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Design & Analysis of Shell and Tube Heat Exchanger With and Without Baffles

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Abstract: Heat exchangers have always been an important part to the lifecycle and operation of many systems.The purpose of this thesis is to analyse the thermal and structural values of shell and tube heat exchanger with and without baffles. Designing is done using CATIA V5 Software. In this work, various materials are used and analysed for the tube material for their performance in the shell and tube heat exchanger with and without baffles. The different materials for tube material used are Copper, Hastelloy and CuproNickel. Structural and Thermal analysis are performed in ANSYS Software. The results obtained are compared for all cases.

Keywords: Shell and Tube Heat Exchanger, CATIA V5, ANSYS, Thermal Analysis, Structural Analysis

I. INTRODUCTION

The heat exchanger is a mechanism used to transfer thermal energy between two or more fluids, between the solid surface and the air, or between the solid particles and the fluid, at varying temperatures and in thermal contact. There are typically no exterior heat and function experiences in heat exchangers. Typical applications require heating or cooling of the related fluid stream and evaporation or condensation of single or multi-component fluid streams. Popular examples of heat exchangers are shell and tube heat exchangers, automotive radiators, condensers, evaporators, pre-heaters and coolers.

Baffles are flow-directing or obstructing vanes or panels used to direct a flow of liquid or gas. Baffles are an integral part of the shell and tube heat exchanger design. A baffle is designed to support tube bundles and direct the flow of fluids for maximum efficiency. Baffle design and tolerances for heat exchangers are discussed in the standards of Tubular exchange manufacturer association.

II. SHELL AND TUBE HEAT EXCHANGER

Shell and Tube heat exchanger is generally built of a bundle of round tubes mounted in a cylindrical shell with the tube axis parallel to that of the shell. One fluid flow inside the tubes, the other flows across and along the tubes. The major components of this exchanger are tubes (or tube bundle), shell, front-end head, rear-end head, baffles, and tube sheets. The shell of a shell and tube heat exchanger is made of pipe or welded metal plates using materials that can withstand extreme temperatures and that are corrosion resistant. The inner shell must be round with a consistent diameter to minimize space between the baffled outer edge and the shell. Tubes of a shell and tube heat exchanger are welded or extruded and made from carbon steel, stainless steel, titanium, Inconel, or copper. Tubes that are longer reduce shell diameter and result in high shell pressure drop.

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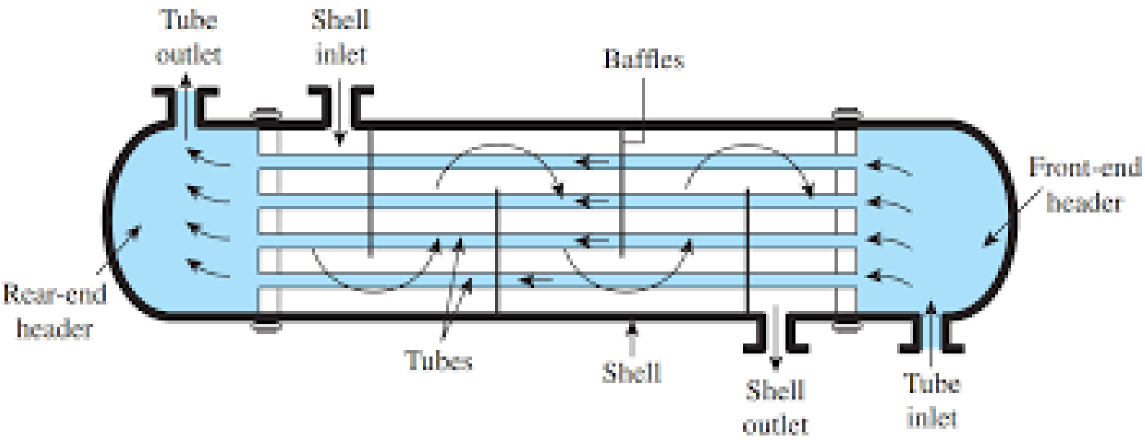

Fig. 1: Shell And Tube Heat Exchanger

III. DESIGN AND ANALYSIS

CATIA V5 software is used for computer-aided design, computer-aided manufacturing, 3D modelling, etc. CATIA provides various tools which allows in collabarative product creation. In this work, we have used various tools such as padding, pocketing, shaft, edge fillet, mirror, plane, trim, apply material, projecting 3D materials and geometrical profile tools.

