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A SETUP FOR GAS MASS FLOW RATE MEASUREMENT IN T - SHAPED MICRO CHANNEL

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Abstract

A setup for mass flow rate measurement was developed for gas flow in T-shaped microchannels. Experiments with N_2 were made on the test bench for the following purposes: 1) to test leakages and outgassing of the system, 2) to study the symmetric property of two side channel inlets of the T mixer.

1 Introduction

Gas mixing is a basic problem for the design of propulsion devices in Power-MEMS and in a variety of these devices, the inside mixing process determines the efficiency of the whole system [1]. Mixing is an important unit operation in a micro scale device and especially micromixers are highly beneficial for certain chemical reactions and analyses. A T - shaped channel is a passive mixer and mixing entirely depends on molecular diffusion [2].

Some T - shaped microchannels will be used for gas mixing study in future and a setup was first developed for gas mass flow rate measurement. Tests in pure gases were first carried out to check the system leakage, outgassing rates and the geometric influence by symmetric property of T channel and its ancillaries.

2 Experimental setup

A novel setup for gas micro mass flow rate measurement in simple channel was introduced in literatures [3, 4]. Based on this former work, the mass flow rate measurement in T-shaped microchannel was developed. The principle of this measurement is called CV method. The experiments are carried out at room temperature T= 21.6±0.5°C. The setup is schematized in Figure 1. The T - shaped microchannel is connected to three tanks, TA, TB and TC. TA and TB are connected to the inlets of microsystem separately via the valves V2A and V2B. The tank TC is connected to the outlet via the valve V2C. Before starting experiments, the whole system is vacuumed and the pressure is measured by three Capacitance Diaphragm Gauges CGA, CGB and CGC. Then the micro channel is isolated by closing V2A, V2B and V2C. V1C keeps closed to maintain vacuum in TC. TA and TB are filled by two gases via V1A and V1B, when the desired pressure is achieved, V1A and V1B are closed. During the experiments, V2C is opened first, and then V2A and V2B are opened simultaneously. The pressure drop in TA and TB and the pressure increase in TC are monitored by CGA, CGB and CBC, and recorded by a personal computer.

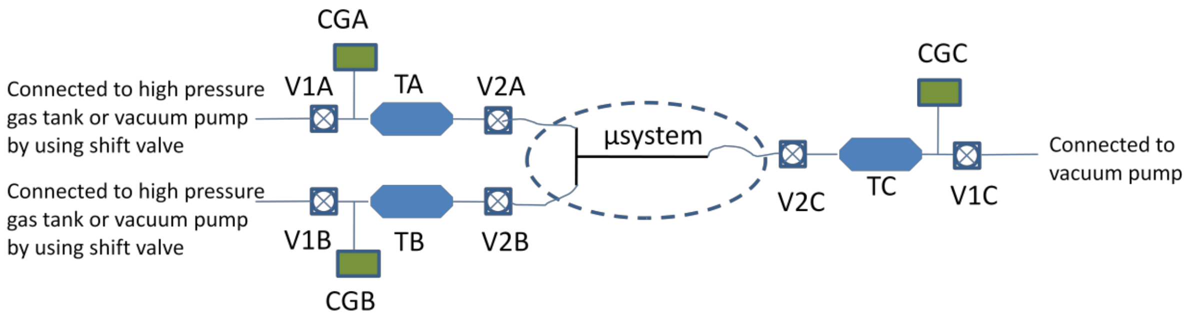

Figure1: Schema of test bench for gas mass flow rate measurement in T channel

The constant method is used for TA, TB and TC, the mass flow rate can be calculated by

$$\frac{dM}{dt} = \frac{d}{dt}\left(\frac{PV}{RT}\right) \tag{1}$$

where M, V, P, R, T and t are, respectively, the mass of the gas in the tank, the volume of the tank, the gas pressure in the tank, the specific gas constant, the temperature and the time. The volume V is constant for a tank and the temperature T is constant. So the Equation (1) can be expressed as:

$$\dot{M} = \frac{dM}{dt} = \frac{V}{RT}\frac{dP}{dt} \tag{2}$$

where $\dot{M}$ is gas mass flow rate, the term $\frac{dP}{dt}$ can be calculated from experimental data.

3 Tests with pure gas

N_2 and CO_2 are selected for mixing study in future. And firstly N_2 is used for mass flow rate measurement tests on pure gas. The rectangular microchannel used in this study was designed and manufactured in previous work [5]. The side length of the main channel's square section is 500 µm.

3.1 Outgassing

When operating at low pressure, outgassing should be taken into consideration for mass flow rate measurement. Because in this experiment, pressure in TA, TB and TC keep changing continuously, it is better to study outgassing in the desired pressure range. By using the method described in Pitakarnnop's work [6], the outgassing in TA, TB and TC are measured and the results are shown in Figure 2.

