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Experimental and Numerical Investigation of Thermal Performance in Spiral Coil Heat Exchangers

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1. Abstract: Spiral coil heat exchangers are widely used in chemical processing, refrigeration, food industries, power plants, and HVAC systems because of their compact size and enhanced heat transfer characteristics. The present study focuses on the experimental and numerical investigation of thermal performance in a spiral coil heat exchanger under varying operating conditions. The experiments were conducted by circulating hot and cold fluids through a spiral copper coil arrangement, while parameters such as inlet temperature, flow rate, pressure drop, and overall heat transfer coefficient were measured. Numerical analysis was carried out using Computational Fluid Dynamics (CFD) techniques to predict temperature distribution and flow behavior inside the coil. The results obtained experimentally were compared with numerical simulations to validate the thermal model. It was observed that the heat transfer rate increased with an increase in flow rate and coil curvature due to enhanced turbulence and secondary flow formation. The numerical results showed good agreement with experimental data, with deviations within acceptable limits. The study concludes that spiral coil heat exchangers provide superior thermal efficiency compared to conventional straight tube exchangers and are suitable for compact thermal systems.

2. Introduction: Heat exchangers are devices used to transfer heat between two fluids at different temperatures without direct mixing. They play an important role in industrial applications such as thermal power plants, refrigeration systems, petrochemical industries, food processing, and automotive cooling systems. Among various types of heat exchangers, spiral coil heat exchangers have gained significant attention because of their high heat transfer efficiency, compact design, and reduced space requirement.

The curved geometry of spiral coils produces centrifugal forces that generate secondary flow patterns known as Dean vortices. These vortices improve fluid mixing and increase the rate of heat transfer. Due to this phenomenon, spiral coil heat exchangers exhibit higher thermal performance than straight tube heat exchangers under similar operating conditions.

The thermal behavior of spiral coil heat exchangers depends on several parameters including coil diameter, pitch, tube diameter, fluid properties, and flow rate. Experimental investigations help determine the actual thermal performance, while numerical simulations provide detailed insight into temperature and velocity distributions inside the exchanger.

In the present work, an experimental setup was fabricated to study the thermal performance of a spiral coil heat exchanger using water as the working fluid. The experimental observations were validated using numerical simulations performed through CFD analysis. The objective of the study is to evaluate heat transfer characteristics, pressure drop behavior, and effectiveness of the spiral coil heat exchanger under different operating conditions.

3. Working Principle of Spiral Coil Heat Exchanger:

The spiral coil heat exchanger works on the principle of heat transfer between two fluids at different temperatures without allowing them to mix directly. In this system, one fluid acts as the hot fluid and the other acts as the cold fluid. Heat energy flows naturally from the hot fluid to the cold fluid through the wall of the copper spiral tube.

During operation, hot water from the heated tank is pumped through the spiral coil tube, while cold water flows through the outer shell surrounding the coil. As the hot fluid moves inside the curved spiral tube, heat is transferred through the tube wall to the cold fluid flowing outside the coil. Because of this heat exchange process, the temperature of the hot fluid decreases and the temperature of the cold fluid increases.

The spiral or helical shape of the coil plays an important role in improving heat transfer performance. When fluid flows through the curved tube, centrifugal forces are created due to the curvature of the coil. These forces generate secondary swirling motions called **Dean vortices**. The secondary flow increases turbulence and fluid mixing inside the tube, which enhances the rate of heat transfer compared to straight tube heat exchangers.

In most cases, the exchanger operates in a **counter-flow arrangement**, where the hot and cold fluids move in opposite directions. This arrangement maintains a larger temperature difference between the fluids throughout the exchanger length, resulting in higher thermal efficiency and better heat transfer effectiveness.

