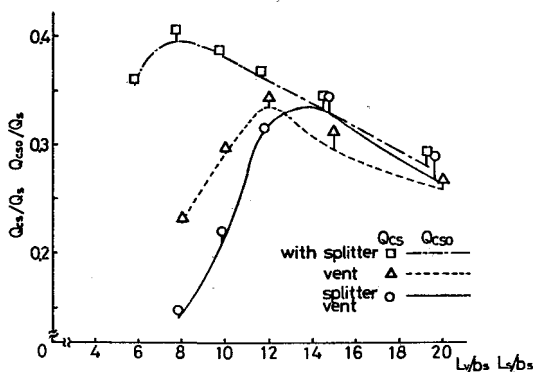Fig.6 Effect of initial
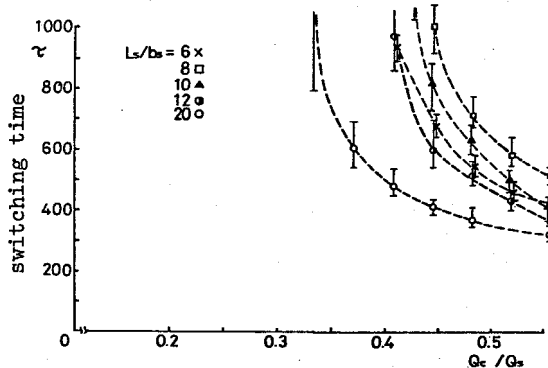control flow rate

Fig.7 Switching control flow rate

Fig.8 Effect of splitter

3.4 Effects of the Side Wall Vents

In order to make clear the effects of the side wall vents, the experimental model with the vents only is dealt with. Fig.9 shows the switching time and its dispersion for various vent distance L_V/b_S. This figure shows that the shrinkage effect of the wall end [7] appears in dynamic switching as well as in statical one. This effect has been explained as follows: when a part of the jet flows out of the vent, the pressure in the reattch-ing bubble lowers and consequently the radius of jet curvature decreases. Fig.7 shows the relationship between the statical switching control flow rate Q_{cso}/Q_S and the vent distance L_V/b_S.

Fig.9 Effect of vents

3.5 Effects of the Splitter and Vents

Fig.10 shows the switching dynamics for various geometrical configurations with the splitter and vents.

The statical switching control flow rate for each configuration is shown in Fig.7. The interaction between the splitter and vents has been explained as follows: if the splitter is located near the vent, the pressure drop in output duct is not remarkable. This means that the shrinkage effect of the splitter will be reduced by the presence of the vent. On the other hand, for small L_V/b_S and large vent width, the splitter effect is strongly reduced, the vent effect becomes dominant. Fig.10 shows that such a interaction exists also in the dynamic switching.
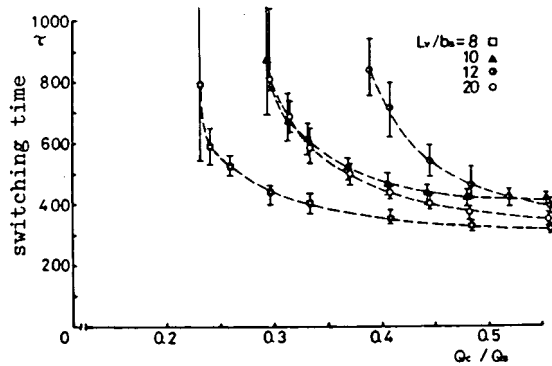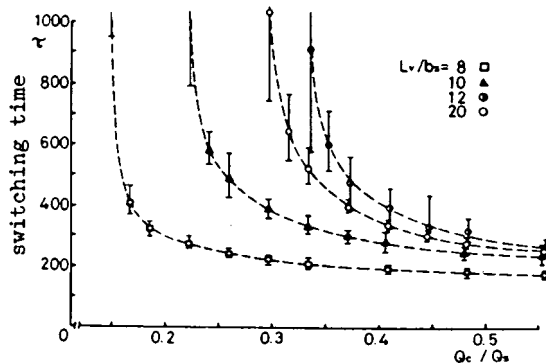

Fig.10 Effect of splitter and vent

3.6 Relationships between Switching Time, Its Dispersion and Geometrical
    Configurations

In this experiment the input pulse duration was less than that of statical

switching, so the minimum control flow rate that made switching probability 100 %

was greater than the statical switching control flow rate Q_{cso}. Hence, the minimum

control flow rate that makes switching probability 90 % is evaluated as switching

control flow rate Q_{cs}, considering experimental error. Fig.7 shows Q_{cs} and Q_{cso} for

various geometrical configurations. As shown in this figure, the switching control

flow rate depends upon the geometrical configurations.

