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DESIGN AND THERMAL ANALYSIS OF A HEAT EXCHANGER

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ABSTRACT

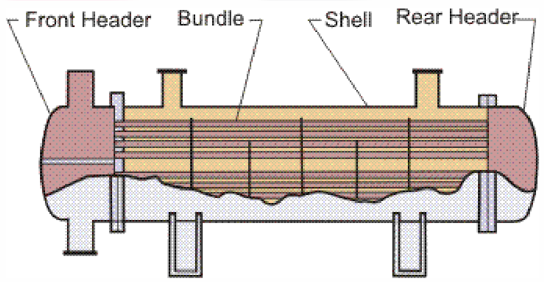
Devices called heat exchangers are used to effectively transfer heat between different media. The media might be positioned closely together or divided by a strong wall to prevent mixing. They are often used in the following sectors: natural gas processing, sewage treatment, power plants, petrochemical and chemical industries, refrigeration, air conditioning, and room heating. Entropy, which is a measure of the number of possible configurations for a system, is frequently interpreted as an indicator of disorder or as a gauge of the system's progress toward thermodynamic equilibrium. An isolated system's entropy never drops because it naturally moves toward thermodynamic equilibrium, the state of maximum entropy.

Constrained thermodynamic optimization is utilized in this study to reduce entropy generation in heat exchangers. The project's purpose is to design and build a counter-low shell and tube heat exchanger with an entropy reduction strategy.This study investigated the heat transfer coefficient and pressure drop of mild steel, stainless steel, and nickel tubes on the shell and tube sides of a heat exchanger. After creating the shell and tube heat exchanger model, thermal properties will be evaluated using FEA-based thermal research.

INTRODUCTION

General Description

Because of its broad tolerance for temperatures and pressures, the shell and tube heat exchanger is one of the most popular forms of exchangers. A shell and tube are formed by arranging many tubes within a cylindrical shell. exchanger. It shows a sample of a typical unit from a petrochemical factory. Heat can transfer between the two by flowing one fluid through the tubes and the other over their surface. Fluids can flow in a cross-counter or parallel pattern and consist of one or two phases.



Four fundamental parts make up a The shell and tube exchanger features a front header that permits fluid to enter the tube side. Also known as the Stationary Header. The rear header is where fluid exits or returns to the front header in exchangers with numerous tubeside channels.

The tubes, tube sheets, tie rods, baffles, and other pieces that keep the bundle together comprise the tube bundle.

- The tube bundle is located within the shell.

TEMA (Designations of Tubular Exchanger Manufacturers)

Because shell and tube exchangers are so often used, the Tubular Exchanger Manufactures Association (TEMA) established a standard designation for them. This phrase contains occurrences and meanings of letters. The first letter represents the kind of front header, the second the type of shell, and the third the type of rear header.

SURVEY OF LITERATURE

A review of the literature is given in this chapter on several topics related to the current endeavor, including heat exchanger analysis, compact Heat exchangers, shell and tube heat exchangers, and the development of ANN models for thermal systems.

The Heat Exchanger Analysis (2.1)

Several studies have been conducted to identify the relationships that improve the performance of tiny heat exchangers. The most prevalent instances include evaporators (Kandlikar 1991), heat exchangers in moist situations (McQuiston 1978), and single phase working conditions (Gray and Webb 1986). According to the review's findings, the heat exchangers' size is optimal when thermal comfort levels are met.

The review's findings showed that the presence of baffles in heat exchangers significantly reduces the fluid's pressure during heat transfer. Fins, dimples, full-length twisted tapes, and vortex generators are some ways to get around these restrictions. Furthermore, the review's findings demonstrated how crucial it is to have appropriate fluid flow designs for small heat exchangers. Reynolds number (Re), separating wall thickness (ts), and thermal conductivity ratio (Kr) are the factors that determine axial heat conduction.

In 2013, Nopparat Katkhawa and colleagues examined various dimple designs and intervals. They assessed the quality of heat transmission when there was external movement. As the air moves across the heated surface, dimples are formed. The air stream moves at a pace of one to five meters per second. Both on dimpled surfaces and in the airstream, temperatures were recorded. Since adding baffles, fins, and turbulators as part of normal improved heat transfer techniques significantly lowers the pressure in the stream, dimples are preferable. In this study, two dimple layouts with different dimple pitches—inline and staggered—are compared and examined. The dimple pitches have a spacing of SL/Dminor = 1.875; ST/Dminor = 1.875. proven to have the highest heat resistance, outperforming flat plates by approximately 21.7%.

Car exhaust heat exchangers are utilized in thermoelectric generators, and Shengqiang Bai et al. (2014) examined them. Pressure drop in the fluids is one of the main drawbacks of heat recovering exchangers. Comparisons between six distinct heat exchanger models have been conducted. A 1.2L gasoline container was used for the trials. According to the study's findings, exchangers with seven baffles allowed for the most heat transfer at a significant fluid pressure decrease.