3D MODEL OF SHELL AND TUBE HEAT EXCHANGER DIMENSIONS :

- Shell Outer Diameter = 84 mm
- Shell Inner Diameter = 80 mm
- Number of Tubes = 4
- Tube Outer Diameter = 20 mm
- Tube Inner Diameter = 16 mm
- Length of Shell = 200 mm
- Inlet & Outlet Outer Diameter = 30 mm
- Inlet & Outlet Inner Diameter = 20 mm
- No of Baffles = 3
- Baffle diameter = 80 mm
- Baffle Thickness = 5 mm
- Baffle Cut = 20 mm
- No of Saddles = 2
- Saddle Angle = 120°

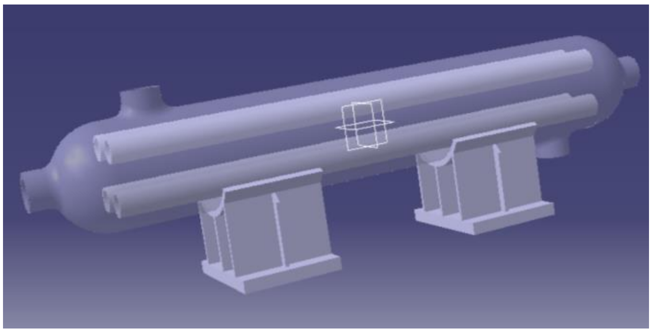

Fig. 2: Design without Baffles

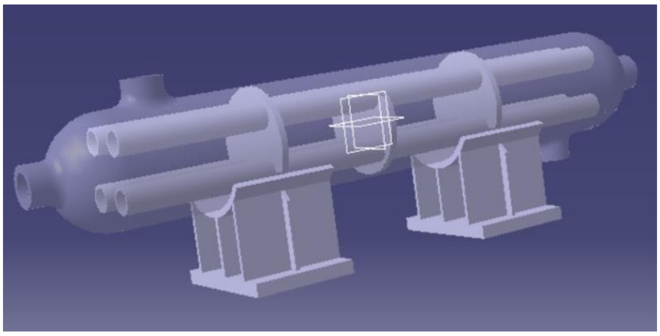

Fig. 3: Design with Baffles

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ANSYS MECHANICAL software is used for simulation os structures, electronics, machine components for analyzing the strength, toughness, elasticity, temperature distribution among various other attributes. It is used to determine how a product performs eithout any building test products or conducting crash tests. In this work we have used Static Thermal Test and Static Structural Test. A total of 5 attributes are analysed which are temperature, heat flux, directional heat flux, deformation & Von-Mises Stresses.

MATERIALS USED

Table 1: Materials

PART	MATERIAL
Shell	Copper
Tubes	Copper, Hastelloy & CuproNickel
Baffles	Titanium Alloy (Ti-6Al-4V)
Saddle Supports	Structural Steel

THERMAL AND STRUCTURAL ANALSYIS :

CASE 1 : SHELL AND TUBE HEAT EXCHANGER WITH COPPER TUBES [WITHOUT BAFFLES]

