Experimental Thermal and Fluid Science 81 (2017) 370–381

Contents lists available at ScienceDirect

Experimental Thermal and Fluid Science

journal homepage: www.elsevier.com/locate/etfs

Flow of refrigerants through capillary tubes: A state-of-the-art

Santhosh Kumar Dubba *, Ravi Kumar

Department of Mechanical and Industrial Engineering, Indian Institute of Technology, Roorkee, Uttarakhand 247667, India

ARTICLE INFO

Article history:
Received 26 June 2016
Received in revised form 10 September 2016
Accepted 18 September 2016
Available online 19 September 2016

Keywords:
Adiabatic
Diabatic
Capillary tube
Refrigerant

ABSTRACT

A review of the research carried out during past decade on flow of different refrigerants through adiabatic and diabatic capillary tubes of different geometries viz. straight and coiled has been discussed in this paper. The paper outlines the effective techniques revealed in literature to improve the overall performance of a capillary tube based refrigeration system. The studies on the flow of HCFC/HFC/CFC refrigerants, their mixtures and natural refrigerants inside capillary tubes has been discussed. The data for the flow of natural refrigerants inside a capillary tube are limited. Amongst all the natural refrigerants, most of the work has been carried out on R-744 during last 10 year literature. The transcritical R-744 cycle is effective with capillary tube in case of small scale heat pump or a refrigeration system.

1. Introduction

The capillary tube is an expansion device in a refrigeration system. It is the best suitable for a system with less than 3 Tons of refrigeration capacity viz. domestic refrigerators and window air-conditioners. The usual dimensions of a typical capillary tube are 0.5–2.0 mm internal diameter and 1.0–6.0 m length. Any generalized method is not available to decide the dimension of a capillary tube for a particular system. However, a few correlations with limited applicability are available [40,57]. The capillary tube has certain benefits viz. easy availability, low price and low initial torque of compressor. The capillary tube in a refrigeration system allows equalization of pressure across the capillary tube during off cycle, which results a low initial torque. Year-wise trend of the research carried out on the flow of refrigerants through different types of capillary tubes has been shown in Fig. 1. As can be inferred from Fig. 1, the investigations on flow characteristics of diabatic-coiled capillary tubes are in scarcity. This paper also reviews the numerical models developed for adiabatic and diabatic capillary tubes, while discussing the effect of coil diameter and pitch on flow characteristics in case of coiled capillary tubes.

A pi diagram is shown in Fig. 2 for the investigations on different refrigerants. Fig. 2(a) is plotted based on the data obtained from Khan et al. [34,35] review. The natural refrigerants have a meager 7% share of the entire research on the flow through a capillary tube. The research data for the last 10 years are shown in Fig. 2(b). It is interesting to note that the natural refrigerants occupied nearly 40% of research done on flow of refrigerants through capillary tube during 2006–2016. After publication of Khan et al. [34,35], which contain the review of articles published up to 2007, the review article on the flow through capillary tube has not been published. Therefore, a comprehensive review of publications in the relevant area are presented in this paper. The present review has been divided into two parts viz. adiabatic and diabatic capillary tube based on the capillary tube configuration. These two parts are again subdivided into straight and coiled capillary tube based on their geometry.

2. Adiabatic capillary tube

Adiabatic capillary tubes in vapor compression system do not exchange heat with the refrigerant flowing through it. A simple vapor compression system with an adiabatic capillary tube and its Ph-diagram are shown in Fig. 3. The basic function of capillary tube is to expand the refrigerant and to regulate the flow of refrigerant to evaporator. The sub-cooled or saturated state of refrigerant enters the capillary tube for the expansion at lower pressure. During the course of flow there is change of phase and increase in the refrigerant vapor quality. An additional pressure drop occurs in refrigerant caused by increased velocity of refrigerant due to phase change i.e., acceleration pressure drop. Finally, the temperature drop is observed in refrigerant due to pressure drop as the temperature is function of pressure in two-phase region. This results in flashing more vapor in capillary tube and subsequently, more pressure drop. In the later part of the capillary tube, enthalpy

* Corresponding author.
E-mail address: santhosh.nita@gmail.com (S.K. Dubba).

http://dx.doi.org/10.1016/j.expthermflusci.2016.09.012
0894-1777/

Nomenclature

d	capillary tube internal diameter, mm
D	coil diameter, mm
L	length of the capillary tube, mm
p	pitch of the coil, mm
T	temperature, °C
ΔT_{sub}	sub-cooling degree, °C
f	friction factor
m	mass flow rate, kg h^{-1}
P	pressure, kPa
x	quality
M	mass, kg

