Experimental Thermal and Fluid Science 35 (2011) 1427–1434

Contents lists available at ScienceDirect

Experimental Thermal and Fluid Science

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

Convective heat transfer characteristics of high-pressure gas in heat exchanger with membrane helical coils and membrane serpentine tubes

Zhen Yang, Zhenxing Zhao, Yinhe Liu *, Yongqiang Chang, Zidong Cao

State Key Laboratory of Multiphase Flow in Power Engineering, Xi'an 710049, China
School of Energy and Power Engineering, Xi'an Jiaotong University, Xi'an 710049, China

ARTICLE INFO

Article history:
Received 24 September 2010
Received in revised form 3 June 2011
Accepted 3 June 2011
Available online 5 July 2011

Keyword:
High-pressure gas
Membrane helical coil
Membrane serpentine tube
Convective heat transfer

ABSTRACT

Since the heat transfer performance of syngas cooler affects the efficiency of the power generating system with integrated coal gasification combined cycle (IGCC) directly, it is important to obtain the heat transfer characteristics of high-pressure syngas in the cooler. Heat transfer in convection cooling section of pressurized coal gasifier with the membrane helical coils and membrane serpentine tubes under high pressure is experimentally investigated. High pressure single gas (He or N_2) and their mixture (He + N_2) gas serve as the test media in the test pressure range from 0.5 MPa to 3.0 MPa. The results show that the convection heat transfer coefficient of high pressure gas is influenced by the working pressure, gas composition and symmetry of flow around the coil, of which the working pressure is the most significant factor. The average convection heat transfer coefficients for various gases in heat exchangers are systematically analyzed, and the correlations between Nu and Re for two kinds of membrane heat exchangers are obtained. The heat transfer coefficient of heat exchanger with membrane helical coils is greater than that of the membrane serpentine-tube heat exchanger under the same conditions. The heat transfer coefficient increment of the membrane helical-coil heat exchanger is greater than that of the membrane serpentine-tube heat exchanger with the increase of gas pressure and velocity.

© 2011 Elsevier Inc. All rights reserved.

1. Introduction

High pressure coal gasification is one of the most promising technologies in clean coal technology (CCT). Cooling of the high temperature crude syngas is critical to ensure the efficient operation for integrated gasification combined cycle (IGCC). The membrane helical coil (Fig. 1a) and membrane serpentine tubes (Fig. 1b) are widely used in waste heat recovery system of high pressure gasifier because of its compact structure and pressure bearing ability.

Many experimental and numerical investigations [1–4] were performed to explore fluid flow and heat transfer in coiled tubes, and it has been widely reported that heat transfer coefficient in helical coils are higher than in a straight tube due to the influence of curvature and torsion on the interior flow. In addition, considerable investigations [5–8] on the heat transfer of the fluid flow across tube banks and finned tubes have been carried out. However, there are rare investigations on shell-side forced convection heat transfer coefficient of shell-and-coil heat exchangers, especially, the membrane helical coil heat exchanger. Fortunately, there are some published investigations on natural convection heat transfer coefficient of flow across the helical coiled tubes.

Moawed [9] reported an experimental investigation of steady state natural convection heat transfer from uniformly heated helicoidal pipes oriented vertically and horizontally. He presented two different equations to correlate the Nusselt number for horizontal and vertical helicoidal pipes. Taherian and Allen [10] considered the effects of tube diameter, coil diameter, coil surface and shell diameter on the shell-side heat transfer coefficient of shell-and-coil natural convection heat exchanger. An correlation between the Nusselt number and Rayleigh number was obtained based on the hydraulic diameter of the heat exchanger. Ali [11] studied natural convection heat transfer from helical coils immersed in a large water tank. Two different tube diameters, five coil diameters and five different pitches with 5 or 10 turns were tested. Two correlations were presented for the Nusselt number data based on different tube diameters. Prabhanjan et al. [12] carried out an experimental investigation of natural convection heat transfer from helical coiled tubes in water. They correlated outside Nusselt number to the Rayleigh number using different characteristic lengths and finally considered the coil height as the best representation for a vertical coil.

Conte et al. [13,14] performed numerical investigations on forced laminar fluid flow over conical and helical coiled pipes and a single round pipe coiled in rectangular pattern. Their results show better heat transfer performance for cases of conical coils

* Corresponding author at: School of Energy and Power Engineering, Xi'an Jiaotong University, Xi'an 710049, China. Tel./fax: +86 29 82668703.
E-mail address: yinheliu@mail.xjtu.edu.cn (Y. Liu).

0894-1777/$ - see front matter © 2011 Elsevier Inc. All rights reserved.
doi:10.1016/j.expthermflusci.2011.06.001