**International Journal of Computational Biology**
ISSN: 2229-6700 & E-ISSN:2229-6719, Volume 3, Issue 1, 2012, pp.-48-51.
Available online at http://www.bioinfo.in/contents.php?id=96

# REVIEW ON EXPERIMENTAL INVESTIGATION OF CONVECTIVE HEAT TRANSFER CHARACTERISTICS OF HIGH PRESSURE GAS IN HEAT EXCHANGER WITH MEMBRANE HELICAL COILS AND SERPENTINE TUBES

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Received: February 21, 2012; Accepted: March 15, 2012

**Abstract-** This paper describes literature review of Convective heat transfer characteristics of high pressure gas in heat exchanger. 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 N2) and their mixture (He + N2)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 .
**Keywords-** High pressure gas, Membrane Helical Coil, Membrane serpentine tube, Convective heat transfer

**Citation:** Gaddamwar S.S. and Shelke R.S. (2012) Review on Experimental Investigation of Convective Heat Transfer Characteristics of High Pressure Gas in Heat Exchanger with Membrane Helical Coils and Serpentine Tubes. International Journal of Computational Biology, ISSN: 2229-6700 & E-ISSN:2229-6719, Volume 3, Issue 1, pp.-48-51.



## 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 and membrane serpentine tubes are widely used in waste heat recovery system of high pressure gasifier due to its compact structure and pressure bearing ability. Many experimental and numerical investigations 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.

From the previous work it is found that there is no data available on convective heat transfer of high-pressure syngas in the annular channel formed by membrane helical coils. Therefore, the present work is identified to provide convective heat transfer data of the annular channel formed by membrane helical coils with various gases, various working pressures and various structures.

## Problem Definition

As shown in fig. in coal mines, underground mines, mineral ore mines in India where the syngas found in large quantity at high temperature and high pressure caused many accidents. Some examples are Raniganj Blast, Jharia Blast and Anjani Blast is these accidents caused many human life’s to death. This accidents happens frequently due to fact that available gas which is at high temp and pressure is directly exhausted to the atmosphere through exhaust fans and fresh new air is sucked into the mines for respiration. But it is not feasible to directly throw this highly toxic, harmful and flammable gas in our surrounding environment.

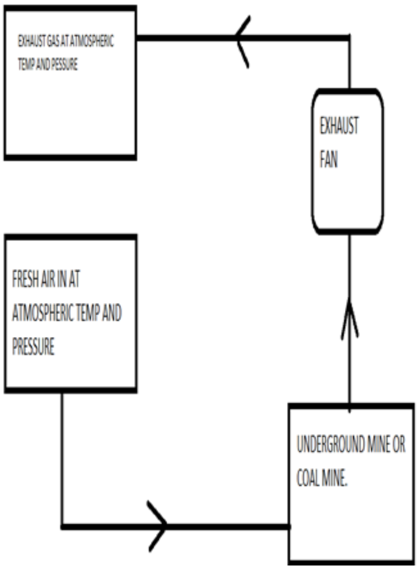

**Fig. 1-** Line Diagram of Mines Exhaust Gases

So it is required to design and fabricate a experimental set which will reduce the pressure and temperature of the harmful gas. This system will also give us some important experimental values which help us to evaluate the performance of the gas when passed through this given system. Results which are obtained from this system can be correlated with different non dimensional numbers and plotted in different graphs.

**Objectives**

1. To find out convective heat transfer coefficient and heat transfer rate by propose fabricated and developed heat exchanger with membrane helical coils and membrane serpentine tubes.
2. To find out the results obtained from passing high pressure and high temperature gases through the newly developed system.
3. To present the various correlations between the non dimensional numbers on the graphs.

**Future scope**

Development and experimental investigation of heat transfer characteristics of high pressure gas (syngas gas) in heat exchanger with membrane helical coils and serpentine tubes, for comparison of its performance with existing system.

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.