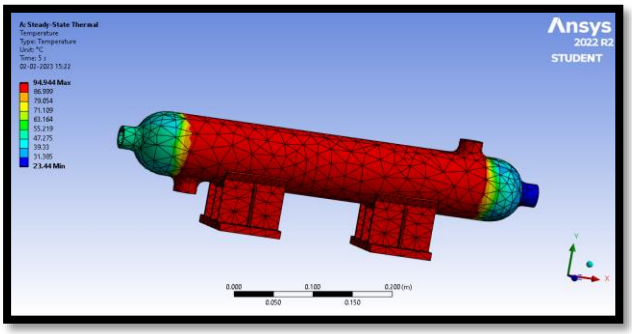

Fig. 4: Variation of Temperature

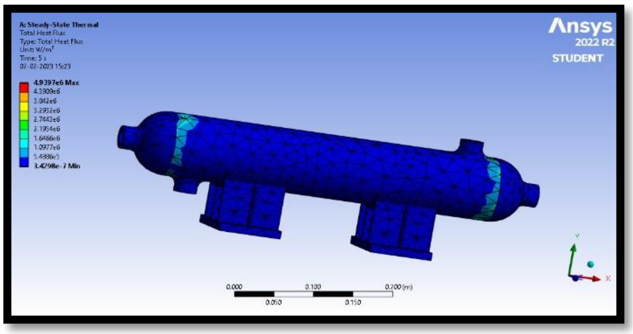

Fig. 5: Variation of Heat Flux

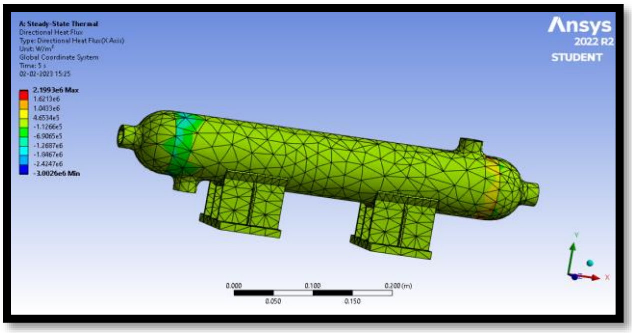

Fig. 6:Variation of Directional Heat Flux

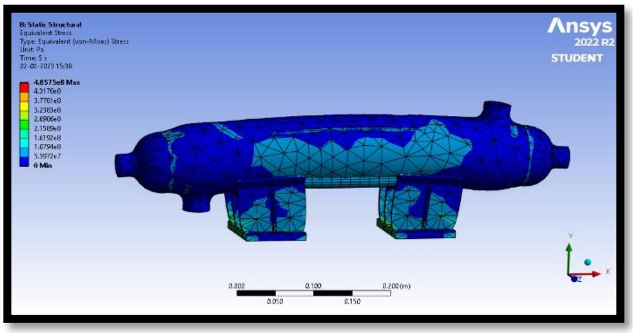

Fig. 7: Variation of Von-Mises Stresses

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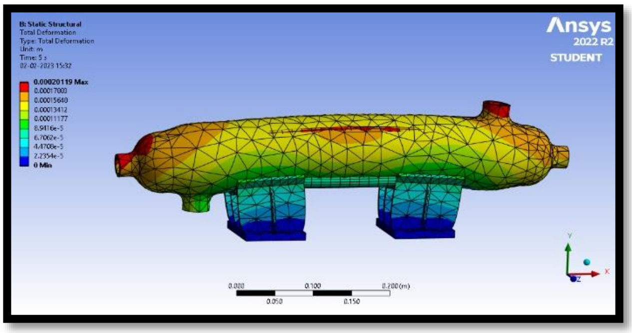

Fig. 8: Variation of Deformation

CASE 2 : SHELL AND TUBE HEAT EXCHANGER WITH COPPER TUBES [WITH BAFFLES]

