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A COMPARISON OF MASS FLOW RATE EXPERIMENTAL DATA OBTAINED USING TWO DIFFERENT EXPERIMENTAL SETUPS BY MEANS OF THE DYNAMIC CONSTANT VOLUME TECHNIQUE

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KEY WORDS

Microchannel, mass flow rate, tangential momentum accommodation coefficient

ABSTRACT

Different techniques have been used to measure the mass flow rate of gases through microchannels, including the liquid drop [1], the constant pressure [2] and the constant volume [1] methods. Recently, Rojas-Cárdenas *et al*. [3] developed a dynamic version of the so-called constant volume technique for isothermal gas flows, which was originally employed for temperature-driven flows [4]. By the employment of these techniques, numerous works were published in literature providing experimental data of tangential momentum accommodation coefficient (TMAC) for noble gases and simple gases [5], especially nitrogen. However, there is a large variability in the results obtained for each gas. The intention of this work is to compare experimental mass flow rate data for nitrogen through a single stainless steel microtube (L = 92.22±0.01 mm, D = 435.5±3.5 μm) obtained using an extension of the dynamic constant volume method proposed by Silva [6] in two different experimental setups. The first setup has been developed at the Federal University of Santa Catarina (UFSC), Florianopolis, Brazil, whereas the second is located at the Institut Clément Ader (ICA), Toulouse, France.

Both experimental setups can be described as two rigid reservoirs, R1 and R2, with volumes V_1 and V_2, respectively, connected by a microtube (Figure 1). Each reservoir contains a pressure transducer (PT1 or PT2) and a temperature transducer (TT1 or TT2). The amount of gas in each reservoir is adjusted by manually operated valves A and B, which are connected to a tank of gas at high pressure and a vacuum pump, respectively. The entire test section, between valves A and B, is thermally insulated in order to avoid temperature oscillations during the experiments. Each experiment is initiated with valves A and B closed and with $P_1 > P_2$. Therefore, a flow of gas is induced from R1 to R2 from the moment the valves are closed until the thermodynamic equilibrium condition is reached, that is $P_1 = P_2$.

The main advantage of the dynamic constant volume method is that the pressure variations in the reservoirs along time in each experiment are fitted using a single function given by

$$P_i = \frac{\Psi_{A,i} e^{\Psi_{B,i} t}}{1 + \Psi_{C,i} e^{\Psi_{B,i} t}} + \Psi_{D,i}, i = 1,2, \qquad (1)$$

where $\Psi_{A,i}$, $\Psi_{B,i}$, $\Psi_{C,i}$ and $\Psi_{D,i}$ are the fitting coefficients. Therefore, the mass flow rate through the microtube along time can be determined directly from the fitting coefficients as the continuous function

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$$\dot{m} = \left| \frac{V_i}{RT} \frac{\left(P_i - \Psi_{D,i}\right)\Psi_{B,i}}{1 + \Psi_{C,i} e^{\Psi_{B,i} t}} \right|, i = 1,2 . \tag{2}$$

In order to guarantee the isothermal condition, $\varepsilon_i = (dT/T)/(dP_i/P_i)$ must be small. In this work the isothermal condition was assumed whenever $\varepsilon_i < 1\%$, taking into account a 1% uncertainty in the mass flow rate measurements.

The results of reduced mass flow rate, G ($= 8L\sqrt{2RT}\,\dot{m} / \pi D^3 \Delta P$), are shown for different values of the rarefaction parameter, δ_m ($= DP / \mu\sqrt{2RT}$), in Figure 2. The variables R, T and μ represent the specific gas constant, temperature and viscosity, respectively, while $\Delta P = P_1 - P_2$. Each point was obtained from one experiment in the moment when $P_1/P_2 = 2$. The experimental data obtained at UFSC and ICA are in close agreement, with the differences within the uncertainty range, proving that the methodology is independent of the experimental setup used. Therefore, one can argue that the variability in the results found in literature could also come from factors associated to the non-uniform treatment of the experimental data. Moreover, the comparison of the experimental data with theoretical results obtained by Porodnov *et al*. [7] shows that the experimental results agree very well with the BGK model when a completely diffuse accommodation is considered.

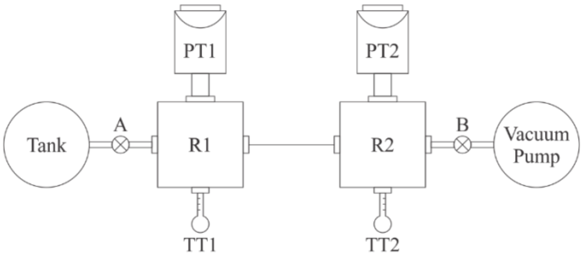

Figure 1: Schematic representation of the experimental setups.

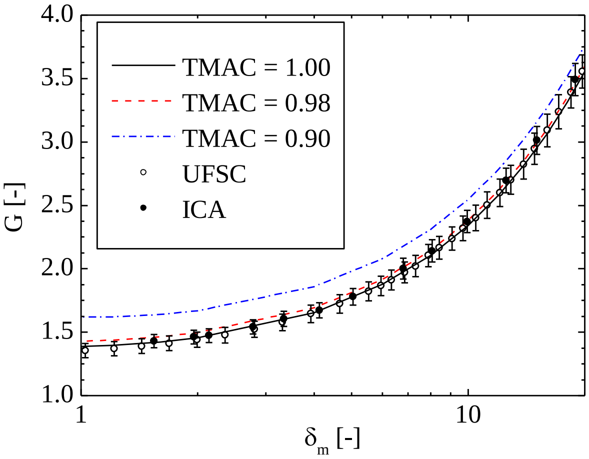

Figure 2: Comparison of reduced mass flow rates using two different experimental setups.

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