The temperatures at the inlet and outlet sections are measured using thermocouples, while flow rates are controlled and measured using valves and rotameters. The collected experimental data is then used to determine the heat transfer rate, overall heat transfer coefficient, effectiveness, and pressure drop characteristics of the spiral coil heat exchange

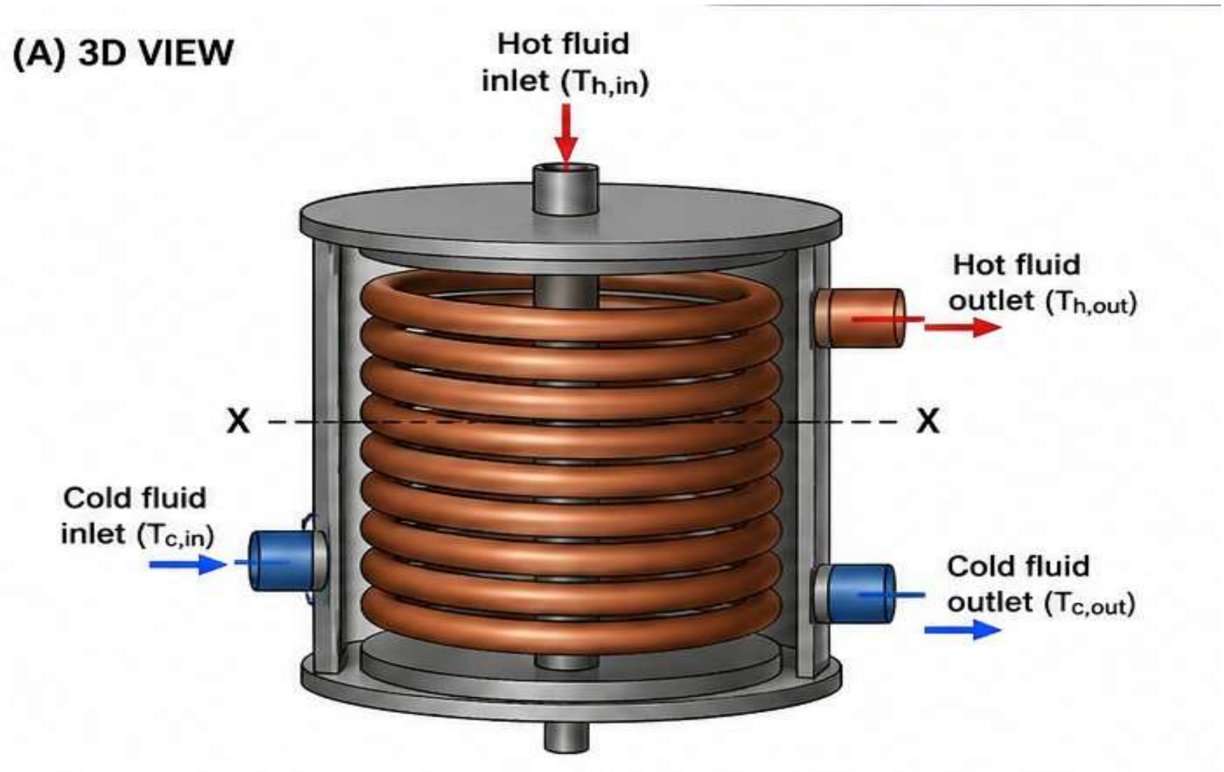
$Q = m\, c_p\, (T_{out} - T_{in})$

The overall heat transfer relation is given by:

$Q = UA\Delta TmQ$

Thus, the spiral coil heat exchanger provides efficient thermal performance due to enhanced turbulence, compact structure, and increased heat transfer area.

4. Explanation of Spiral coil Heat Exchanger with Figure



3D View of Spiral Coil Heat Exchanger

Main Parts

1. Spiral Coil (Copper Tube)

- The copper tube is wound in a spiral/helical shape.
- Hot fluid flows through this coil.

- Copper is used because it has high thermal conductivity.

2. Shell

- The outer cylindrical body surrounding the coil.
- Cold fluid flows through the shell side around the coil.
- It supports the structure and separates the two fluids.

3. Hot Fluid Inlet ($T_{h, in}$)

- Entry point of hot fluid into the spiral coil.
- Usually connected to a heated water tank.

4. Hot Fluid Outlet ($T_{h, out}$)

- Exit point of hot fluid after losing heat.
- Temperature decreases after heat transfer.

5. Cold Fluid Inlet ($T_{c, in}$)

- Entry point of cold fluid into the shell side.
- Cold fluid absorbs heat from the coil.