Vahabzadeh et al. (2014) conducted an analytical investigation of porous pin fins with various sections in completely saturated conditions. This study summarises the results of experiments into temperature distribution, efficiency, heat transfer rate, and porous pin fin optimisation in totally wet settings. Fins manufactured of aluminium with insulated tips are utilised. The fin's heat transfer coefficient is impacted by temperature. The temperature distribution is analytically solved using the Least Squares Method (LSM), the Darcy model, and the energy balance. The thermographical and geometric characteristics, including relative humidity, porosity, Biot number, and geometry power index. Subsequent deductions are made. LSM is an effective method for addressing engineering difficulties.Temperature distribution and relative humidity have a direct correlation. The most common approaching fin profiles are concave parabolic and rectangular.

Although the technique used in this work is limited to Shell-and-tube heat exchangers, it may easily be extended to various compact heat exchanger designs. including twin pipe, plate and frame, and others. Christopher Ian Wright studied the effectiveness of a Light End Removal Kit (LERK) in regulating the flash point temperature of the heat transfer fluid in 2014. Light ends from fluids used in heat transmission are collected via heat exchangers. This is a major concern since the light-ends may catch fire. To prevent the growth of the light ends, an LERK has been introduced. With the LERK's assistance, the mean closed flash point temperature appears to be stabilizing.

METHODS AND OBJECTIVES

This project's goal is to effectively construct a heat exchanger with the intention of minimizing entropy. Reliability, simplicity, affordability, and practicality are required of the mechanism. Constrained thermodynamic optimization, which enables the measurement of entropy inside the heat exchanger is the device's intended use. This technology is also intended to increase the temperature and conducive conditions.

The approach taken in the design process was to employ current, standard components rather than creating every component from scratch. One benefit of this approach is that it saves a ludicrous amount of money and entropy level to examine each part's integrity because they have already demonstrated their value in

The concept was originally based on an existing heat exchanger, with small modifications made to meet our needs. The first idea was to use the fluid between the wall, shell, and pipes set, lowering the system's entropy levels at each level.

The subsequent circumstances led to the testing of this mechanism.

Capabilities summary

It is constantly updated with new features, just like any other application. The information below is intended to offer an overview of the product's capabilities rather than detailed details on each feature.

Software package Catia Elements belongs to the CAID/CAD/CAM/CAE category, along with other related products on the market today. A single database strategy is integrated with extensive rule-based design capabilities through Catia Elements, a parametric and feature-based modeling architecture.

Technical Drafting

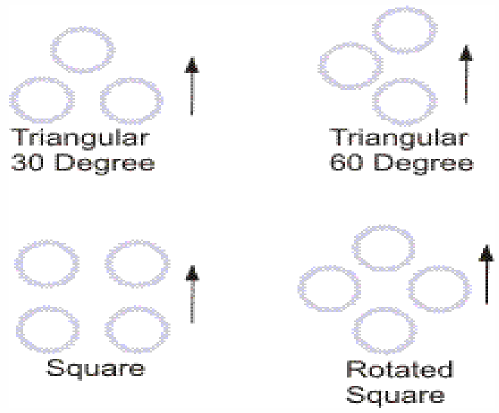
Catia Elements offers a number of tools to help you create a detailed digital depiction of the product you're designing. In addition to conventional geometry tools, it can generate geometry for additional integrated design disciplines, including precise electrical standards and industrial and standard pipe construction. Accessible tools facilitate cooperative creation as well. A variety of idea design tools that offer draft Industrial Design concepts can be employed later on while engineering the product. They offer a wide range of freeform surface tools, point cloud data reverse engineering, and industrial design concept drawings.

THE PROJECT'S GEOMETRIC APPROACH

Alternative Geometric Shapes

Pitching and tube diameter arrangement

The two most popular tube diameters are 25.4 mm (1 in) and 19.05 mm (0.75 in). with a range of 12.7 mm (0.5 in) to 50.8 mm (2 in). On the tube sheets, the tubes are arranged in triangle or square configurations.



Square shapes are required if mechanical cleaning requires access to the tube surface. The design of the triangle allows for additional tubes being installed in a certain location. The smallest Tube pitch refers to the The distance between tubes measured from centre to centre. The tube spacing is dictated by its pitch to diameter ratio, which is typically 1.25 or 1.33. To clean, square tubes must be at least 6.35 mm (0.25 in) apart.