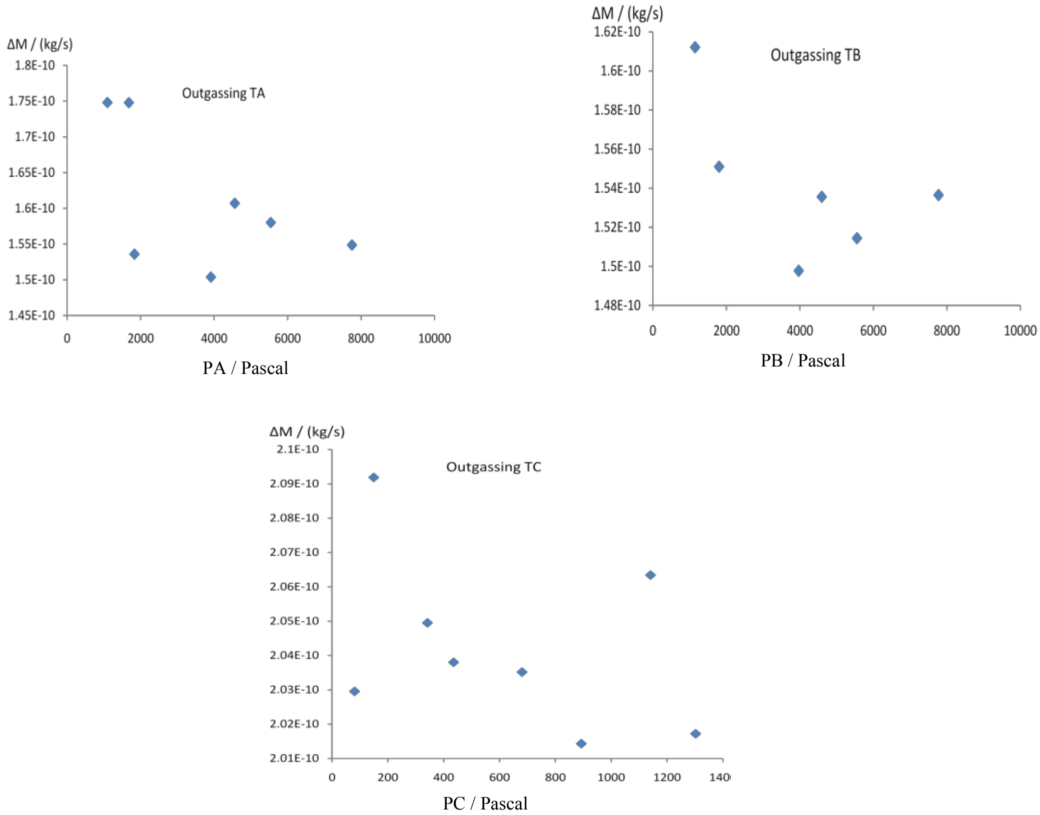

Figure 2: Outgassing tests in TA, TB and TC

The pressure verifies from 1000 to 8000 Pascal for outgassing tests in TA and TB, and it varies from 0 to 1400 Pascal for tests in TC. The outgassing has only a magnitude of 1 x 10^{-10} kg/s and it does not vary much with pressure in desired pressure range. To simplify the calculation, an average value of outgassing can be used for outgassing correction. From the results of initial mass flow rate measurements, the mass flow rate in the microchannel has a magnitude of 10^{-8} and it can be very well corrected by these outgassing values determined in this study.

3.2 **Leakage tests and geometric influence**

In Figure 3, at the beginning of tests, the pressure in TA and TB were practically the same, but after opening the valves, a sudden pressure drop appears in TA and TB. Because the tubes used for connecting V2A (or V2B) and the inlet of the T channel has a large diameter compared to microsystem, this connection part is named CA (or CB), the gas from TA (or TB) first fills CA (or CB) quickly before starting filling the microchannel, which forms the sharp pressure drop. Because the volume of CA is bigger than that of CB, the sharp pressure drop in TA is larger than that in TB. For the same reason, the gas coming near T outlet has to fill first the connection part CC between V2C and T outlet, so the pressure increase has a delay compared to pressure drop in TA and TB.

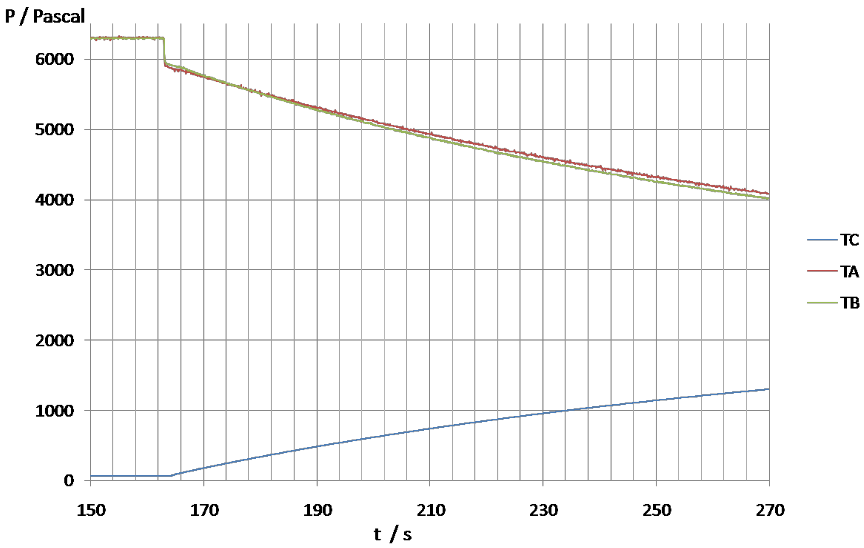

Figure 3: Pressure variation in TA, TB and TC during N_2 mass flow rate measurement