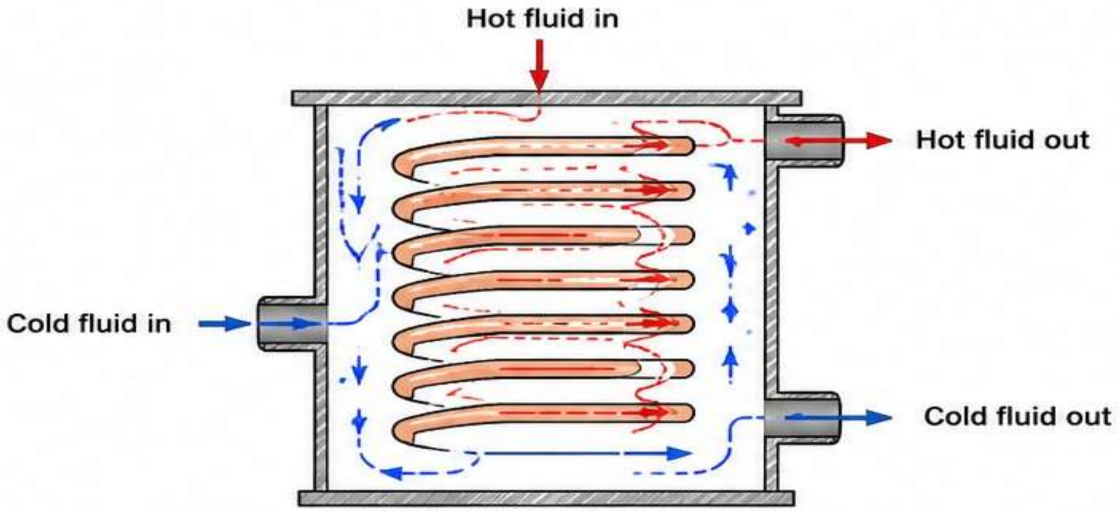
6. Cold Fluid Outlet ($T_{c, out}$)

- Exit point of cold fluid after gaining heat. Temperature increases due to heat absorption.

Flow Arrangement :

Hot Fluid Flow

- Hot fluid moves inside the spiral tube.
- Represented by red arrows.
- Transfers heat to the surrounding cold fluid.



Cold Fluid Flow

- Cold fluid flows outside the coil within the shell.
- Represented by blue arrows.
- Absorbs heat from the hot fluid.

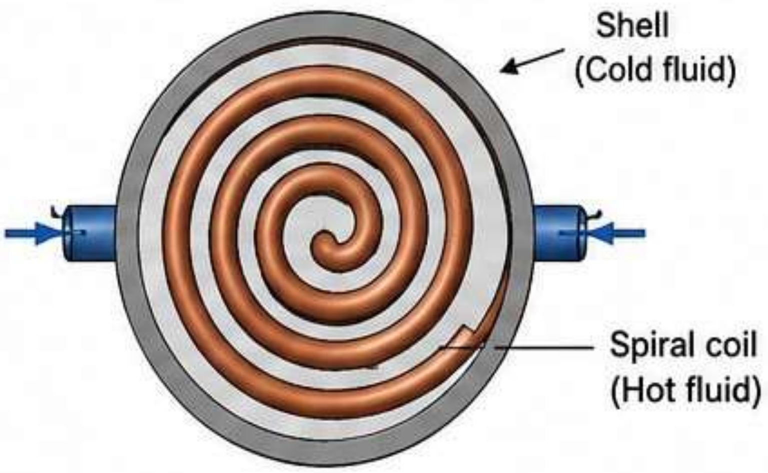
Counter Flow Arrangement

- The fluids move in opposite directions.
- This arrangement improves thermal efficiency and heat transfer rate.

Secondary Flow Formation

- Curved coil geometry creates centrifugal force.
- This produces swirling motion called **Dean vortices**. Improves mixing and increases heat transfer

Cross-Section :



This section shows the internal arrangement when viewed from the top.

Spiral Coil Region

- Inner spiral tube carrying hot fluid.
- Multiple turns increase contact area.

Shell Region

- Space surrounding the coil.
- Cold fluid circulates through this region.

Importance of Spiral Shape

- Provides large heat transfer area in compact space.
- Enhances turbulence and thermal performance.

5. Methodology and Experimental Setup:-

The methodology adopted for the investigation of thermal performance in a spiral coil heat exchanger involves experimental testing and numerical analysis. Initially, a spiral coil heat exchanger was designed and fabricated using a copper tube wound in helical form inside a cylindrical shell. Copper material was selected because of its high thermal conductivity and good heat transfer characteristics.