DESIGN PRINCIPLES FOR SHELL AND TUBE TYPE HEAT EXCHANGERS

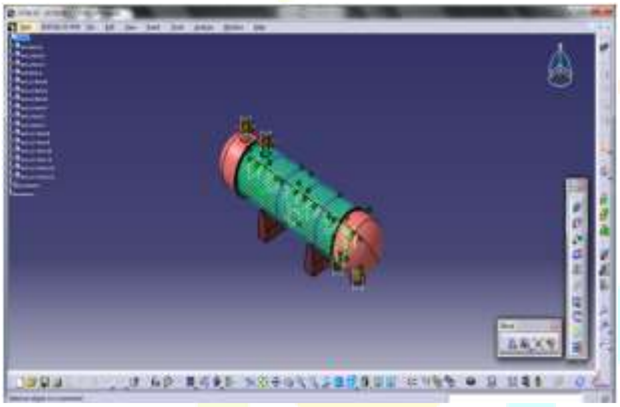
A Brief Overview of CATIA

Dassault Systems, a French business, is the developer of the commercial CAD/CAM/CAE software suite known as CATIA, or Three-dimensional Interactive Application Assisted by Computer. There are several platforms where you may access the program. The foundation of Dassault

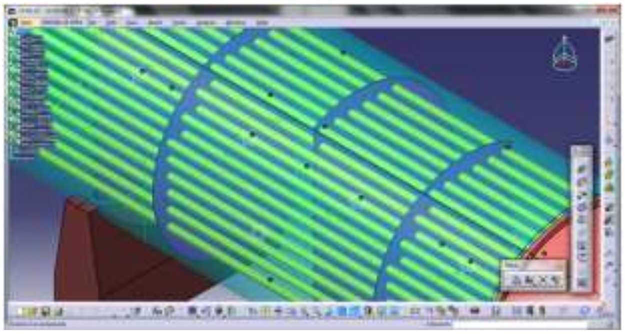
Systems' product lifecycle management software is CATIA, which is integrated into C++.

Shell and tube heat exchanger modeling in CATIA V5

The heat exchanger was constructed utilising a shell and tube design using CATIA V5. This software is used by several sectors, including as consumer products, heavy engineering, automotive, and aerospace. This is an extremely effective program for constructing complex 3D objects. It works with CATIA Version 5 and may be used to create assemblies and parts.Below is a comparison of the exact same CATIA V5 R20 3D model and 2D sketch model. Measurements are extracted. CATIA V5 is used during the 3D model design process. This software is meant to be used for testing.



Model Design for a Shell and Tube Heat Exchanger Using CATIA-V5



the working area and mechanism are arranged in CATIA-V5.

ANALYSIS OF SHELL AND TUBE-TYPE HEAT EXCHANGER

How to Perform FE Analysis Employing ANSYS

ANSYS is used to study Heat exchangers of the shell and tube type. By applying moments at the fluid's circulation site—the axis we need to specify—the assembly may be completed. Completing the assembly is not mandatory. Lower limbs serve as the attachment points.

6.2 Preprocessor

- At this juncture, the subsequent activities were executed:
- Importing files using the ANSYS window

  Step > File Menu > Import > Select the file saved from CATIAV5R20 by clicking "Browse" in the dialog box that appears after clicking "OK." To import the file, click OK.

Ansys import panel.

Meshing:

"Grid generation" is a phrase that's frequently used interchangeably. Rendering on a computer screen for computational fluid dynamics or finite element analysis are common applications. Although there are many other model formats that may be used as input, some popular. With contributions from computer science, engineering, and mathematics, the topic is very multidisciplinary.For finite element analysis, three-dimensional meshes have to be built using hexahedra, pyramids, prisms, or tetrahedra.

Finite Element Method:

The finite element method (FEM) is a numerical approach used in mathematics to approximate solutions to boundary value issues. It achieves a stable solution by minimising an error function using variation techniques, often known as the Calculus of Variations. Finite element modelling (FEM) refers to any strategies for linking numerous basic element equations across a number of tiny subdomains, known Finite elements are used to model a more difficult problem across a larger region.

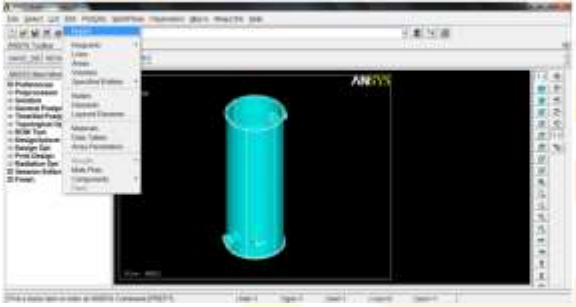


Fig: Using the menu bar to reposition the component (Refresh).

Fig: It is acceptable to provide preferences to the thermal solid component.

Fig: Enter using the preprocessor to choose the attributes of the Material Model.

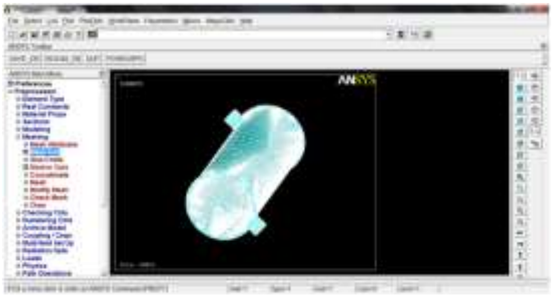


Fig: going into the meshing preprocessor.