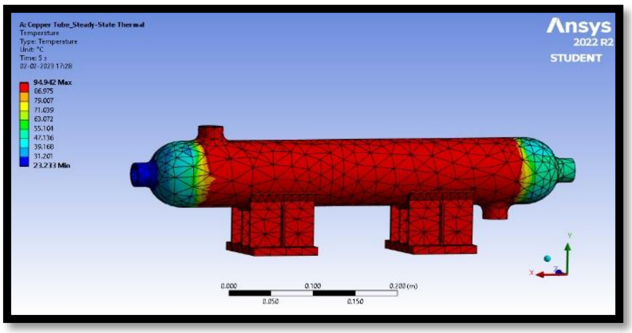

Fig. 9: Variation of Temperature

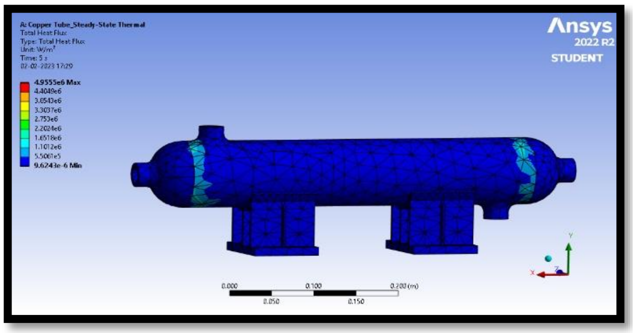

Fig. 10:Variation of Heat Flux

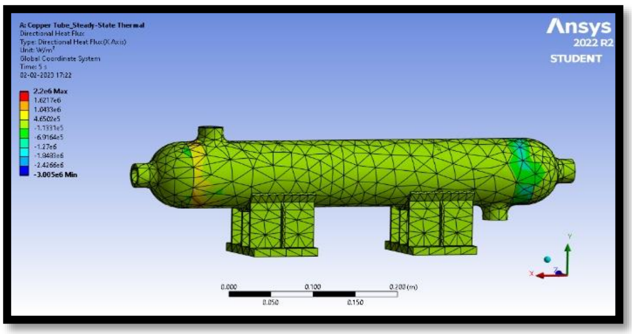

Fig. 11: Variation of Directional Heat Flux

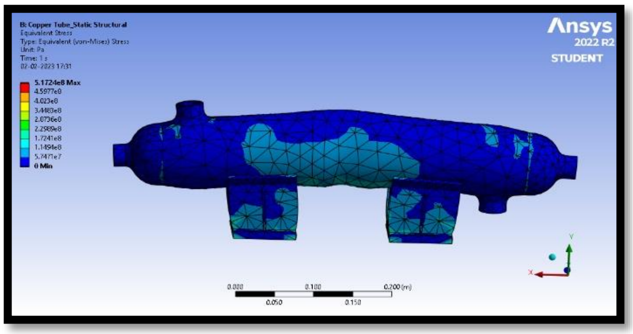

Fig. 12: Variation of Von-Mises Stresses

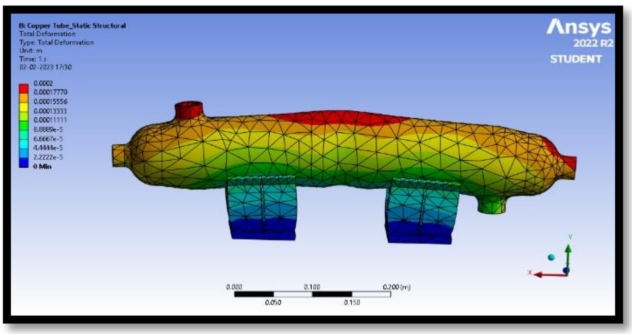

Fig. 13: Variation of Deformation

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CASE 3 : SHELL AND TUBE HEAT EXCHANGER WITH HASTELLOY TUBES [WITHOUT BAFFLES]