The experimental setup consists of a hot water tank with an electric heater, a cold water tank, centrifugal pumps, control valves, rotameters, thermocouples, and the spiral coil heat exchanger. Hot water was circulated through the spiral coil while cold water flowed through the shell side in a counter-flow arrangement. The flow rates of both fluids were controlled using valves and measured using rotameters.

During the experiment, water in the hot tank was heated to the desired temperature. After achieving steady-state conditions, inlet and outlet temperatures of both hot and cold fluids were measured using thermocouples. The experiments were repeated for different flow rates and operating temperatures to study the variation in heat transfer characteristics.

Experimental setup consists of the following major components: -

1. Spiral coil heat exchanger
2. Hot water tank with heater
3. Cold water tank
4. Centrifugal pump
5. Rotameters for flow measurement

6. Thermocouples for temperature measurement
7. Control valves
8. Connecting pipes and fittings
9. Data acquisition system

The spiral coil was fabricated using a copper tube wound helically around a cylindrical frame. Hot water flows through the inner coil while cold water circulates around the outer shell. Thermocouples are placed at inlet and outlet sections to measure fluid temperatures. Flow rates are controlled using valves and measured using rotameters.

The heat transfer rate is calculated using:

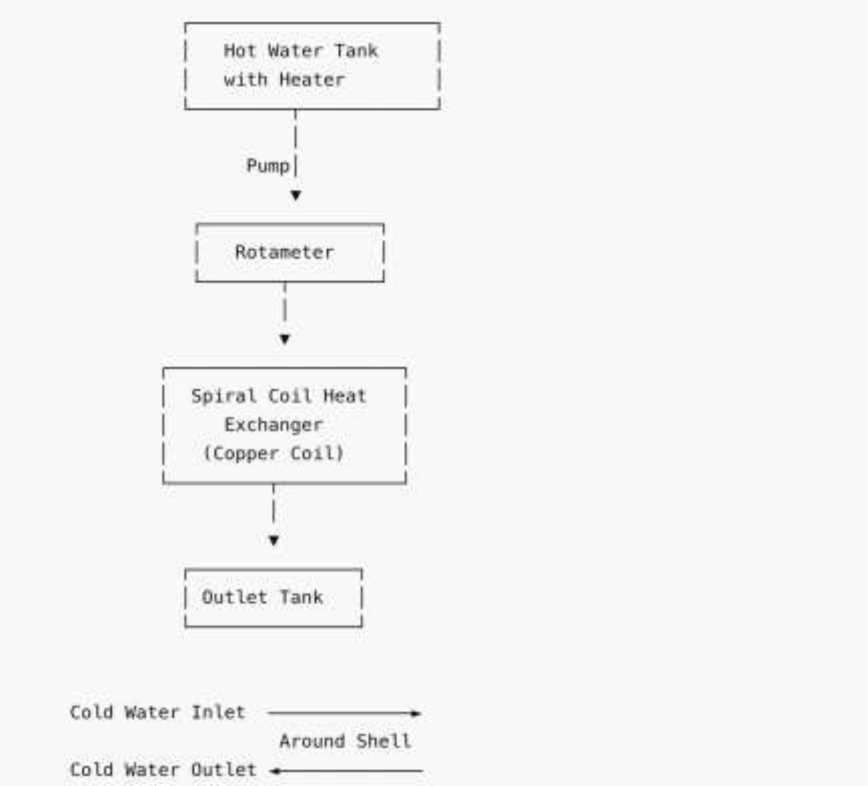
$Q = mc_p(T_{out} - T_{in})$

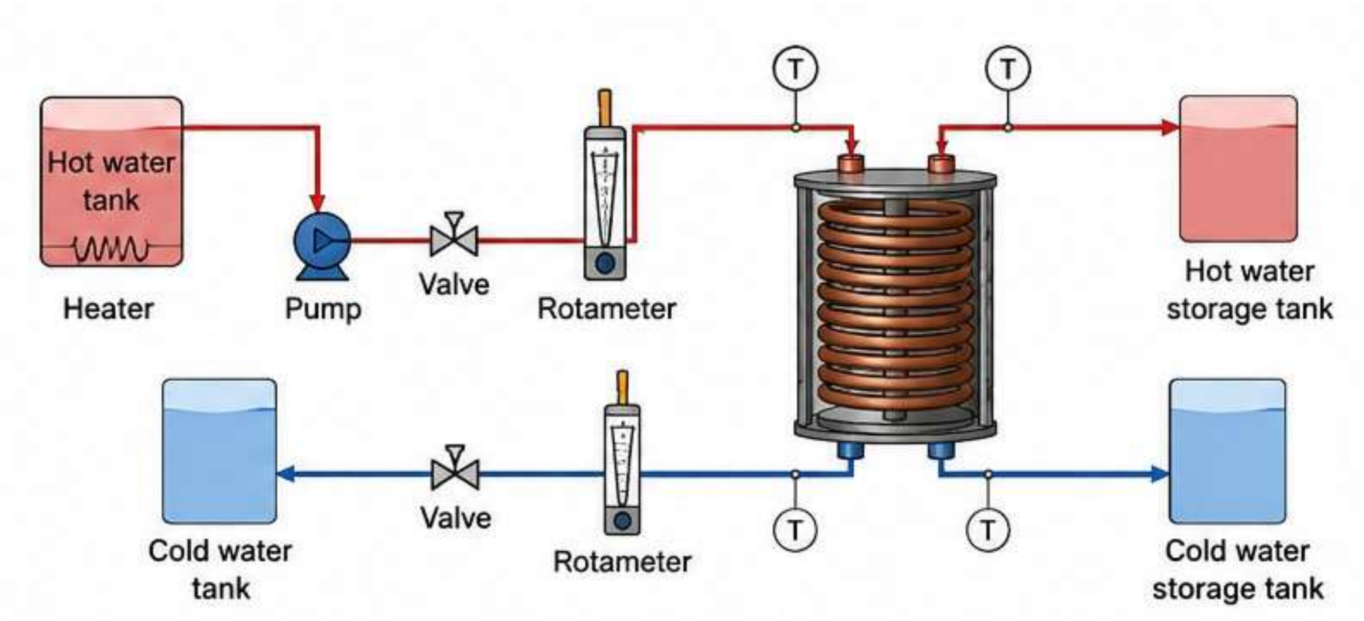