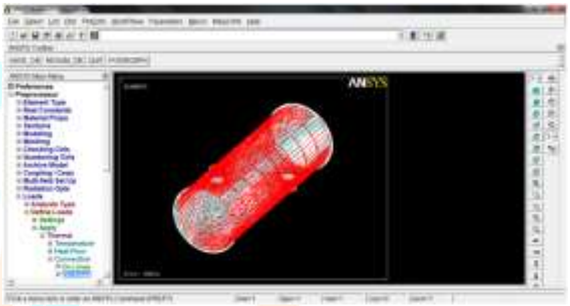


Fig: entering the element's force and moment preprocessor.

DISCUSSION ON ANALYSYS RESULT

Results of Nodal Temperature:

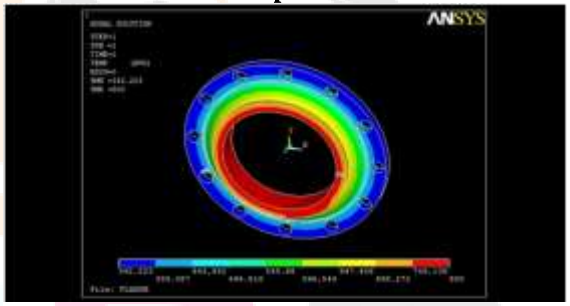


Fig: 7.1: FLANGE's Nodal Temperature

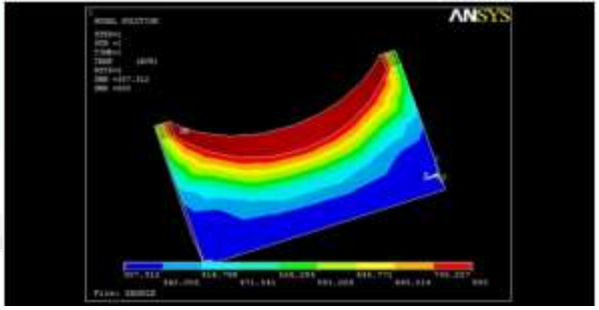


Fig: 7.2: SADDLE's Nodal Temperature

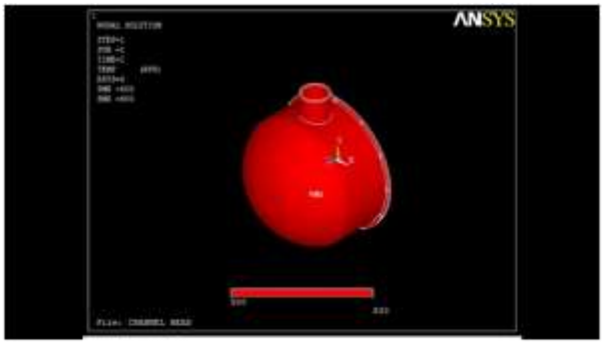


Fig: 7.3: Temperature Nodal of the Canal Head

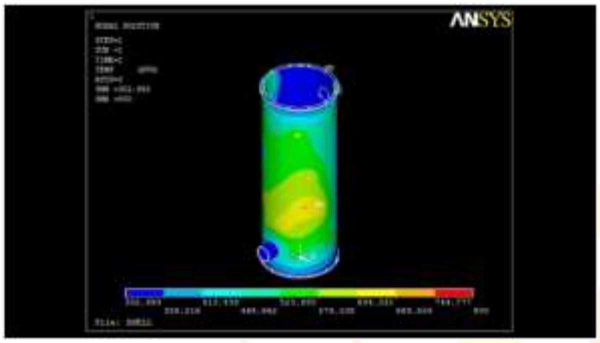


Fig: 7.4: Nodal Temperature ofSHELL+ TUBES BUNDLE(MS)

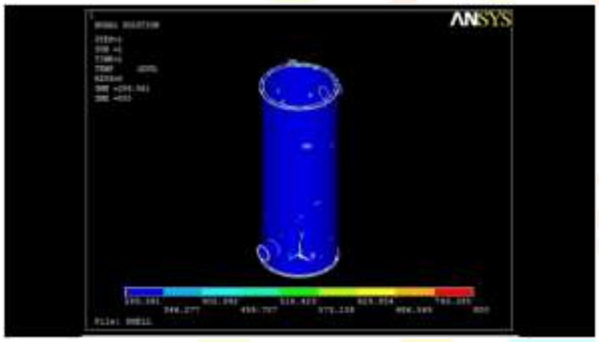


Fig: 7.5: The SHELL+ TUBES BUNDLE's nodal temperature (NI)

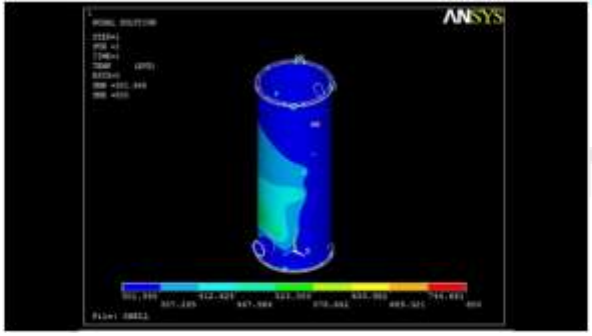


Fig: 7.6: N The average temperature of the Shell+ Tubes Bundle (SS)

