Design, Fabrication and Analysis of Double Pinned Force Convected with Porus Material

Santosh Kumar[1], Aditya Singh[2], Jitesh Kumar[3]

[1]Assistant Professor Department of Mechanical Engineering Axis Institute of Technology and Management Kanpur UP, (209402), India
[2,3] U.G Student, Department of Mechanical Engineering Axis Institute of Technology and Management Kanpur UP, (209402), India

---***---

ABSTRACT

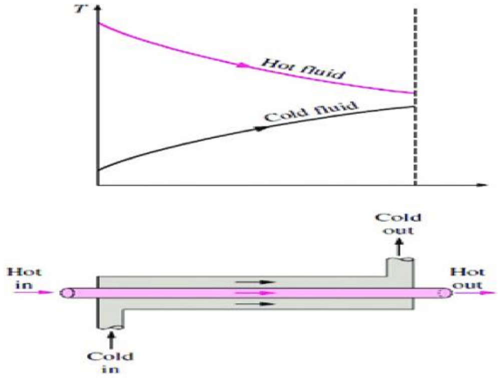
A double pipe heat exchanger will be modelled using a 3D software called SolidWorks. This paper focuses on analyzing and numerically simulating a double-piped heat exchanger with forced convection in a porous medium to determine its heat transfer characteristics and overall heat transfer coefficient. The relevant properties of the fluids involved—hot and cold water—are already identified. In industrial settings, it is common to adopt more efficient methods for energy transfer to improve the effectiveness of heat exchangers. This improvement is typically achieved by increasing the heat transfer surface area, which is done by incorporating four circular disc fins of various geometries. This research examines the transfer of heat by utilizing different fin designs on the heat exchange surface of a double pipe heat exchanger. The fins used in this study were interrupted circular fins. The research numerically explores the performance and design of double pipe heat exchangers with circular fins on the annulus side.

Key Words: Annulus tube, Fluidized substances, Proportionate, Petrochemical products, Depicted.

1. INTRODUCTION

1.1 Introduction to Heat Exchange in Heat Exchangers

Heat exchangers are devices specifically made to helps move heat energy from one thing to another fluids, either within themselves or to external systems (see Figure 1.1). Often, this process involves significant working media or waste materials like water, which either gives off heat to or absorbs heat from more valuable fluids such as crude oil, petrochemical products, or even fluidized substances. There is a wide range of designs and configurations for heat exchangers. These fluids may exist in the same state or in different phases, such as liquid-to-liquid or vapor-to-liquid. During the design process, engineers take into account the phase changes that both fluids will experience.



1.2 Mechanism of heat transfer

In the case of heat exchangers, the heat transfer process integrates both conduction and convection. The temperature difference across two or more areas serves as the impetus for heat transfer.

1.2.1 Conduction

This process involves the transfer of heat energy through direct contact between neighbouring areas. A section with higher kinetic energy will transfer thermal energy to a section with lower kinetic energy. According to Fourier's Law of Heat Conduction (as shown in Equation 1.1), the rate at which heat is transferred perpendicular to the material's surface is proportional to the negative temperature gradient.

$$Q = -kA.(dT/dx) \qquad (1.1)$$

1.2.2 Convection

In heat exchangers, convection results from the volumetric mixing of the fluid with the wall, thus, it is represented by Newton's law of cooling (given as Equation 1.2) which states. The rate of heat loss exemplarily of a body is proportionate to the difference in the value of the temperature of the body versus the environment with the wall, and the fluid in this instance performing the role of the surrounding.

$$[Q = ha\,(T2-T1)] \qquad (1.2)$$

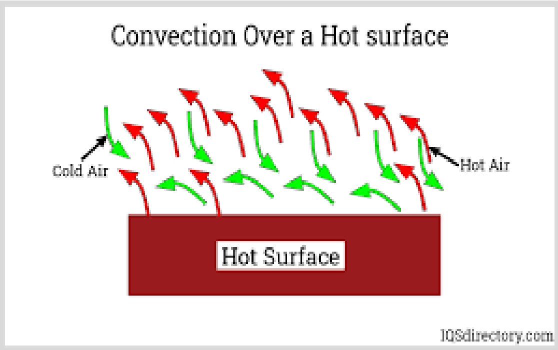


Figure (1.2) Convection Over a hot surface

The process of heat transfer from the hot fluid to the cold fluid in a heat exchanger with a conductive partition takes place in the following stages:

