IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429

Volume 6, Issue 17, April 2026

Impact Factor: 8.2

Simulation of STHE

Prof. G. S. Shendre, Dr. M. R. Dharme, Chetan Wanare

DRGITR Amravati

Abstract: *This project focuses on the thermal design, modelling, and performance analysis of a shell and tube heat exchanger using Kern's method, followed by computational validation through CFD simulation. The primary objective is to design an efficient heat exchanger for cooling benzene using water as a coolant, ensuring optimal heat transfer with acceptable pressure drops. Initially, thermal design calculations were carried out using Kern's method based on given process parameters such as mass flow rate, inlet and outlet temperatures, and thermophysical properties of fluids. Key design parameters including heat duty, logarithmic mean temperature difference (LMTD), overall heat transfer coefficient, and required heat transfer area were determined. The mechanical design was further developed by selecting appropriate tube dimensions, tube layout, number of passes, shell diameter, and baffle configuration. A three-dimensional model of the shell and tube heat exchanger was then created using CATIA software, incorporating all critical components such as tubes, shell, baffles, and nozzles. The designed model was subsequently imported into ANSYS for computational fluid dynamics (CFD) analysis. Simulation was performed to study temperature distribution, velocity profiles, pressure drop, and flow behaviour inside the exchanger.*

Keywords: Shell-and-tube heat exchanger, Kerns method, Modelling & Drafting, ANSYS Analysis, Thermal-hydraulic design

I. INTRODUCTION

Background

Heat exchangers are essential thermal systems used across industries such as chemical processing, petroleum refining, power generation, and HVAC applications. Among the various types, shell-and-tube heat exchangers (STHEs) are the most widely adopted due to their mechanical robustness, ability to handle high pressures and temperatures, and flexibility in design. Despite their apparent geometric simplicity, designing an efficient STHE is a complex task. The designer must balance multiple, often conflicting requirements: achieving the desired heat duty, maintaining allowable pressure drops, minimizing material cost, and ensuring uniform flow distribution. THEORY OF SHELL-AND-TUBE HEAT EXCHANGER 1.2 Introduction to Heat Exchangers Heat exchangers are thermal devices used to transfer heat between two or more fluids at different temperatures, without allowing them to mix with each other. They are among the most widely used components in engineering systems and play a critical role in energy conversion, energy conservation, and thermal management across various industries.

Introduction to Heat Exchangers

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Classification of Heat Exchangers

Heat exchangers can be classified in several ways based on their construction, method of heat transfer, flow arrangement, and phase of the working fluids. Proper classification helps in selecting the most suitable heat exchanger type for a given industrial application.

(a) Direct-Contact Heat Exchangers In direct-contact heat exchangers, the hot and cold fluids come into direct physical contact, and heat is transferred through direct mixing. These heat exchangers are generally simple in construction and have high heat-transfer rates. However, they are limited to applications where fluid mixing is permissible. Cooling towers and spray condensers are common examples.

(b) Indirect-Contact Heat Exchangers In indirect-contact heat exchangers, the hot and cold fluids are separated by a solid wall, and heat transfer occurs through conduction and convection. There is no mixing of fluids, which makes these heat exchangers suitable for most industrial processes. Shell-and-tube heat exchangers, plate heat exchangers, and doublepipe heat exchangers fall under this category.

Shell-and-Tube Heat Exchanger: Construction

A shell-and-tube heat exchanger (STHE) is one of the most widely used types of heat exchangers in industrial applications due to its simple construction, mechanical strength, and ability to operate under high pressure and temperature conditions. The basic construction of a shell-and-tube heat exchanger consists of a cylindrical shell enclosing a bundle of tubes through which one of the working fluids flows, while the other fluid flows over the tube bundle inside the shell

Working Principle of Shell-and-Tube Heat Exchanger

The working principle of a shell-and-tube heat exchanger is based on the transfer of thermal energy between two fluids at different temperatures through a solid separating wall. One fluid flows inside the tubes, known as the tube-side fluid, while the other flows over the outer surface of the tubes within the shell, referred to as the shell-side fluid. Heat is transferred from the hotter fluid to the colder fluid due to the temperature difference between them. In a typical shell-and-tube heat exchanger, the hot fluid may be passed either through the tubes or through the shell, depending on design requirements, fluid properties, pressure levels, and fouling considerations. The cold fluid flows on the opposite side, ensuring effective heat exchange without direct contact between the two fluids. The tube-side fluid enters the heat exchanger through the inlet nozzle and flows through the tubes. Depending on the number of tube passes, the fluid may change direction one or more times before exiting through the outlet nozzle. Multiple tube passes increase fluid velocity, which enhances the tube-side heat-transfer coefficient but also results in higher pressure drop. The shell-side fluid enters the shell through a separate nozzle and flows across the tube bundle. Baffles installed inside the shell force the shell-side fluid to flow in a zig-zag or crossflow pattern rather than flowing straight through the shell. This redirection increases turbulence and improves heat-transfer performance by continuously disrupting the thermal boundary layer formed on the tube surfaces.

Tube Layout and Tube Pitch

The arrangement of tubes inside the shell, known as the tube layout, plays a crucial role in determining the thermal and hydraulic performance of a shell-and-tube heat exchanger. Tube layout directly affects the heat-transfer area, shell-side flow pattern, pressure drop, and ease of maintenance. Therefore, careful selection of tube layout and tube pitch is essential during the design stage.

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