7.2 Results of Thermal Gradient:

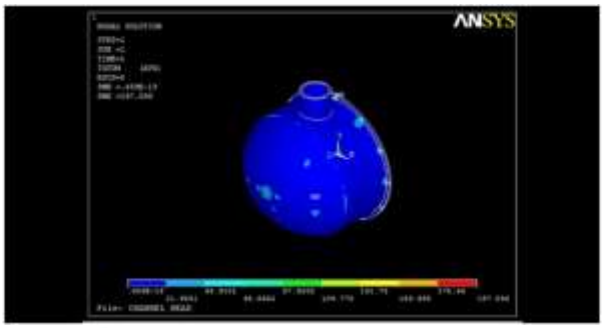


Fig: 7.18: Channel Head Thermal Gradient Analysis

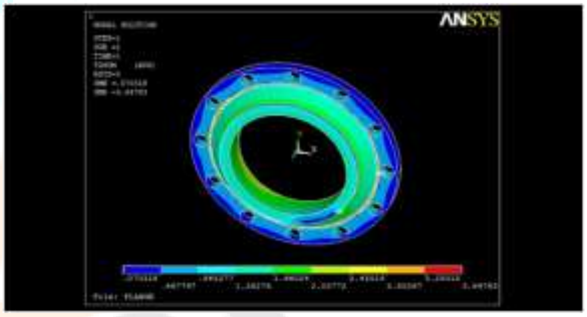


Fig: 7.19: Thermal Gradient Examination of the Flanc

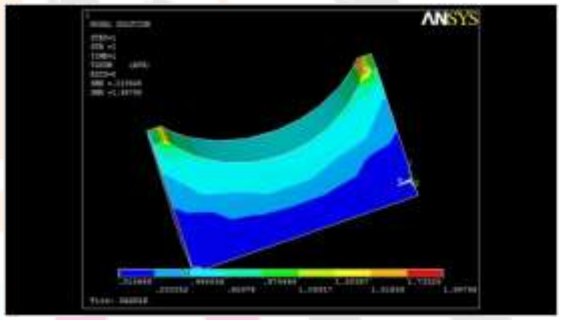


Fig: 7.20: The SADDLE's Mean Gradient Analysis

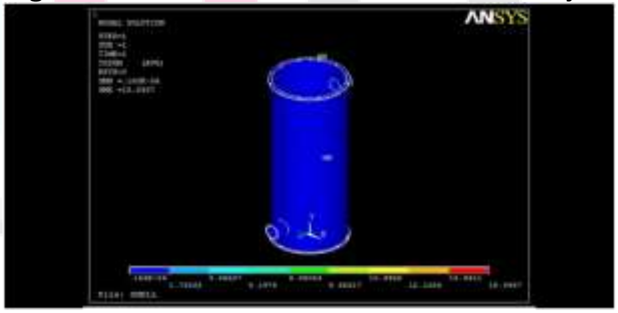


Fig: 7.21: Analysis of the Shell+ Tubes Bundle's Thermal Gradient (MS)

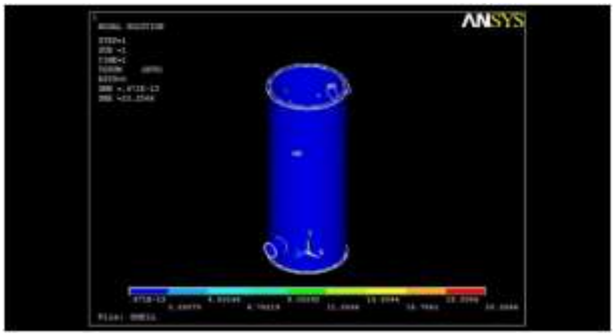


Fig: 7.22: Analysis of the Shell+ Tubes Bundle's Thermal Gradient (NI)

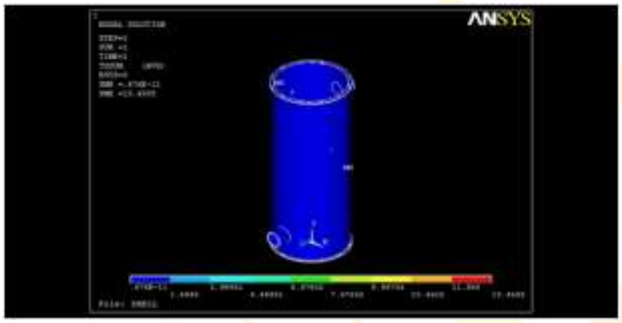


Fig: 7.22: Analysis of the Shell+ Tubes Bundle's Thermal Gradient (SS)