1. Hot fluid to the adjacent wall surface, convection.

2. Through the wall surface side, conduction.

3. Convection transfers heat from the wall surface to the cold fluid.

1.3 Constructive Design of Heat Exchangers.

1.3.1 Counter current Flow

In heat exchangers, both fluids are classified as hot and cold, positioned appropriately within the constructed systems. In these installations, operators differentiate between the fluid and the utility. The process fluid holds greater value as it can be seen as a raw material, a product, or sometimes even a by-product. The diagrams provided below depict how the process and utility fluids interact within the exchangers. Figure 1.3 illustrates that in counter current heat exchangers, the flow of the process fluid and the utility fluid travels in opposing directions. This type of flow pattern is the most common and efficient for heat exchangers. For fluids with significant temperature differences, this variation remains relatively constant across specific sections of the heat exchanger.

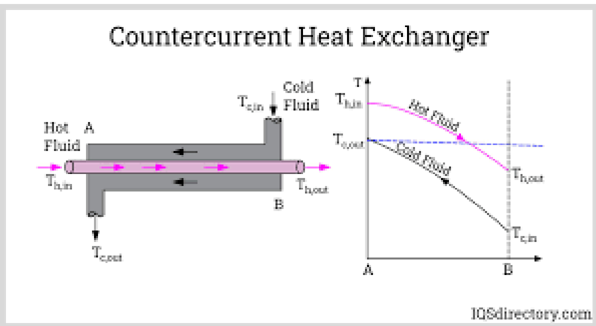


Figure 1.3: countercurrent heat exchanger

1.3.2 Co-existing or Concurrent Movement

As depicted in Figure 1.4, in heating exchange systems, the process fluid and the mileage fluid pipeline flow in parallel or co-exist. This is likely the best scenario when the two imposed outlet temperature differences are similar to each order. Under most conditions, when the fluids are about to enter the heat exchanger, the temperature difference between the two fluids is quite large. However, this input difference tends to reduce significantly over the length of the heat exchangers which results into massive thermal stress and material failure.

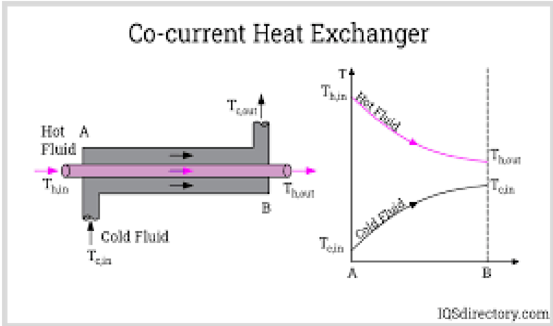


Figure 1.4: co-current-heat-exchanger

2. LITERATURE REVIEW

2.1 Introduction

Automatic annulus tube double pipe heat exchanger was set up to have working outer tube lengths up to 1000mm. Hot water enters through a tube with an immersion rod while cold water is allowed to flow into the annulus through either end thus, the heat exchanger can operate as a parallel flow exchanger. It has four circular disc fins of height 200mm manufactured from aluminum.

2.2 Development by Other Researchers

1. The use of heat exchangers in various industries helps reduce costs and conserve energy. The double pipe heat exchanger has been a focal point in research due to its versatility and effectiveness (Luki, 2008). To enhance the heat transfer rate and boost the performance of heat exchangers, different geometric configurations of the surface area are being proposed.

2. Researchers have also analyzed the impact of the heat exchanger's wall and its contact surface area with the working fluids (JM and KR, 2016). This can be achieved by enlarging the contour surface area of the metal. It is believed that this will enhance the heat transfer rate; however, this improvement largely depends on the shape of the additional surface and the prevailing hydrodynamic conditions.

