Experimental and CFD Simulation in Modified heat Exchanger with Baffles

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Abstract: ***In modern industrial era heat transfer management has been given a prime importance in order to achieve an efficient system. The shell and tube type heat exchangers are the most prominently used heat transfer equipment's. The design of shell and tube heat exchanger requires a balanced approach between the thermal design and pressure drop.. Water is the working fluid in the heat exchanger and metal-based heat exchanger. Experimental set up will be manufactured with minimum possible dimensions to reduce the cost. Thermocouples are used to measure the temperature of water at the inlet and outlet. The flow control valves are used to control the flow rate. The effect of mass flow rate of fluids on heat exchanger was studied. CFD simulation technique is used to study flow rate across shell and tube heat exchanger along with standard design in CATIA software. The result & conclusion was drawn after the experimental resting. Experimental validation of CFD results is to be performed.***

Keywords: heat transfer, shell and tube heat exchanger, thermal design

1. Introduction

In the contemporary industrial landscape, effective heat transfer management stands as a pivotal aspect for achieving optimal system efficiency. Among the various heat transfer equipment available, shell and tube heat exchangers hold a predominant position. The design of these heat exchangers necessitates a meticulous balance between thermal efficiency and pressure considerations. Water functions as the primary working fluid within these heat exchangers, which are predominantly constructed using metallic materials. To minimize costs, the experimental setup is designed with compact dimensions. Thermocouples are employed to gauge the water temperature at both the inlet and outlet points. Flow control valves are utilized to regulate the flow rate. Optimizing heat exchanger design holds significant importance in current research. The modification of existing heat exchangers aims to enhance the mass flow rate while considering the pressure drop within the flowing fluid across baffles. Baffles serve a dual role, providing support for tubes in the shell and guiding the continuous flow of fluids.A classic example of a heat exchanger is evident in internal combustion engines where engine coolant circulates through radiator coils, and air passing over the coils cools the coolant while warming the incoming air. Another instance is the heat sink, a passive heat exchanger transferring the heat generated by electronic or mechanical devices to a fluid medium, typically air or liquid coolant. Heat exchangers facilitate the transfer of heat between two or more fluids, essential in both cooling and heating processes. These fluids can be separated by a solid barrier to prevent mixing or can come into direct contact. They find wide application in space heating, refrigeration, air conditioning, power stations, chemical and petrochemical plants.

2. Literature Review

Effect of Different types of Baffles on Heat Transfer & Pressure Drop of Shell and Tube Heat Exchanger: A review, Swapnil S.Kamthe and Shivprakash B.Barve, International Journal of Current Engineering and Technology E-ISSN 2277 – 4106, P-ISSN 2347 – 5161, ©2017 INPRESSCO. This paper provides an overview of exploratory research aimed at examining the influence of different baffle types on pressure loss and heat transfer within a heat exchanger. Baffles are fundamental components in the design of Shell and Tube Heat Exchangers (STHE), serving to support tube bundles and control flow speed on the shell side. Various types of baffles, such as segmental, flower, ring, trefoil-hole, plate, doughnut, and helical, are employed in STHEs Thermohydraulic Analysis of Shell-and-Tube Heat Exchanger with Segmental Baffles, Amarjit Singh and Satbir S. Sehgal, Hindawi Publishing Corporation ISRN Chemical Engineering Volume 2013, Article ID 548676, 5 pages.In this study it introduces the experimental analysis was performed on the shell- and-tube type heat exchanger containing segmental baffles at different orientations. Three angular orientations (θ) 0∘, 30∘, and 60∘ of the baffles were analysed for laminar flow having the Reynolds number range 303–1516. It was concluded that, with increase of Reynolds number from 303 to 1516, there was a 94.8% increase in Nusselt number and 282.9% increase in pressure drop. Due to increase of Reynolds number from 303 to 1516, there is a decrease in nondimensional temperature factor for cold water (ω) by 57.7% and hot water (ξ) by 57.1%, respectively. The heat transfer coefficient increases with increase in Reynolds number in shell-and-tube heat exchanger for both hot fluid inlet and cold fluid inlet. The Nusselt number increases with increase in Reynolds number in shell-and-tube heat exchanger for both hot fluid inlet and cold fluid inlet. The value of LMTD increases with increase in Reynolds number from 303 to 1516. The value of temperature constants ξ and ω decreased with increase in Reynolds number. The value of pressure drop gradually increases with increase in Reynolds number.