In oder to estimate the switching dynamics on the common basis, the control

flow rate in excess of Q_{cs} was introduced. Fig.11 (a), (b) and (c) show the switch-

ing time by using the excess control flow rate, rearranged from Fig.8, 9, and 10,

respectively. The dispersion of the switching time is normalized by the average

switching time. These show that there is no significant difference among the geo-

metrical configurations. In particular, Fig.11 (a), showing the splitter effects,

shows such a tendency remarkably. In all cases, the dispersion decreases as the

control flow rate increases, but remains about 15 % of the average switching time

for Qc/Qcs > 1.2.

In Fig.11 (c), for Lv/bs = 12, the dispersion is remarkable as compared with
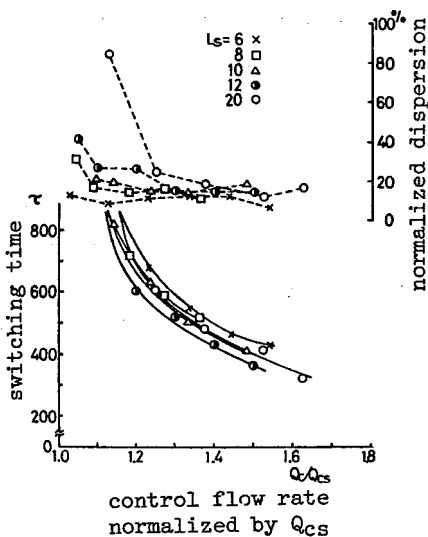

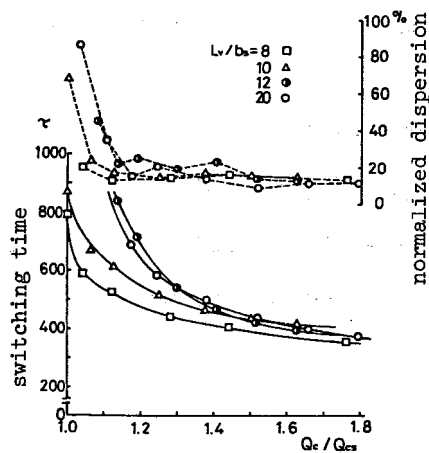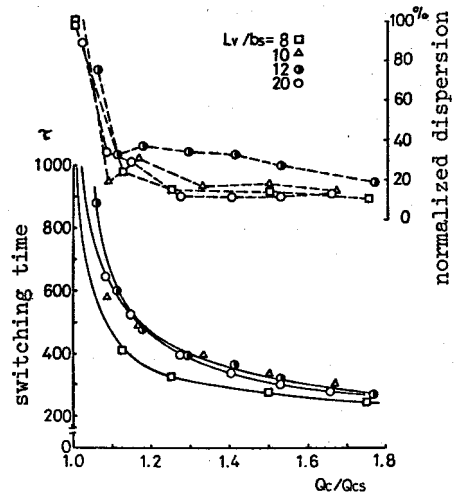Fig.11(a) Effect of splitter

Fig.11(b) Effect of vent

other cases. This is considered to be

due to the wall end effect mentioned in

section 3.5.

Fig.11(c) Effect of splitter
and vent

4. Conclusion

Effects of the geometrical configuration of the wall-reattachment fluidic
device on the switching time and its dispersion were investigated experimentally.
The results are summarized as follows:

(1) The switching time, its dispersion, and switching probability depend upon the
connecting situation of input duct to the control port (impedance matching).
The mismatched impedance may cause the hazard in the fluidics circuits.

(2) Effect of the vent and splitter on the jet in dynamic switching is similar to
that of statical one. Comparing some geometrical configurations in the switch-
ing time and its dispersion, there is no significant difference among them.

(3) The switching time decreases as the control flow rate increases, whereas the
dispersion remains constant for $Q_c/Q_{cs} > 1.2$.

Acknowledgement

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Turbulent Reattachment Amplifier, Proc. 2nd Cranfield Conference, A1 (1967)

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