3. Naikel (1987) examined convection heat transfer from a horizontal rectangular base equipped with vertical rectangular fins. The study demonstrated that the heat transfer coefficient increased when the clearance between the shroud and the fin height was larger, as well as with a rise in fin height above the horizontal base.

4. Ji et al. (2005) investigated a cooling heat sink featuring triangular fins. Their results indicated that the effectiveness of the fin is influenced by the Reynolds number and the height of the fin.

5. Zhang et al. (2012) conducted experimental research on heat transfer in a double pipe heat exchanger system incorporating helical fins and vortex generators. Their findings revealed improvements ranging from 87% to 115% for heat exchangers without fins compared to those using smooth tube heat exchangers.

6. Syed et al. (2015) explored the effects of longitudinal fins with varying tip thicknesses on the heat transfer rate in a finned double pipe heat exchanger. They discovered that these fins resulted in a significant increase of 170% in the heat transfer coefficient.

3. DESIGN AND FABRICATION

3.1 Material Selection

In the design of a heat exchanger, the choice of materials is the primary consideration. For double pipe heat exchangers, suitable materials include copper, stainless steel, and aluminum. The selection is influenced by the specific temperature and pressure requirements of the process, particularly when handling a hot fluid. Aluminium is chosen for the inner tube and annulus due to its superior thermal conductivity. Additionally, the nickel braze used in aluminium exchangers possesses suitable melting and welding characteristics that allow it to be categorized as a nickel-based alloy.

3.2 Basic Working Process of Double Piped Heat Exchanger

A double piped heat exchanger can be generally defined as a device in which two liquids that do not mix, each at different temperatures, exchange heat with one another. The metallic contact between the two fluids facilitates this heat transfer, as demonstrated in Figure 3.1.

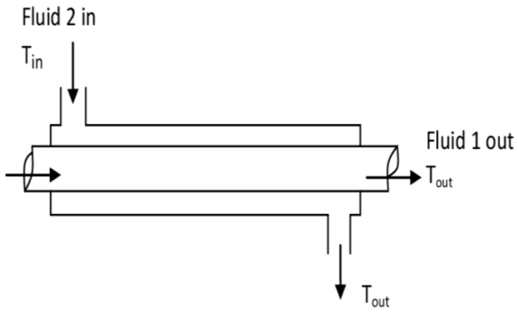


Figure 3.1: Schematic diagram of a parallel flow

HOT WATER (Fluid 2)	COLD WATER (Fluid 1)
Aluminum outer tubes (Dia=76mm)	Aluminum inner tube (Dia=51mm)
Flow rate = 0.42 kg/s	Flow rate = 0.42 kg/s
Temperature Inlet = 48.1°C	Temperature Inlet = 32.9°C

Table 3.1: Table of theoretical calculation

3.3 Theoretical Calculations

Distinct temperatures can lead to individual characteristics for their respective fluid values, which can be retrieved from the Properties Table. Here, h denotes the convection heat transfer coefficient for both the inner and outer surfaces of the tube, while U signifies the overall heat transfer coefficient. The hydraulic perimeter of an annular tube, determined through forced convection principles, is the result of subtracting the perimeter of the inner tube from that of the outer tube. Consequently, average water velocity and the Reynolds number can be calculated. A Reynolds number exceeding 10,000 suggests turbulence in the flow, while a value below 10,000 indicates laminar flow.

3.4 Modelling Work

The project entails the development of a 3D model for a double pipe heat exchanger. The specific fluids and materials that will be employed for both the heat exchanger shell and the body are considered to achieve the necessary maximum condensation heat transfer rate. The modelling task has been completed. To enhance heat transfer efficiency, the author is exploring designs that incorporate circular disc fins. The modelling is performed using SolidWorks, a 3D modelling program. The inner tube is designed to a scale of approximately 1100mm in length, while the outer tube measures 1000mm. To avoid complications from erroneous simulation components along the pipes, the author intends to keep the control volume of the heat exchanger compact. The models for the simulation work can be viewed in Figure 3.2.

