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# A comparison of flow characteristics of refrigerants flowing through adiabatic straight and helical capillary tubes ☆

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ABSTRACT

This paper presents a numerical investigation of the flow characteristics of helical capillary tubes compared with straight capillary tubes. The homogenous two-phase flow model developed is based on the conservation of mass, energy, and momentum of the fluids in the capillary tube. This model is validated by comparing it with the experimental data of both straight and helical capillary tubes. Comparisons of the predicted results between the straight and helical capillary tubes are presented, together with the experimental results for straight capillary tubes obtained by previous researchers. The results show that the refrigerant flowing through the straight capillary tube provides a slightly lower pressure drop than that in the helical capillary tube, which resulted in a total tube length that was longer by about 20%. In addition, for the same tube length, the mass flow rate in the helical capillary tube with a coil diameter of 40 mm is 9% less than that in the straight tube. Finally, the results obtained from the present model show reasonable agreement with the experimental data of helical capillary tubes and can also be applied to predict the flow characteristics of straight capillary tubes by changing to straight tube friction factors, for which Churchill's equation was used in the present study.



## 1. Introduction

A capillary tube is commonly used as an expansion device in small refrigeration systems with cooling capacities below 10 kW because it has the lowest cost and a low starting torque and requires no maintenance. It is the simplest means of flow control of refrigerant from the condenser to the evaporator and also maintains the required operating pressure differential between the two units. Nominal size of the capillary tube is ranging between 0.5–2.0 mm in diameter and 1–6 m in length. In the past decades, the design and analysis of capillary tubes have been studied both numerically and experimentally, mostly for straight capillary tubes [1–20]. However, in practical applications, domestic refrigerator systems use a helical capillary tube in order to construct a compact unit. The works reviewed that use helical coils are summarized as follows:

Ali [21] proposed the pressure drop correlations for helical coil tube which were developed in terms of the flow rate ($V$), the tube geometry ($d_i$, $D_c$, $p$ and $L$) and fluid properties ($\rho$ and $\mu$). It should be noted that in most of the previous works, the relevant correlations were developed in terms of Reynolds number (Re), curvature ratio ($d_i/D_c$), Dean number ($De$), Helical number ($He$) and Euler number (Eu) and the obtained geometrical group.

Kim et al. [22] presented experimental results of mass flow rate and proposed a correlation based on the Buckingham-π-theorem for predicting the mass flow rate of R-22, R-407 °C, and R-410A. Their results indicated that the mass flow rates of R-407 °C and R-410A were higher than those of R-22 about 4.0% and 23%, respectively. In addition, the mass flow rates of the coiled capillary tubes are quite lower than those of straight capillary tubes, especially at smaller coiled diameter. For example, mass flow rates for 40 mm coiled diameter are lower than the straight capillary tubes approximately 9.0%.

In 2006, Zhou and Zhang [23] studied the performance of coiled adiabatic capillary tubes both theoretically and experimentally. The results were used for comparison with straight capillary data, and showed that the mass flow rate of the refrigerant increased significantly with increases in the coil diameter. However, little change was observed for the coil diameter larger than 300 mm. Valladares [24] presented numerical simulation based on finite volume formulation for describing the flow characteristics of coiled adiabatic capillary tubes. The numerical model was considered for various aspects such as geometry, type of fluid (pure substances and mixtures), critical or non-critical flow conditions, metastable region, and transient behaviour. The prediction showed an agreement of 97.7% of 211 data points evaluated within an error of ±10%. Park et al. [25] studied the flow characteristics of coiled capillary tubes for R-22 and developed mass flow rate correlation for coiled capillary tubes. At the same operating condition, they found that the mass flow rates of

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