The overall heat transfer coefficient is determined by:

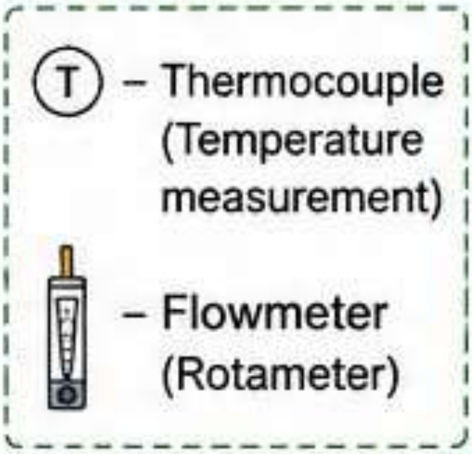
$Q = UA\Delta T_m$

where:

- Q = Heat transfer rate
- M = Mass flow rate
- Cp = Specific heat capacity
- U = Overall heat transfer coefficient
- A = Heat transfer area
- ΔTm = Log mean temperature difference (LMTD)







This section explains the laboratory setup used for experimentation.

Components and Functions-

i) Hot Water Tank with Heater

- Stores water and heats it to the required temperature.
- Heater maintains constant hot fluid temperature.

ii) Pump

- Circulates hot water through the spiral coil.
- Maintains continuous fluid flow.

iii) Control Valve

- Used to regulate fluid flow rate.
- Helps perform experiments at different flow condition

iv) Rotameter (Flow Meter)

- Measures flow rate of the fluid.
- Important for heat transfer calculations.

v) Spiral Coil Heat Exchanger

- Main test section where heat transfer occurs.

vi) Cold Water Tank

- Supplies cold water to shell side.

vii) Thermocouples (T)

- Measure inlet and outlet temperatures.
- Installed at different points in the setup.

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viii) Storage Tanks

- Collect hot and cold water after circulation.
- Enable continuous operation.

6. Numerical Analysis

Numerical analysis of the spiral coil heat exchanger was carried out using CFD software to study heat transfer and fluid flow characteristics. A 3D model of the exchanger was created and meshed for simulation. Boundary conditions such as inlet temperature, flow rate, and pressure were applied to the model.