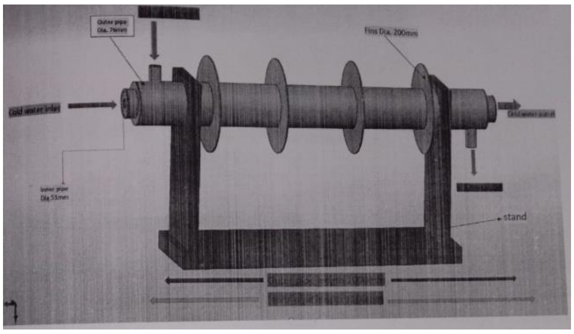


Figure 3.2: Designing in solid works

3.5 Experimental setup

We constructed a double-pipe finned heat exchanger that is force convected with porous material. A smaller inner pipe is placed concentrically within a larger outer pipe working as a double pipe finned heat exchanger.

• The inner pipe is a barrier for conduction, where a cold fluid enters through the inner pipe and the assisting fluid at a higher temperature passes around it in the annulus shaped region which has fins.

• Four fins in the shape of circular discs are employed and the fin has a diameter of 200mm.

• The outer diameter of the inner tube and the inner diameter of the outer tube is 51mm and 76mm respectively. The inner pipe and outer pipe have lengths 1100mm and 1000mm respectively.

• The joining of the outer tube to the circular disc fins is done by brazing.

Figure 3.11 Experimental setup of double pipe heat exchanger

The double pipe heat exchanger with concentric tubes was set up to conduct experiments. Hot water circulates through pipes that have an immersion rod linked to them. Cold water can enter the annular space at either end to allow the heat exchanger to operate as a parallel flow exchanger. For both pipes, the water mass flow rate is 0.42 kg/sec. First, to observe temperature effect on outer tube with four circular disc fins. Second, to observe temperature effect on middle height of four circular disc fins. Third, to observe temperature effect on full height of four circular disc fins.

Name of the Materials	Specifications Details
Annuals material	Aluminum
Outer diameter	76mm
Inner diameter	51mm
Tube Material	Aluminum
Length of the annulus tube	1100mm
Length of the outer tube	1000mm
Thermal conductivity of aluminum	251 W/m K

Table3.2: Table for material and specifications.

To perform experiment for different parameters like effect and variation of temperatures for the outer tubes, middle and full length on the fins, Temperatures of the outer tubes with Porus material and table fans can be measured using digital thermometers

4. RESULT AND DISCUSSION

The values received for the heat transfer estimation of a simple double pipe heat exchanger is compared with experimentally obtained data so as to validate the numerical results. Validation is done for Temperature's for the outer tubes is measurable with thermocouples at hot water inlet temperature of 48.1 degrees Celsius with mass flow rate of 0.42 kilograms per second and constant mass flow rate of 0.42 in the outer and inner pipes. Validation of rate of heat transfer and heat transfer coefficient is done at the inlet hot temperature of 48.1 degrees Celsius for parallel flow direction with outer tube and outlet Temperature's for hot water is 42.9 degrees Celsius and 34.8 degrees Celsius for cold water. (See in Table 4.1), (see in figure 4.1

Temperature for the outer tubes can be measured using thermocouples.			
T_1	T_2	T_3	T_4
$45.2^{o}C$	$45.1^{o}C$	$44.7^{o}C$	$44.3^{o}C$

Table4.1: Temperatures for the outer tubes

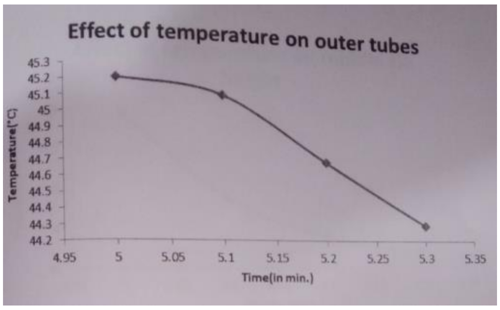


Figure 4.1: Effect of temperature on outer tube

Temperatures for the middle fin height can be measured using thermocouple's			
T_1	T_2	T_3	T_4
43.6°C	42.9°C	42.4°C	42.2°C

Table 4.2Temperature for the middle fin tube.