**Experimental apparatus and procedure**

The syngas from gasifier mainly consists of CO (50–60vol%),H2 (25–35vol%),CO2, H2O, CH4, H2S, N2 and COS. The purpose of this experiment is to get the effect of CO and H2 in the syngas on convective heat transfer coefficient. However, CO and H2 are toxic, flammable and explosive, so the safe gases (N2 and He) whose physical properties are similar to CO and H2 are adopted to substitute

CO and H2 in present experiment. The experiments are performed with demonized water as the testing fluid in the helical coils, with N2,He and their gas mixture (N2:He = 2:1 in the mixture) as the testing gas outside the helical coils.

The system consists of the following components: the test section, the heat recovery section, the cooling section, the heater, the compressor and other parts. To achieve high pressure, the whole experimental system is closed and airtight. The gas pressure is controlled by inflation from gas cylinder. The gas flow is maintained by a volumetric compressor. The counter-current flow is used in this system.

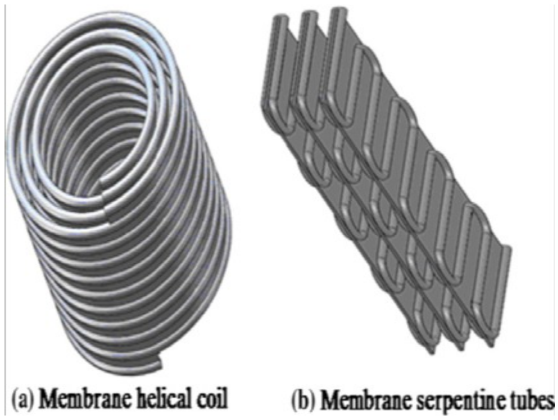

**Fig. 2-** Geometrical configuration of two types of membrane heat transfer surfaces

The idea behind the project is improvement in existing system with a new concept, therefore the dedicated literature couldn't be retrieved, but existing systems and including technology advancements relevant to the scope of project have been studied. Extracts of relevant papers are as under –

**Review of work carried out**

**1. Paisarn Naphon, Somchai Wongwises**

had experimentally investigated the heat transfer characteristics and the performance of a spiral coil heat exchanger under cooling and dehumidifying conditions are investigated. The heat exchanger consists of a steel shell and a spirally coiled tube unit. The spiral-coil unit consists of six layers of concentric spirally coiled tubes. Each tube is fabricated by bending a 9.27mm diameter straight copper tube into a spiral-coil of five turns. Air and water are used as working fluids. The chilled water entering the outermost turn flows along the spirally coiled tube, and flows out at the innermost turn. The hot air enters the heat exchanger at the center of the shell and flows radially across spiral tubes to the periphery. A mathematical model based on mass and energy conservation is developed and solved by using the Newton–Raphson iterative method to determine the heat transfer characteristics.

**2. Karahalios G.**

Mixed convection flow in a heated curved pipe with core.

In the present work attempts were made to investigate the hydrodynamics and heat transfer characteristics of tube-in-tube helical heat exchanger at the pilot plant scale. The experiments were carried out in counter current mode operation with hot fluid in the tube side and cold fluid in the annulus area. The outer tube was fitted with semicircular plates to support the inner tube and also to provide high turbulence in the annulus region. Overall heat transfer coefficients were calculated and heat transfer coefficients in the inner and outer tube were determined using Wilson plots.

**3. Prabhanjan D.G., Ragbavan G.S.V. and Rennie T.J.**

had experimentally investigated the use of a helical coil heat exchanger was seen to increase the heat transfer coefficient compared to a similarly dimensioned straight tube heat exchanger. Both heat exchangers had higher heat transfer coefficients when the bath temperature was increased, most probably due to increased buoyancy effects. Flow rate did not effect the heat transfer coefficient, most likely from the fact that the flow was turbulent and increasing the flow rate does not greatly change the wall effects. Temperature rise of the fluid was found to be effected by coil geometry and by the flow rate.

**4. Figueiredo, Raimundo A.**

had experimentally investigated the analysis of the performance of heat exchangers used in hot water stores. The thermal response of a hot-water store and the thermal discharge characteristics from heat exchanger coils placed inside have been experimentally investigated. The analysis of the experimental results shows that it is possible to describe the thermal behaviour of these systems by the use of a convenient set of dimensionless parameters. Two different geometric configurations of the heat-exchanger coils were investigated, namely the classic cylindrical coil and the flat spiral coil, this last one presenting a greater heat transfer efficiency. The hypothesis of a lumped heat capacity for the thermal evolution of the water store enables the construction of a simplified theoretical model. The solution of which, obtained by a numerical method, predicts with reasonable accuracy the time evolutions of both the average temperature of the water tank and of the inlet-outlet temperature difference of the circulating water.