Experimental investigation of shell side heat transfer and pressure drop in a mini-channel shell and tube heat exchanger, Hasan Kücük, Murat Ünverdi , Mehmet Senan Yılmaz , International Journal of Heat and Mass Transfer 143 (2019) 118493.In this literature it represents research on shell side heat transfer and pressure drop of a mini-channel shell and tube heat exchanger (MC-STHE) designed and manufactured using Kern's method. A shell with an inner diameter of 30 mm and four horizontally oriented transverse baffles with a 25% baffle cut were used in the mini-channel heat exchanger. Using rotated triangular layout, the tube bundle was composed of 13 mini-channel copper tubes with an outer diameter of 3 mm and a length of 240 mm. The shell-side Reynolds numbers ranged from 250 to 2500 while the tube-side Reynolds number was kept constant at 5900 based on the experimental surface flow area goodness factor (j/f) results. The shell side convective heat transfer coefficients and total pressure drop results were compared with correlations for macro tubes commonly used in the literature. The experimental convective heat transfer coefficients were in good agreement with the Kern design, VDI-HA and McAdam's correlations within the Reynolds numbers ranging from 250 to 2500. The experimental total pressure drop of the MC-STHE was 2.3 times higher than that of macro tube heat exchangers. In addition, the Nusselt number and Colburn factor correlations were proposed for the estimation of shell side convective heat transfer coefficient in MC-STHEs. The optimum working range for shell side is Re < 1000 according to surface flow area goodness factor by which heat transfer and hydrodynamic effects in MC-STHE are evaluated together.

3. Problem Definition

Heat exchangers stand as integral components within various industries including power plants, process industries, and oil refining, among others. Specifically, shell and tube heat exchangers (STHE) represent 40% of the equipment used across diverse industrial sectors. Hence, there is a crucial necessity to concentrate on enhancing the performance of this particular device

4. Objectives

1) The design of the shell-and-tube heat exchanger is created using Catia V5R20 software.
2) A comparison between a conventional single plate and a new type of porous baffles plate in the shell and tube heat exchanger is conducted through CFD simulations in ANSYS Fluent software
3) Shell and tube heat exchanger with a conventional single plate and a new type of porous baffles plate is designed and tested by compared using CFD simulation in ANSYS Fluent software.
4) To understand the effect of baffle plate in Shell and tube heat exchanger for improvisation of heat transfer rate.
5) Compare experimental and CFD result of Shell and tube heat exchanger with a conventional single plate and a new type of porous baffles plate.

5. Methodology

Step 1 Initiated the project by conducting a comprehensive literature survey to gather relevant research papers. This served to familiarize with shell-and-tube heat exchangers and the study of baffle plates

Step2:- Identified the necessary components of the shell-and-tube heat exchanger relevant to our project

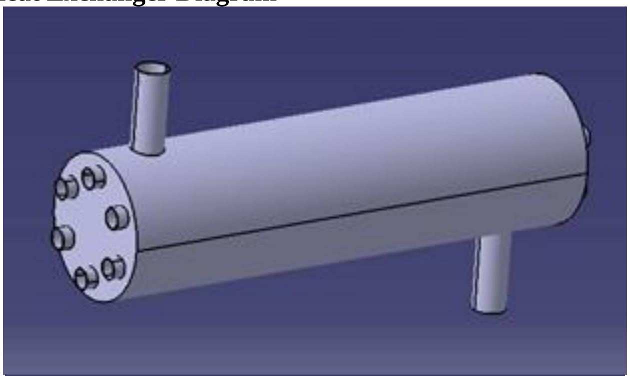
Step 3:- Utilized CATIA software to create the 3D model and technical drawings of the selected components

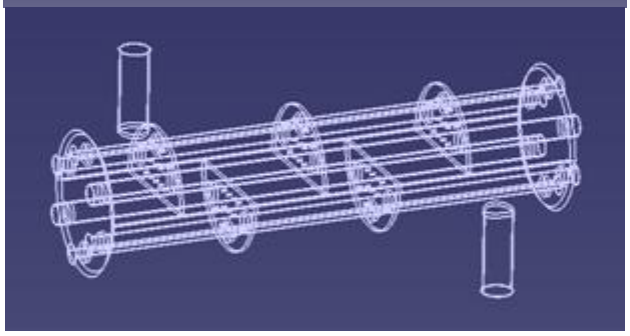
Step 4:- Utilized ANSYS Fluent software to conduct Computational Fluid Dynamics (CFD) simulations on the single plate and the new porous baffles plate in the shell-and-tube heat exchanger