Checking how fast heat moves and how much heat is transferred coefficient at inlet hot temperature of 48.0°C for parallel flow direction with outer tube and outlet temperature of hot water and cold water is 41.8°C and 33.7°C (see in Table 4.2) and (see in Figure 4.2). Validation is completed for the Temperature's for the entire fin height, utilizing measuring thermocouples at the hot water inlet temperature of 48.0°C while changing the mass flow rate of 0.42 kg/s in the heat exchanger and maintaining a constant mass flow rate of 0.42 kg/s in the outer pipe. Validation is done for a cold water inlet temperature of 32.9°C by varying the mass flow rate, 0.42 kg/s in the annulus side of the heat exchanger, keeping constant mass flow rate of 0.42 kg/s in the outer pipe. Validation of rate of heat transfer and heat transfer coefficient at inlet hot temperature of 48.0°C for parallel flow direction with outer tube and outlet temperature of hot water and cold water is 41.6°C and 33.5°C (see in Table 4.3) and (see in Figure 4.3).

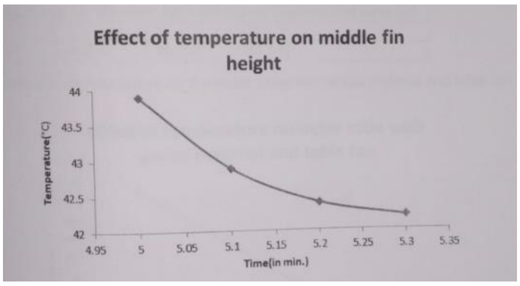


Figure 4.2: Effect of temperature on middle fin height.

Temperatures for the full fin height can be measured using thermo-couples.			
T_1	T_2	T_3	T_4
41.6°C	41.5°C	41.3^{c}C	40.1°C

Table 4.3: Temperatures for the full fin height.

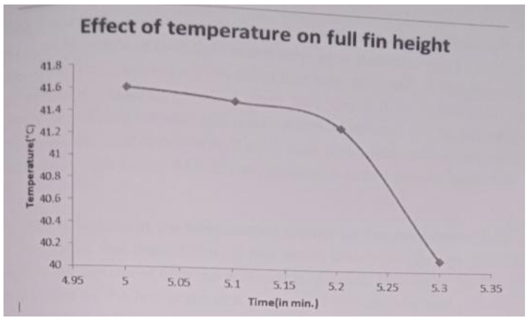


Figure 4.3: Effect of temperature on full fin height.

Temperatures for the outer tube with Porus material fan.			
T_1	T_2	T_3	T_4
40.9°C	40.3°C	39.7°C	39.1°C

Table 4.4: Temperatures for the outer tubes with Porus material and table fan

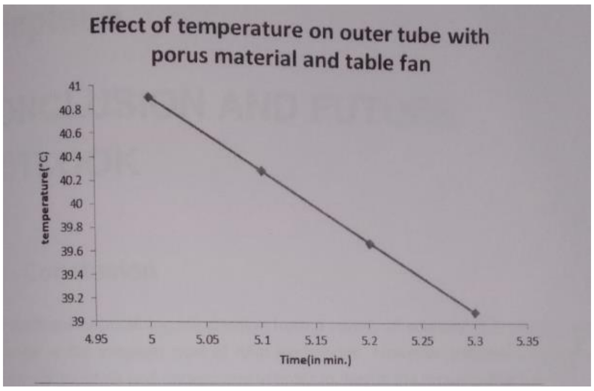


Figure 4.4: Effect of temperature on outer tube with Porus material and table fan