6.3 Results of Thermal Flux:

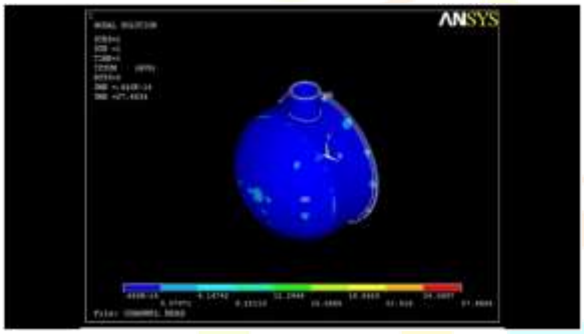


Fig: 7.35: Th Analysis of the Channel Head's Thermal Flux

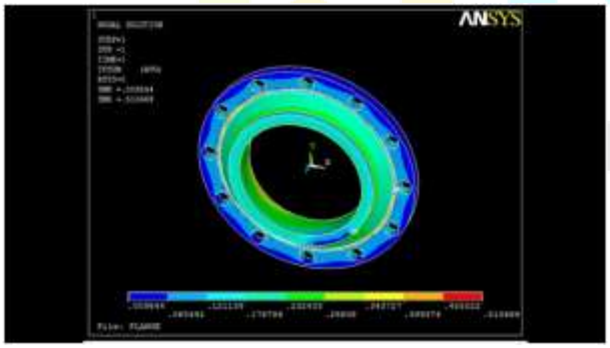


Fig: 7.36: Thermal Flux Evaluation of the Edge

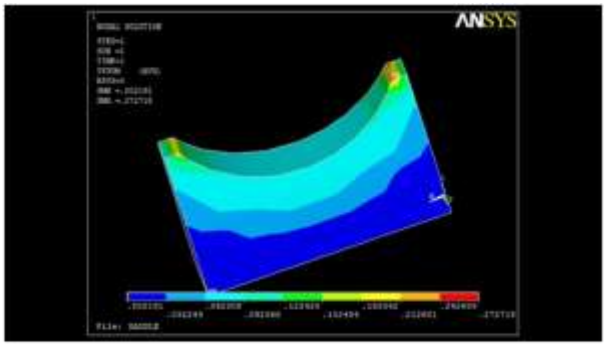


Fig: 7.37: SADDLE's Thermal Flux Analysis

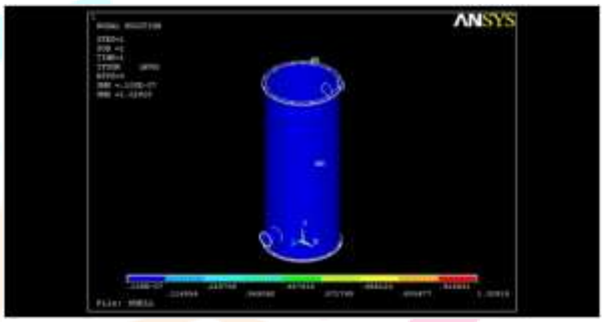


Fig: 7.38: Analysis of Shell+ Tubing Bundle Thermal Flux (MS)

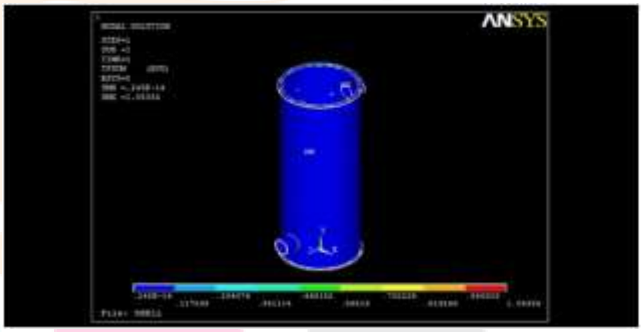


Fig: 7.39: Analysis of Shell+ Tubes Bundle Thermal Flux (NI)