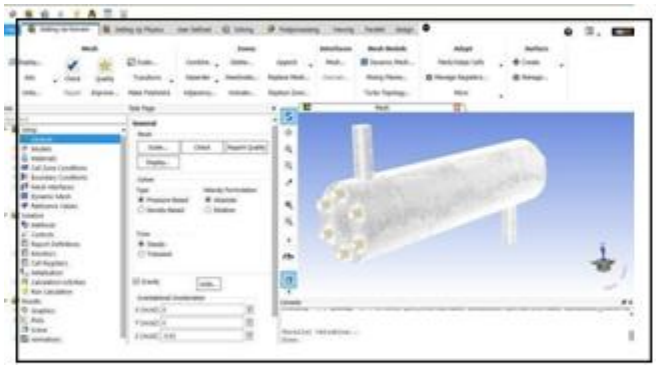
Step 5:- Implemented the physical manufacturing of the shell- and-tube heat exchanger, followed by recording experimental data

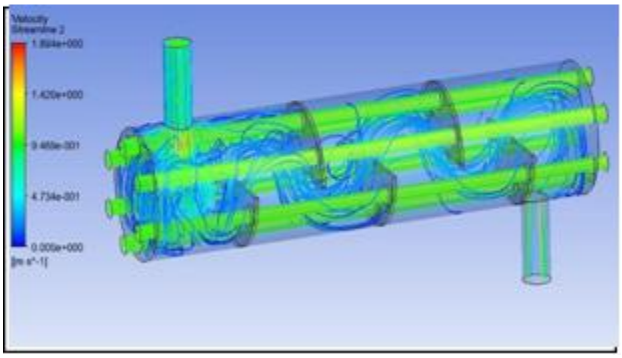
Step 6:- Conducted a comparative analysis between the experimental findings and the CFD results, leading to the drawing of conclusions. If feasible, the results should be presented and printed in a suitable format, with the title placed above the table

Heat Exchanger Diagram









6. Calculation

T1 = Hot Water Inlet Temperature
T2 = Hot Water Outlet Temperature
T3 = Nano fluid Inlet Temperature
T4 = Nano fluid Outlet Temperature
The measured mass flow rates are as follows: Mass Flow rate of water = 1.1 m/s Mass flow rate of Nano fluid = 1 m/s

Calculations for Nano Fluid Used:
Design Parameters- Inner Tube Material = Mild Steel (M.S.)
Water Tube Diameter = D = 50 mm
Tube Length = 60 cm = 0.6 m
Water Flow Velocity = mw = 1.1 m/s
Specific Heat of Water = Cpw = 4.186 * 10^3 J/kgK
Nano Fluid Tube Diameter = 100 mm
Nano Fluid Tube Length = 50 cm = 0.5 m
Specific Heat of Nano Fluid = Cpc = 765 J/kgK
Nano Fluid Flow Velocity= Cpn = 1 m/s
Converting the mass flow rate of water from m/s to kg/s is achieved by the formula:
$m = \rho * V * A$
where m represents the mass flow rate in kg/s,
Density of water is 1000 kg/m³
Water Flow Velocity = 1.1 m/s
Flow Area = π/4 * d^2 = π/4 * 50^2 = 1.96 * 10^-3 m.

Therefore, m = 1000 * 1.1 * 1.96 * 10^-3 m = 2.16 kg/s

Components Used

Thermocouple
A thermocouple is an electrical device composed of two dissimilar electrical conductors forming junctions at different temperatures

Nano Fluid
Nano fluid refers to a fluid containing nanometer-sized particles, known as nanoparticles. These fluids are specifically engineered colloidal suspensions of nanoparticles within a base fluid. Nanoparticles utilized in Nano fluids are commonly made of metals, oxides, carbides, or carbon nanotubes. Base fluids used include water, ethylene glycol, and oil.

Pump:
A pump is a mechanical device that moves fluids (liquids or gases), and sometimes slurries, through mechanical action. Pumps are generally categorized into three major groups based on the method they employ to move the fluid: direct lift, displacement, and gravity pumps

7. Conclusion

Employing the aforementioned configuration allows for the augmentation of heat transfer rates in a Shell & Tube Heat Exchanger through the application of Computational Fluid Dynamics (CFD) analysis

References

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[4] Experimental investigation of shell side heat transfer and pressure drop in a mini-channel shell and tube heat exchanger," Hasan Kücük, Murat Ünverdi, Mehmet Senan Yılmaz, International Journal of Heat and Mass Transfer 143 (2019) 118493.