47.2°C by varying the mass flow rate, from 0.42 kg/s in the heat exchanger, keeping constant mass flow rate of 0.42 kg/s in the inner pipe. Validation for a cold water inlet temperature of 33.5°C by varying the mass flow rate, 0.42 kg/s in the annulus side of the heat exchanger, keeping constant mass flow rate of 0.42 kg/s in the outer pipe. Validation of rate of heat transfer and heat transfer coefficient at inlet hot temperature of 48.0°C for parallel flow direction with outer tube and outlet temperature of hot water and cold water is 40.5°C and 34.3°C (see in Table 4.4) and (see in Table 4.4). The difference in the temperature profiles for the heat exchangers can be seen. This shows that the addition of fins would also have positive improvements towards the heat transfer of both hot and cold fluid sides. This is due to the extended surface provided by the fins that helps in the heat transfer process. This extended surface provides a larger surface area and thus increase in heat transfer between those fluids.

5. CONCLUSION

After reading and obtaining information from a variety of sources, a double-pipe heat exchanger is the simplest type of heat exchanger. However, the basic concepts of heat transfer must be well understood in order to design the required high-density two-pipe heat exchanger with liquid. Involves the design of the inner tube to be considered which are the wings attached to the outer wall of the outer tube to improve heat transfer. Some water-like parameters are used as a constant parameter taking the liquid properties at 48.1 °C and 32.9°C respectively. The conclusions of this project may be abbreviated as follows:

1. The primary goal is to examine and study the fluid motion within the double pipe heat exchangers with respect to the finned outer tube design.

2. Prior to the implementation of the analysis, the entire model was created in a drop down 3D modeling application known as solid works.

3. This observation gives some knowledge of the enhancement made at the outer fins tubes in a parallel flow double pipe heat exchanger.

4. The temperature profile for the outlet's inner and outer fluids was measured for both types of 3D models: with a tube with fins and simple tube without a tube with fins. As it is known, in a double pipe heat exchanger, when the outer fluid is the hot fluid, the maximum outlet temperature (hot) of the outer fluid is 42.9°C when no fins are used, while for the finned design it is 41.6°C.

5. Some recommendations for improvements of the simulation is to use more various flow rates for each fluid in order to find better heat transfer profiles along the tubes. To conclude, in order to improve the heat transfer rates of the heat exchanger, there is various methods to enhance it such as using enhanced surface, fining the tubes and Porus material with table fan to the heat exchanger.

6. REFRENCES

Ameen, Sameer H. and Deyaa Mohammed N. Mahmood. "Experimental and Numerical Investigation for Structural and Thermal Characteristics of Externally Finned Double Piped Heat Exchanger." Int. J. of Eng. Res. Tech, 3 (2014).
Bhola, Mayank Kumar Singh, and Dr. Satyendra Singh. "Heat Transfer Enhancement in Concentric Tube Heat Exchanger in Ansys Fluent." International Journal of Engineering Research Technology (IJERT) 4, (2015) https://doi.org/10.21275/ijertv41s040092. licensed under a Creative Commons Attribution 4.0 International License.
Dr. Y. Krishna. "CFD Analysis and Performance of Parallel and Counter Flow in Concentric Tube Heat Exchanger." International Journal of Engineering Technology and Research 2 no. 11 (2017):709-727.

Duan et al. "Numerical and Experimental Study on Using Internal Fins in a Double Tube Structure." International Research Journal of Engineering and Technology, 5 no. 4, (2018):4415-4419.

Hameed, Vinous M. "Experimental Study of Turbulent Flow Heat Transfer and Pressure Loss in a Double". Journal of Energy and Environment 7 (2015):149-158.

Hasan et al. "Study of Heat Transfer Enhancement in Double Pipe Heat Exchanger with Implemented Helical Wire." Progress in Aeronautics Science and Technology 1 no. 1 (2017):1-12.

BIBLIOGRAPHIES

Santosh Kumar
Assistant Professor
Axis Institute of Technology and Management
Kanpur affiliated from AKTU Lucknow (UP)
INDIA.

Aditya Singh
U.G Student
Axis Institute of Technology and Management
Kanpur affiliated from AKTU Lucknow (UP)
INDIA.

Jitesh Kumar
U.G Student
Axis Institute of Technology and Management
Kanpur affiliated from AKTU Lucknow (UP)
INDIA.