Applied Thermal Engineering 39 (2012) 114–120

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

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

Heat transfer characteristics of a helical heat exchanger

Jung-Yang San*, Chih-Hsiang Hsu, Shih-Hao Chen

Mechanical Engineering Department, National Chung Hsing University, 250 Kuo-Kuang Road, Taichung, Taiwan, Republic of China

ARTICLE INFO

Article history:
Received 4 September 2011
Accepted 19 January 2012
Available online 28 January 2012

Keywords:
Helical heat exchanger
Effectiveness
Darcy friction factor
Nusselt number

ABSTRACT

Heat transfer performance of a helical heat exchanger was investigated. The heat exchanger is composed of a helical tube with rectangular cross section and two cover plates. The ε–Ntu relation of the heat exchanger was obtained using a numerical method. In the analysis, the flow in the tube (helical flow) was considered to be mixed and the flow outside the tube (radial flow) was unmixed. In the experiment, the Darcy friction factor (f) and convective heat transfer coefficient (h) of the radial flow were measured. The radial flow was air and the helical flow was water. Four different channel spacing (0.5, 0.8, 1.2 and 1.6 mm) were individually considered. The Reynolds numbers were in the range 307–2547. Two correlations, one for the Darcy friction factor and the other for the Nusselt number, were proposed.

1. Introduction

Due to shortage of energy resource and increasing demand on energy, efficient use of energy has already become an issue of great urgency for mankind. However, in many industrial processes, a large amount of low-grade (low temperature, ≦200 °C) thermal energy is directly dumped into environment through flues. This results in not only a waste of energy, but also an impact on the global warming. Recently, this issue draws public attention and researchers start to seriously find solution for it. One of the remedies for this issue is to recover this low-grade thermal energy through heat exchangers and then uses it as the heat source in low temperature heat engines. Heat exchangers are widely used to recover thermal energy from medium/high-temperature gases [1]. But for recovering thermal energy from low temperature flue gases, they must meet some stringent criteria. These criteria include a high heat transfer performance, a low utility cost and being corrosive resistant, etc.

During the past few decades, much research work has been done on predicting and improving performance of heat exchangers [2–4]. More recently, Rennie et al. [5,6] experimentally and numerically investigated the heat transfer performance of a double-pipe helical heat exchanger. Prabhanjan et al. [7] compared the heat transfer rates of a straight tube heat exchanger to that of a helically coiled heat exchanger. Kumar et al. [8] compared experimental fluid friction and heat transfer data to numerical predicted result for a tube-in-tube helical heat exchanger. Wongwises et al. [9] experimentally investigated the condensation heat transfer in a tube-in-tube helical heat exchanger. Wijeysundera et al. [10] experimentally determined the effectiveness of a spiral coil heat exchanger. In addition, extensive research work also had been done on the performance of other types of heat exchangers [11–19].

In this work, the heat transfer performance of a helical heat exchanger (Fig. 1) was investigated. The heat exchanger is composed of a helical tube with rectangular cross section and two cover plates. The two cover plates are used for sealing the top and bottom of the helical tube respectively. The fluid in the tube flows helically from one end (inlet) to the other (outlet). The fluid outside the tube enters the space surrounded by the tube through a hole locating at the center of the bottom cover plate, and then it flows in the radial direction toward the environment. The helical tube with rectangular cross section allows a small spacing and thus a high convective heat transfer coefficient for the radial flow. This achieves an efficient use of heat transfer surface. In addition, for avoiding corrosion problem, the helical tube can be made of corrosive resistant stainless steel.

The first objective of this work was to obtain the ε–Ntu relation of the helical heat exchanger. The second objective of this work was, through an experimental measurement, to obtain the heat transfer and friction data of the radial flow in the heat exchanger. The acquired data can be used in designing this type of heat exchangers for waste heat recovery.

2. Mathematical model

In the analysis, the ϕ-coordinate was chosen to be along the path of the tube (helical) flow and the x-coordinate was along the

* Corresponding author. Tel.: +886 011 4 2220 5585; fax: +886 011 4 2285 1941.
E-mail address: jysan@dragon.nchu.edu.tw (J.-Y. San).

1359-4311/$ – see front matter
doi:10.1016/j.applthermaleng.2012.01.048