Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 109 (2017) 322 – 330

Energy Procedia

International Conference on Recent Advancement in Air Conditioning and Refrigeration, RAAR 2016, 10-12 November 2016, Bhubaneswar, India

# Performance analysis of three fluid heat exchanger used in solar flat plate collector system

Taraprasad Mohapatra[a*], Biranchi N Padhi[b], Sudhansu S Sahoo[c], Rudra N Pramanik[a]

[a,]*Department of Mechanical Engineering, CVRCE, Bhubaneswar, 752054, India*

[b,]*Department of Mechanical Engineering, IIIT, Bhubaneswar,751003, India.*

[c,]*Department of Mechanical Engineering, CET, Bhubaneswar, 751003, India.*

**Abstract**

In the present study, the thermal performance of a three fluid heat exchanger (TFHE) used in solar flat plate collector system is studied. The TFHE is an improved version of double pipe heat exchanger, where a helical tube is inserted between two concentric straight tubes for better performance. This paper presents a new technique of simultaneous air and water heating in TFHE using solar energy. The heating cost can be minimised considerably by supplying the hot water or thermal fluid from a solar flat plate collector through the helical tube of TFHE to heat incoming cold air and water in the inner most pipe and outer annulus. The TFHE is investigated experimentally and validated by comparing the result of experimental approach with literature. Decent agreements between the experimental and literature values are observed. The purpose of this study is to determine the effect of Reynolds number and Dean number on performance of the TFHE in steady-state for both flow configurations. The overall heat transfer coefficients, $U_{o,h-n}$ varies directly and effectiveness, $\varepsilon_{h-n}$ varies inversely with hot water volume flow rate, however hot water flow rate have least or no effect on coil side Nusselt number, $Nu_h$. The effect of inner Dean Numbers on overall heat transfer coefficients, $U_{o,h-n}$ and effectiveness, $\varepsilon_{h-n}$ is negligible in parallel flow configuration, however is appreciable in counter flow configuration.
ommittee of RAAR 2016.



*Keywords:* Three Fluid Heat Exchanger, Helical tube, Heat transfer, Overall heat transfer coefficient, Effectiveness

## 1. Introduction

The heating and cooling of air and water are essential parts of our everyday lives, supporting our comfort, safety, and productivity. However, these services come at a cost, with approximately (30 – 45) % of energy

* Corresponding author. Tel.: +91-9437101642; fax: +0-000-000-0000 .
*E-mail address:* taraprasad1980@gmail.com


doi:10.1016/j.egypro.2017.03.075

consumption of any country attributable to heating and cooling. Solar heating and cooling can play a significant role in providing an economically viable and environmentally sustainable long-term solution to these essential needs. In this paper a new technique is imposed for simultaneous space heating and water heating by a three fluid heat exchanger (TFHE) using solar energy. TFHE is an improved version of double pipe heat exchanger, where a helical tube is inserted between two concentric straight tubes for better performance. The cost of air heating and water heating can be reduced considerably by supplying the hot water or thermal fluid (nanofluids) from a solar flat plate collector through the TFHE in a closed loop to heat incoming cold air and water without using any immersion heater, geyser, room heaters or A/C. TFHE with solar flat plate collector system draws from an inexhaustible energy source while displacing fossil fuels and electricity otherwise needed for heating. This reduces emissions of $CO_2$ and air pollutants while stimulating local job and economic growth. As an efficient and low-risk technology, the proposed work may be deployable throughout the India during winter for space and water heating.

Heat exchangers constitute the most important components of many industrial processes with a wide range of engineering applications. Recently numbers of heat transfer enhancement techniques are employed to produce more efficient heat exchangers. These techniques are dependent upon types of flow (parallel-flow, counter-flow, and cross-flow), type of construction (such as tubular or plate heat exchangers), way of contact between the fluids (direct or indirect), product specifications, various physical characteristics of the fluid and the material. Many researchers have designed and performed theoretical as well as experimental analysis of double pipe (straight/helical) and triple pipe (straight) heat exchanger. But the information available for helical tube inserted type three fluid heat exchanger is still least or nil, which will divert researchers and scholars to do analysis on TFHE. In this paper for the experimental analysis of TFHE, some literatures of helical coil and triple concentric pipe heat exchanger are referred. Rennie and Raghavan [1] and [2] studied a double-pipe helical heat exchanger experimentally and numerically for both flow configurations. They investigated experimentally the performance of the heat exchanger and the heat transfer coefficients are calculated using Wilson plot technique for different flow rates in the inner tube and annulus. They determined numerically the heat transfer characteristics of the heat exchanger for different flow rates, tube sizes, temperature dependent viscosity and residence timing using a CFD package (PHOENICS 3.3). An improved simulation model of a diary heat exchanger (helical triple tube heat exchanger) is suggested by Nema and Dutta [3] for the accurate estimation of fouling thickness and milk outlet temperature. They noted that fouling is controlled by surface temperature and shear stress. Vimal Kumar et al. [4] investigated experimentally the hydrodynamics and heat transfer characteristics of tube-in-tube helical heat exchanger and reported that the friction factor value in the inner-coiled tube was in agreement with literature. The experimental study carried out by Thongwik et al. [5], indicated that, ice fraction, coil diameter and mass flow rate of circulating water affect heat transfer coefficient between slurry ice and helical coil surface. Shokouhmand et al. [6] in their experimental investigation calculated overall heat transfer coefficients of a shell and helically coiled tube heat exchangers using Wilson plots and compared coil side Nusselt number with literature. Their empirical correlations for constant temperature boundary condition were quite in agreement with the present data in low Dean number region in counter-flow. Jayakumar et al. [7] studied experimentally heat transfer characteristics of a helically coiled heat exchanger for various boundary conditions. They found that the specification of a constant temperature or constant heat flux boundary condition for an actual heat exchanger does not yield proper modeling. The mixed convection heat transfer in a coil-in-shell heat exchanger was studied by Nasser Ghorbani et al. [8] for various Reynolds numbers, various tube-to-coil diameter ratios and with different dimensionless coil pitch. The results revealed that the equivalent diameter of shell was the best characteristic length and tube diameter influenced negligibly the shell-side heat transfer coefficient.

This paper proposes one of the optimized techniques i.e. inserting a helical tube in a double pipe heat exchanger for improved performance, because internal insertions of tubes (straight tube or helical tube) are found to be more efficient for convective heat transfer enhancement. Helical tube heat exchangers are considered to yield more uniform heat transfer as compared to straight tubes, because the centrifugal force causes secondary flow within