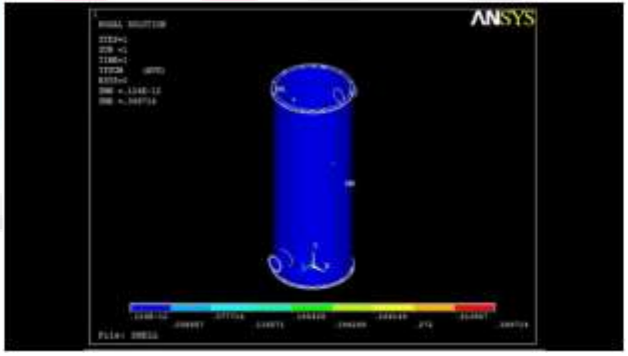


Fig: 7.40: Therm The Shell+ Tubes Bundle (SS) Flux Analysis

6.4 Results of Heat Flow:

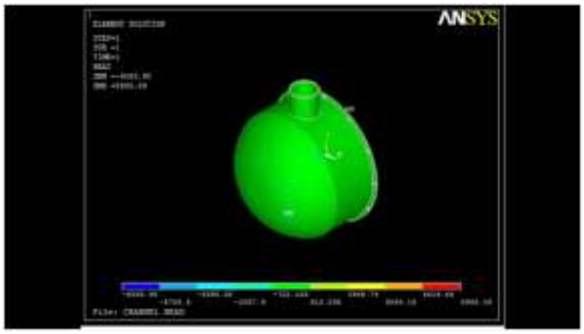


Fig: 7.35: Analysis of Heat Flow in the Channel Head

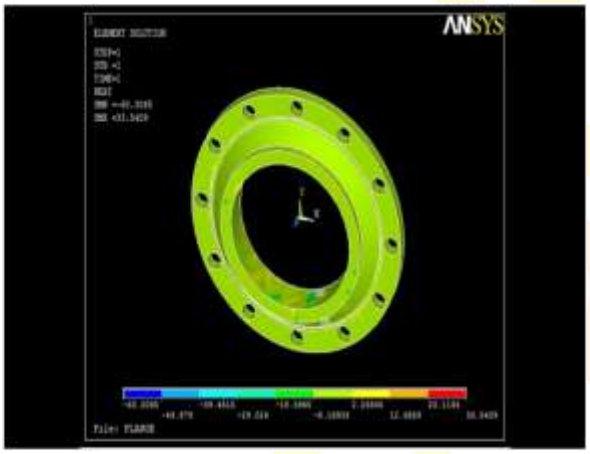


Fig: 7.36: Heat Transfer Study of the Channel Head

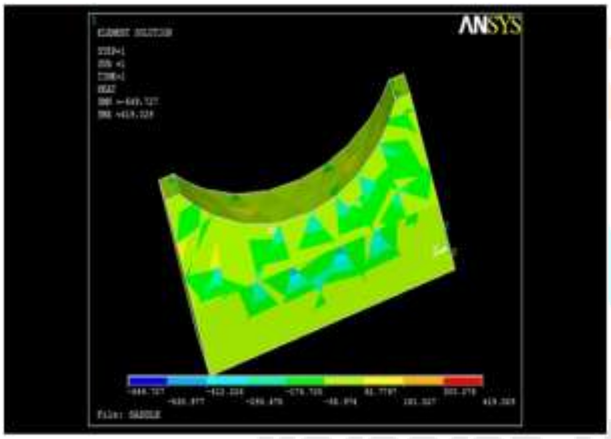


Fig: 7.37: Analysis of Heat Flow in SADDLE

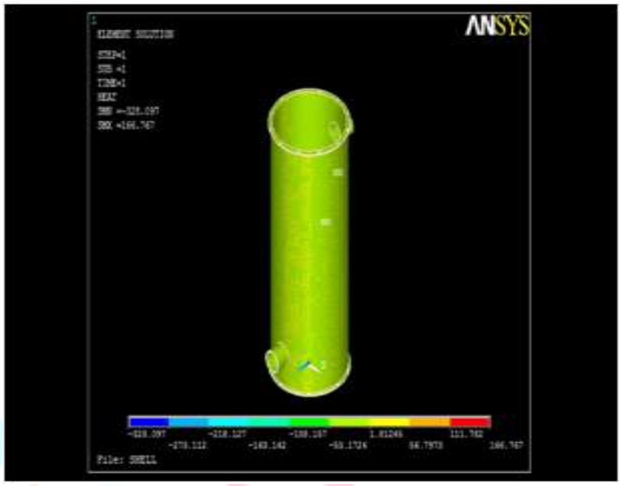


Fig: 7.38: Analysis of Heat Flow in the Shell+ Tubing Bundle (MS)

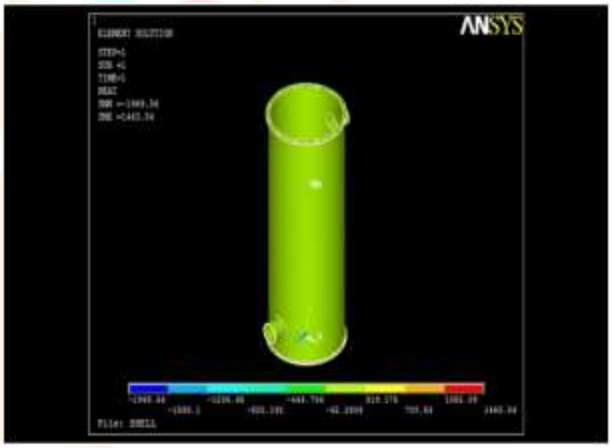


Fig: 7.39: Analysis of Heat Flow in the Shell+ Tubing Bundle (NI)