**5. Yan Li, Xiumin Jiang, Xiangyong Huang, Jigang Jia, Jianhui Tong**

had experimentally investigated the three-dimensional numerical simulations for Syngas coolers with different baffle configuration and working condition are performed to reveal the effects of baffle configuration and working condition on the heat transfer and pressure drop characteristics. The major findings are summarized as follows:

i. Higher operation pressure can improve the heat transfer, however brings bigger pressure drop because of the different mass flow rate.
ii. The components of the syngas significantly affect the pressure drop and the heat transfer. The heat transfer increases with higher $H_2O$ percentage and lower $H_2$ percentage. The pressure drop increases with higher $CO_2$ percentage and lower $H_2$ percentage.
iii. The arrangement of the baffles influences the fluid flow.In a certain range, shortening the height of the baffles, decreasing the number of the baffles and widening the space between the baffles can decrease the resistance effectively.

**6. Wang C.**

had experimentally investigated the study of the air-side heat transfer and pressure drop characteristics of plate, wavy and louver fin surfaces was carried out. Thirty-six samples of plate, wavy and louver fin-and-tube heat exchangers with different fin pitch and tub row number were tested. Various comparison methods have been adopted to evaluate the performance of the heat exchanger among various fin surfaces.

**7. Taherian H., Allen P.L.**

In the present study an experimental investigation of the mixed convection heat transfer in a coil-in-shell heat exchanger is reported for various Reynolds and Rayleigh numbers, various tube-to-coil diameter ratios and dimensionless coil pitch. The purpose of this article is to assess the influence of the tube diameter, coil pitch, shell-side and tube-side mass flow rate over the performance coefficient and modified effectiveness of vertical helical coiled tube heat exchangers. The calculations have been performed for the steady-state and the experiments were conducted for both laminar and turbulent flow inside coil. It was found that the mass flow rate of tube-side to shell-side ratio was effective on the axial temperature profiles of heat exchanger.

**8. Ghorbani N., Taherian H., Gorji M., Mirgolbabaei H.**

In this study the mixed convection heat transfer in a coil-in-shell heat exchanger for various Reynolds numbers, various tube-to-coil diameter ratios and different dimensionless coil pitch was experimentally investigated. The experiments were conducted for both laminar and turbulent flow inside coil. Effects of coil pitch and tube diameters on shell-side heat transfer coefficient of the heat exchanger were studied. Different characteristic lengths were used in various Nusselt number calculations to determine which length best fits the data and several equations were proposed. The particular difference in this study in comparison with the other similar studies was the boundary conditions for the helical coils. The results indicate that the equivalent diameter of shell is the best characteristic length.

## Conclusion

From the above literature review it is found that heat transfer of pressurized coal gasifier convection cooling section with the membrane helical coils and membrane serpentine tubes under high pressure is experimentally investigated. High pressure single gas (He or $N_2$) and the gas mixture (molar ratio$N_2$:He = 2:1) were adopted as the gas medium, and the working pressure for each gas varies from 0.5 MPa to 3.0 MPa. The experimental results show that the working pressure, gas composition and symmetry of flow around the coil (single-side heating, double-side symmetrical heating and double-side asymmetrical heating)affect the convection heat transfer coefficient for high pressure gas. The average convection heat transfer coefficients for various high pressure gases in membrane helical-coil heat exchanger and membrane serpentine-tube heat exchanger, the correlations of the typical flow patterns and its applicable condition are systematically obtained. The heat transfer coefficients of heat exchanger with membrane helical coils are greater than that of the heat exchanger with serpentine tubes under the same heat transfer conditions. The heat transfer coefficients of the annular channel heat exchanger increases faster than that of the parallel channel heat exchanger with the increase of gas pressure and gas velocity.

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