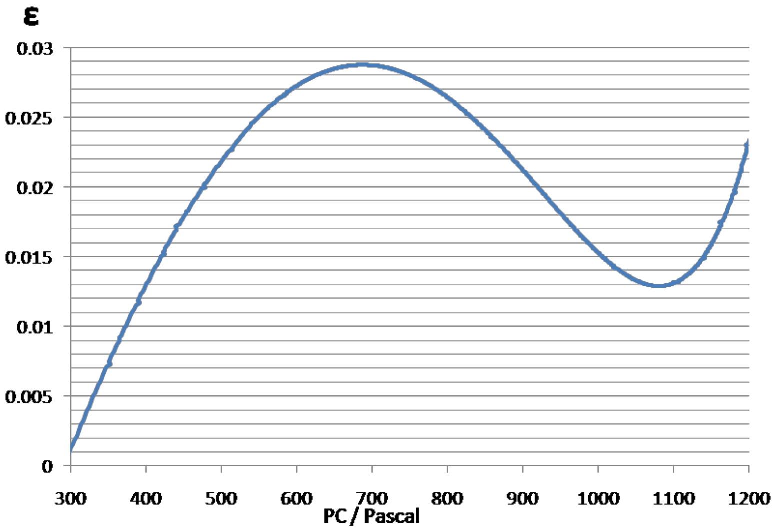

Figure 4: Leakage test of the system

If the mass flow rate calculated from TA and TB matches that calculated from TC, the leakage of this system should be negligible. The error ε is defined by expression (3). Figure 4 shows when the pressure in TC is between 300 and 1200 Pa, the maximal value of ε is 3%, which is still acceptable for the study.

$$\varepsilon = \frac{\dot{M}A + \dot{M}B - \dot{M}C}{\dot{M}A + \dot{M}B} \qquad (3)$$

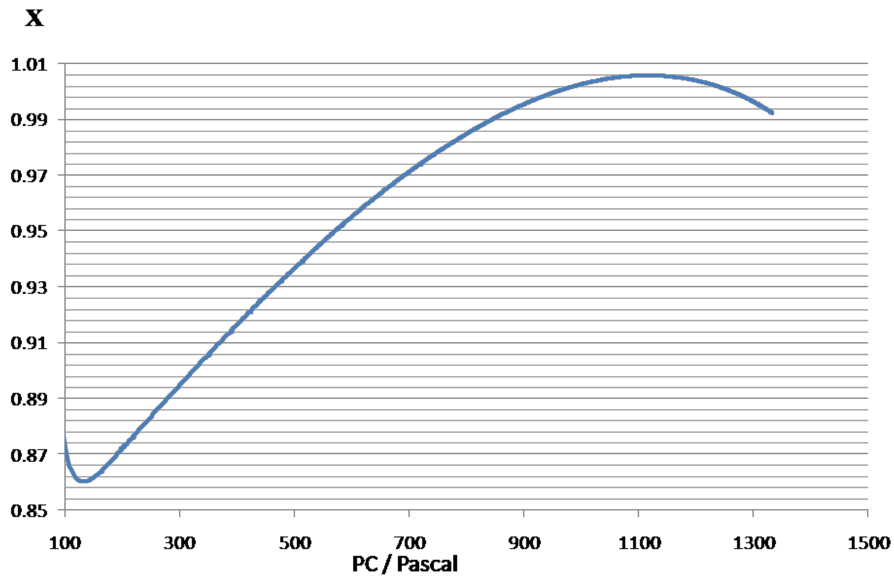

Figure 5: Ratio of mass flow rate measurement in TA and TB

If the T channel and its accessory connection are perfectly symmetric, the mass flow rate from TA and TB should be equal. In Figure 5, X is the ratio of mass flow rate from TA and TB, defined by expression (4)

$$X = \frac{\dot{M}A}{\dot{M}B} \tag{4}$$

The initial pressure in TA and TB were equal, but after the sharp pressure drop at the beginning of curves (figure 5), the pressure in TA then became smaller than that in PB. That is why the mass flow rate in TA is always smaller than that in TB, X < 1. Figure 5 shows when the pressure is between 300 and 1200, X is between 0.89 and 1.

Conclusion

The leakage in the system is not important. Geometric properties have influence in mass flow rate measurement. If accurate initial pressure is needed, the volume of connection between V2A (or V2B) and T inlet should be carefully modified so that the sharp pressure drop at the beginning of experiments can be avoided.

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