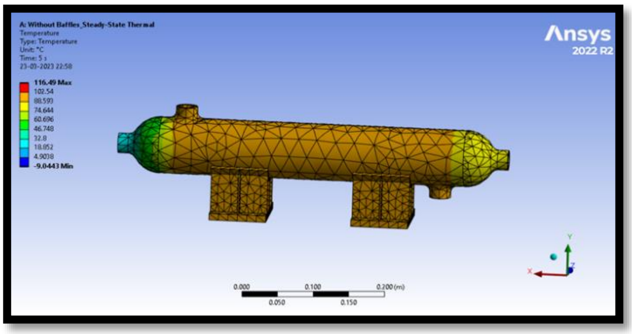

Fig. 14: Variation of Temperature

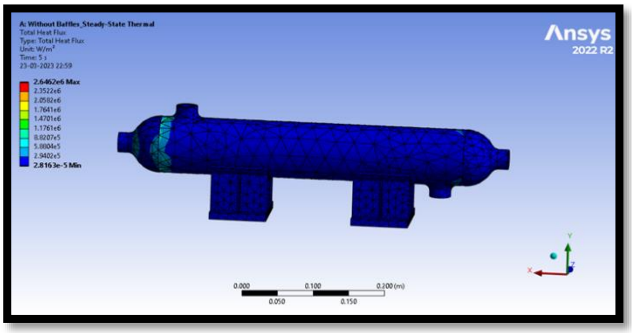

Fig. 15:Variation of Heat Flux

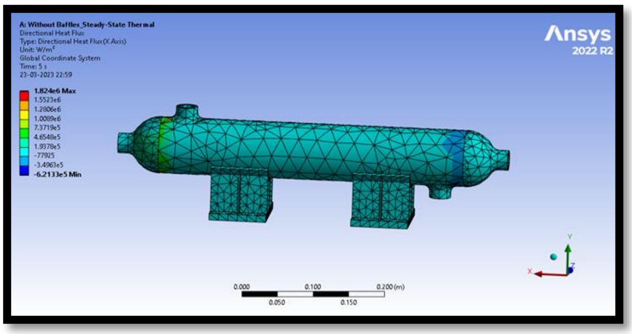

Fig. 16: Variation of Directional Heat Flux

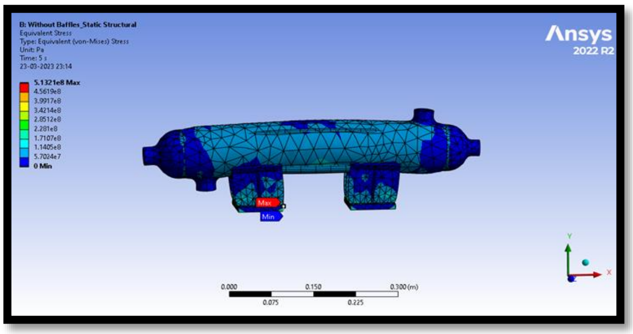

Fig. 17: Variation of Von-Mises Stresses

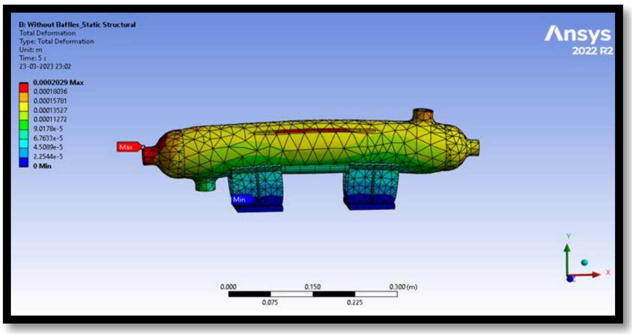

Fig. 18: Variation of Deformation

CASE 4 : SHELL AND TUBE HEAT EXCHANGER WITH HASTELLOY TUBES [WITH BAFFLES]

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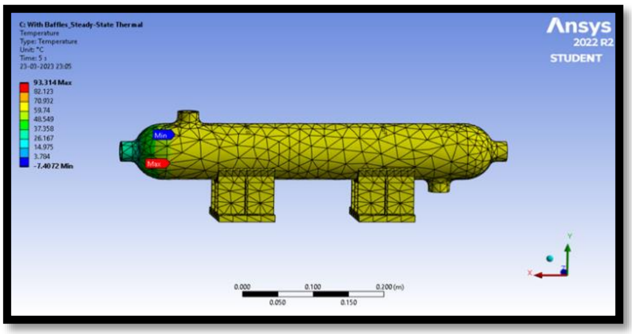