The governing equations of continuity, momentum, and energy were solved numerically to obtain temperature distribution, velocity profile, and pressure drop inside the exchanger. A turbulence model was used to analyze the flow behavior accurately.

The simulation results showed improved heat transfer due to secondary flow formation in the spiral coil. The numerical results were compared with experimental data and showed good agreement, validating the thermal performance of the spiral coil heat exchanger.

The following assumptions were considered during numerical simulation:

- Steady-state fluid flow
- Incompressible fluid
- Constant fluid properties
- Negligible heat loss to surroundings
- Turbulent flow conditions

Boundary conditions were applied to the model as follows:

- Hot fluid inlet temperature and flow rate specified at coil inlet
- Cold fluid inlet temperature and flow rate specified at shell inlet
- Pressure outlet condition at exits
- No-slip condition at solid walls

The governing equations of fluid flow and heat transfer were solved numerically, including:

- Continuity equation
- Momentum equation
- Energy equation

The continuity equation is:

$$\nabla\cdot(\rho V)=0$$

The momentum equation is:

$$\rho(V\cdot\nabla)V=-\nabla P+\mu\nabla^2V$$

The energy equation is:

$$\rho\, c_p\,(V\cdot\nabla T)=k\nabla^2 T$$

A suitable turbulence model such as the k−ε model was used to simulate turbulent flow behavior inside the spiral coil. The CFD solver iteratively calculated velocity, pressure, and temperature values until convergence criteria were satisfied.

Post-processing of results was carried out to obtain:

- Temperature contours
- Velocity vectors
- Pressure distribution
- Heat transfer coefficient
- Turbulence intensity

The numerical results showed that the spiral curvature generated secondary flow patterns known as Dean vortices, which enhanced fluid mixing and increased the heat transfer rate. The temperature of the hot fluid gradually decreased along the coil length, while the cold fluid temperature increased due to heat absorption.

The heat transfer rate obtained from CFD analysis was compared with experimental values for validation. The numerical predictions showed good agreement with experimental data, confirming the accuracy of the simulation model.

Thus, the numerical analysis provided a detailed understanding of fluid flow and thermal behavior inside the spiral coil heat exchanger and helped evaluate its thermal performance effectively.

7. Conclusion:

The experimental and numerical investigation demonstrates that spiral coil heat exchangers provide enhanced thermal performance because of secondary flow generation and improved turbulence. The heat transfer coefficient increases with increasing flow rate, while numerical simulations closely match experimental results. The compactness and efficiency of spiral coil heat exchangers make them suitable for modern industrial thermal applications.

8. REFRENCE: -

1. Heat Exchangers: Selection, Rating, and Thermal Design, *Heat Exchangers: Selection, Rating, and Thermal Design*, CRC Press, 3rd Edition, 2012.

2. Process Heat Transfer, *Process Heat Transfer*, McGraw-Hill Education, 1950.
3. Fundamentals of Heat and Mass Transfer, *Fundamentals of Heat and Mass Transfer*, Wiley Publications, 7th Edition, 2011.

4. Heat Transfer, *Heat Transfer*, Tata McGraw-Hill, 10th Edition, 2010.

5. Compact Heat Exchangers, *Compact Heat Exchangers*, McGraw-Hill, 3rd Edition, 1984.
6. Naphon, P., and Wongwises, S., “A Review of Flow and Heat Transfer Characteristics in Curved Tubes,” *Renewable and Sustainable Energy Reviews*, Vol. 10, No. 5, pp. 463–490, 2006.

7. Kumar, V., Saini, S., and Sharma, R., “Experimental Investigation of Heat Transfer Enhancement in Helical Coil Heat Exchanger,” *International Journal of Engineering Research and Technology (IJERT)*, Vol. 4, Issue 6, 2015.

8. Rennie, T.J., and Raghavan, G.S.V., “Numerical Studies of a Double-Pipe Helical Heat Exchanger,” *Applied Thermal Engineering*, Vol. 26, pp. 1266–1273, 2006.

9. Patankar, S.V., Numerical Heat Transfer and Fluid Flow, Hemisphere Publishing Corporation, 1980.

10. Cengel, Y.A., and Ghajar, A.J., Heat and Mass Transfer: Fundamentals and Applications, McGraw-Hill Education, 5th Edition, 2015.