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Experimental investigation of pressure drop and friction factor for water flow in microtubes

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A B S T R A C T

The pressure drop and friction factor for the flow distilled water in microtubes with the diameters ranging from 0.20 mm to 0.589 mm were investigated experimentally. The experiments were carried out in the Reynolds number range of approximately 100–10000 and the length-to-diameter ratios (L/d) in the range of 16–265. It was observed that two different mechanisms of transition from laminar to turbulent flow occurred as smooth and abrupt. The pressure drop and friction factor values agreed with the values of classical channel flow theory. The L/d ratio had an important effect on the apparent friction factor in case of $L/d < 100$. It was found that the critical Reynolds number for the transition was between 2000 and 2500.

1. Introduction

With development of the microsystem technology, the investigation of the flow phenomena in microtube and channels has been one of the most important subjects. There are several studies, experimental or theoretical, on the heat transfer and the pressure drop for laminar and turbulent liquid or gas flow in microchannels. The reviews of these studies are given by several researchers [1–5]. The effects of the surface roughness, geometry of channel, type of fluid (gas or liquid, single or two phase), flow rate, surface fluid interaction, have been the major parameters, which were considered in the studies on the fluid flow in the microchannel. In general, the experimental data have been compared with the conventional theories, and in many cases contradictory results have been reported. The first diversity between studies is that the fact that there are three different results of the friction factor values; that is, the results smaller than, higher than and similar to the friction factor values predicted by classical theory. These results have been reviewed by several researchers [1–4,6]. The second is related to the critical value of Reynolds number at which the flow regime changes from laminar-to-turbulent. For the transition from the laminar to turbulent flow, different Reynolds numbers have been reported for very similar conditions. It was also reported very early transition Reynolds numbers such as, in the range of 200–700 for water flowing through rectangular channels having hydraulic diameters of 0.133–0.367 mm [7], and of 300–900 for water flowing in microtubes with the diameters ranging from 0.050 to 0.245 mm [8], and 240 for water flowing through a rectangular channel with the hydraulic diameter of 0.146 mm [9].

Vijayalakshmi et al. [10] investigated the effect of compressibility, and the transition to turbulence flow through microchannels of hydraulic diameter ranging from 0.0605 mm to 0.211 mm, employing nitrogen as the working fluid. They reported that the transition to turbulent occurred in the Reynolds number range of 1600–2300. They claimed that the slight decrease in the transition range may be due to the relative roughness or the edge effects of the trapezoidal channel geometry. Morini et al. [11] studied the laminar to turbulent transition in the fused silica and stainless steel microtubes having the diameters ranging from 0.125 to 0.180 mm, using nitrogen as working fluid. They reported that the transitional regime started at the Reynolds numbers around 1800–2000, and the surface roughness had no effect on the hydraulic resistance in the laminar region for a relative roughness lower than 4.4%, taking compressibility into account. Lorenzini et al. [12] investigated the flow of nitrogen inside circular microchannels having the diameters ranging from 26 μm to 508 μm with different surface roughness values and L/d ratios in the range of 591–1689.

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