Greek letter

ϵ	roughness height, μm

Subscripts

in	capillary tube inlet
e	evaporator
out	capillary tube outlet
c	condenser
s	superheat
suc	suction line
cap	capillary

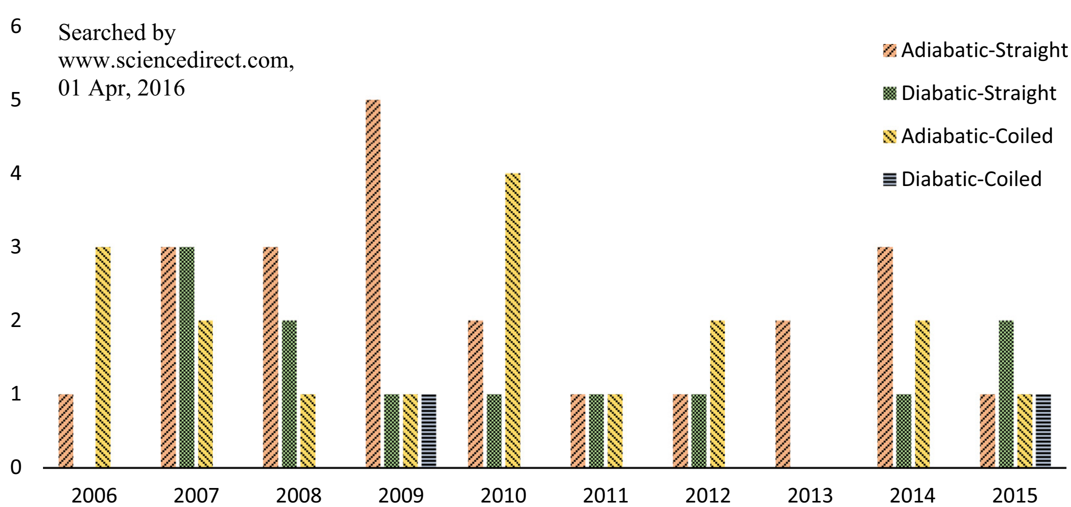

Fig. 1. Year wise publication trend of research on capillary tubes of different configuration and geometry in 2006–2015 past decade.

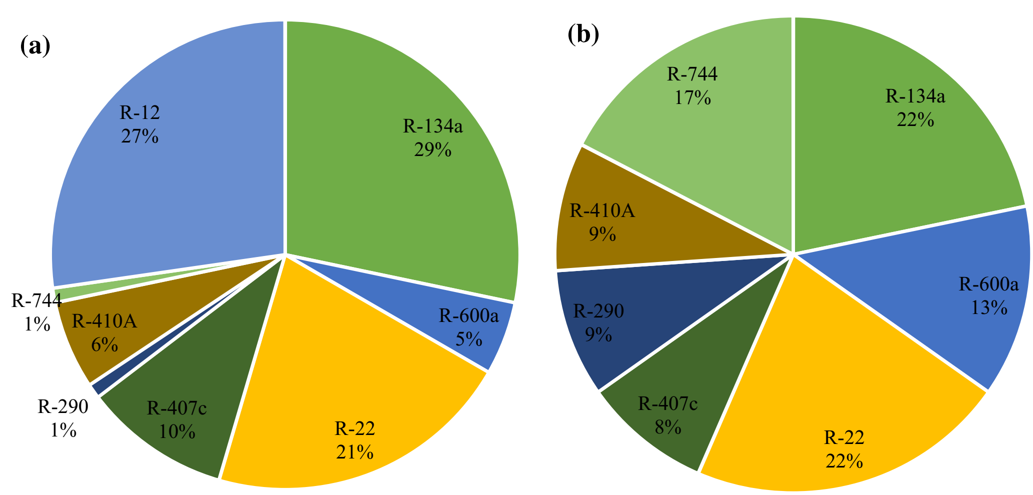

Fig. 2. Approximate percentage of research done on capillary tubes with familiar refrigerants (a) till the year 2006 and (b) 2006–2016.

decreases as velocity of vapor becomes significantly high. An adiabatic expansion process in vapor compression cycle has been represented by the process 3–4 in P-h curve shown in Fig. 3 (b). A large number of investigations on adiabatic capillary tubes have been included and briefly reviewed below in categorized structure.

2.1. Adiabatic-Straight capillary tube

The investigations have been carried out for different kind of flow viz. sub critical and transcritical cycles as shown in Fig. 4. The investigations for sub-cooled and two-phase inlet conditions of refrigerant entering the capillary tube have also been included.