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Average Friction Factors of choked gas flow in Microtubes

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Abstract

There A micro-tube passage is a basic and important element in the design of micro heat exchangers and for this reason during the last decade a series of investigations have been made with the aim to clarify the main scaling effects playing an important role in microtubes. In this paper, a combined analysis of numerically and experimentally obtained average friction factors in microtubes under the situation of under-expanded (choked) gas flow is presented. The working fluid (nitrogen) passes through the microtube and discharges into the atmosphere under an increasing inlet pressure. Experiments and numerical computations are performed for microtubes with 249 and 528.9 μm in diameter, by varying the aspect ratio (i.e. length/diameter) from 100 to 200. The numerical methodology to solve the governing equations is based on the Arbitrary-Lagrangian-Eulerian (ALE) method. In order to capture the under-expansion characteristics of the flow during choking, the computational domain is extended in the downstream region beyond the microtube outlet. Both experimental and numerical results were obtained for a wide range of Mach number and Reynolds number. In the previous study, it was demonstrated how the outlet Mach number can be expressed as a function of the tube diameter under choked conditions. In this paper, a data reduction procedure for the estimation of the average friction factor between the inlet and the outlet of the microtube is proposed for choked flows in which the outlet gas temperature and pressure are obtained by using the outlet Mach number calculated numerically as a function of the microtube diameter. It is demonstrated how this data reduction method allows an accurate calculation of the average friction factors in microtubes by using a limited number of parameters which are easy to measure. The results obtained in this way are in good agreement with the numerical predictions as well as with the most common empirical correlations.

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