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Choked flow mechanism of HFC-134a flowing through short-tube orifices

Kitti Nilpueng, Somchai Wongwises *

Fluid Mechanics, Thermal Engineering and Multiphase Flow Research Lab (FUTURE), Department of Mechanical Engineering, King Mongkut's University of Technology Thonburi, Bangmod, Bangkok 10140, Thailand

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This paper is a continuation of the author's previous work. New experimental data on the occurrence of choked flow phenomenon and mass flow rate of HFC-134a inside short-tube orifices under choked flow condition are presented. Short-tube orifices diameters ranging from 0.406 mm to 0.686 mm with lengths ranging from 1 mm to 3 mm which can be applied to a miniature vapour-compression refrigeration system are examined. The experimental results indicated that the occurrence of choked flow phenomena inside short-tube orifices is different from that obtained from short-tube orifice diameters of greater than 1 mm, which are typically used in air-conditioner. The beginning of choked flow is dependent on the downstream pressure, degree of subcooling, and length-to-diameter ratio. Under choked flow condition, the mass flow rate is greatly varied with the short-tube orifice dimension, but it is slightly affected by the operating conditions. A correlation of mass flow rate through short-tube orifices is proposed in terms of the dimensionless parameters. The predicted results show good agreement with experimental data with a mean deviation of 4.69%.

1. Introduction

During the past decade, two-phase gas–liquid flows through small channels have been encountered in a wide variety of applications including medical devices, high heat-flux compact heat exchangers, and cooling systems for various types of equipment, such as high performance micro-electronics, supercomputers, and high-power lasers. For two-phase flow inside small channels, it found that the flow characteristics strongly depend on surface tension in addition to viscosity and inertia forces. As a result, the flow behaviour inside channels is different from that in channels of ordinary size [1]. In order to achieve optimum design and process control of small systems, a comprehensive understanding of flow and heat transfer characteristics inside small channels is very necessary.

An expansion device is an important component in the basic elements of a refrigeration system. The purpose of the expansion device is to reduce the pressure of the refrigerant from the condenser pressure to the evaporator pressure and to regulate the mass flow rate of refrigerant flowing from the condenser to the evaporator. During the flow of liquid refrigerant through the expansion device, pressure is rapidly decreased below the saturation pressure and the refrigerant is changed from subcooled liquid or saturated liquid to liquid–vapour mixture. This phase-change mechanism is described as a flashing process. The short-tube orifice is one type of expansion device popularly used in residential and automotive air-conditioning systems. Its simplicity, low initial cost, high reliability, and ease of maintenance are the main reasons for its use. Normally, the diameters of short-tube orifices which is utilized the normal air-conditioner are larger than or close to 1 mm. However, in the recent years, a miniature vapour-compression refrigeration system has been developed and applied for the cooling of high power components in computers and several electronic devices such as power supplies, microprocessors, integrated circuits, and microcontrollers [2,3]. Some of these miniature systems will employ the smaller diameter short-tube orifices being studied and reported herein. In order to obtain appropriate operation and performance of systems, the flow of refrigerant inside the short-tube orifice should be choked flow [4]. Under this condition, the flow of refrigerant through the short-tube orifice corresponds to the critical flow rate, which is the maximum flow rate that can be attained by reducing the downstream pressure under given upstream conditions. Therefore, the comprehensive knowledge of the appearance of choked flow phenomena and the critical flow rate that can be produced at a given operating conditions is useful for designing of the miniature refrigeration system.

In the past, studies associated with performance characteristics of short-tube orifices have been conducted by a number of researchers. Early experimental investigations on flashing flow inside short-tube orifices focused exclusively on CFC-12 and HCFC-22 [4–8]. Pasqua [5] examined the flow characteristics of subcooled and saturated liquid CFC-12 through glass short-tube

* Corresponding author. Tel.: +66 2 470 9115; fax: +66 2 470 9111.
E-mail address: somchai.won@kmutt.ac.th (S. Wongwises).

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