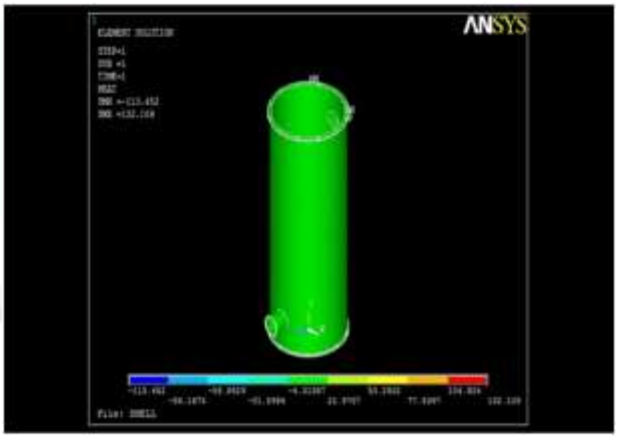


Fig: 7.40: Analysis of Heat Flow in the Shell+ Tubing Bundle (SS)

CONCLUSION

The above result shows that we were successful in achieving our goal of applying constrained thermodynamic optimization to minimize the entropy in the heat exchanger. The Nodal Temperature of the entire design, as illustrated in the preceding figures, is 302.9 for MS, 289.5 for NI, and 301.9 for SS after it has been meshed and solved with Ansys. This demonstrates that every part of the assembly has a negligible amount of entropy.

The maximum thermal gradient is approaching; Ansys software is used to solve this problem, resulting in maximum thermal gradients of 15.593 for MS, 20.256 for NI, and 13.450 for SS.

Using Ansys software, the maximum thermal flux—1.029 for MS, 1.053 for NI, and 0.349 for SS—is approaching. We may so conclude that our design parameters are basically correct. The design of the heat exchanger mechanism likewise operated flawlessly during the inspection; taken together, these results indicate that our goal was met.

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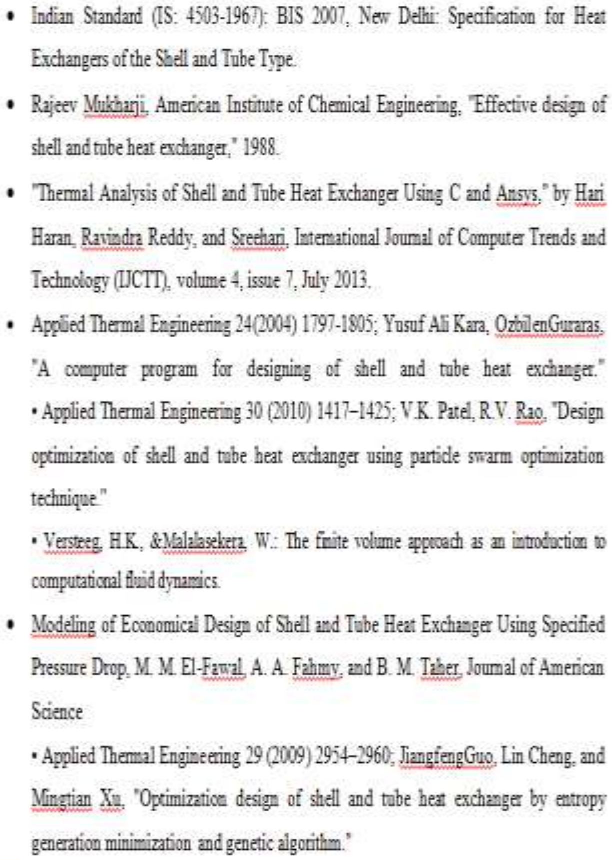

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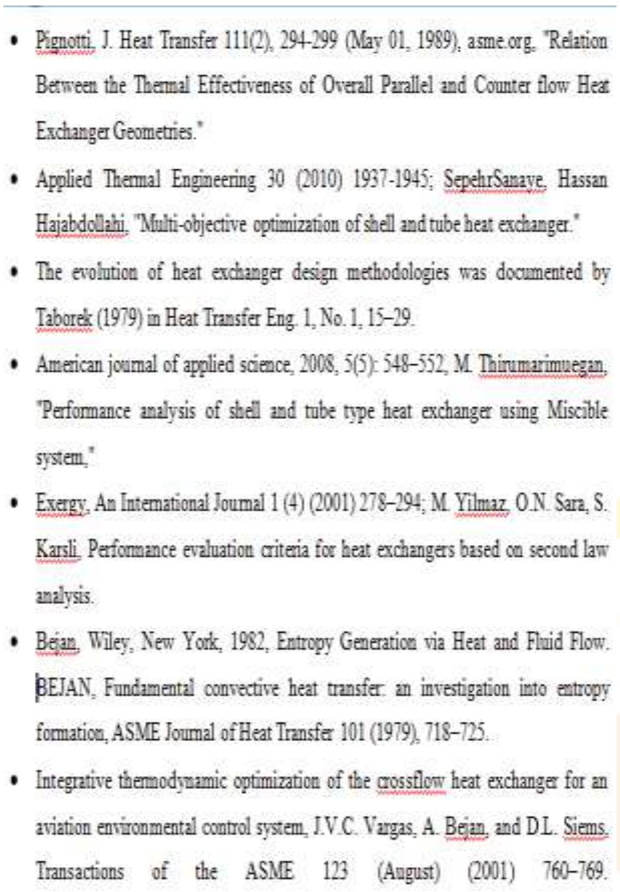

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