Fig. 19: Variation of Temperature

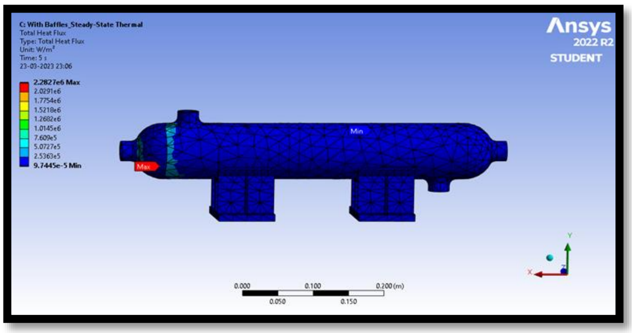


Fig. 20: Variation of Heat Flux

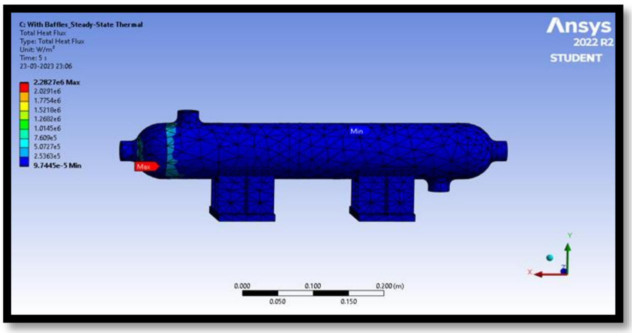


Fig. 21: Variation of Directional Heat Flux

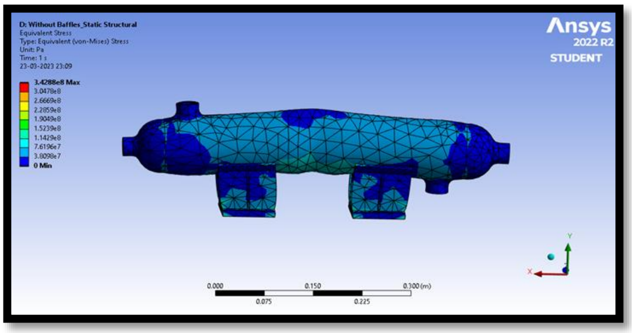


Fig. 22: Variation of Von-Mises Stresses

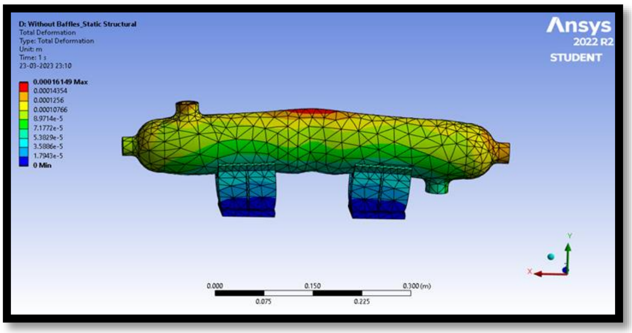
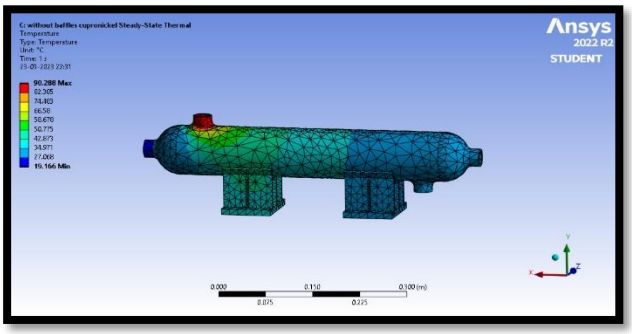


Fig. 23: Variation of Deformation

CASE 5 : SHELL AND TUBE HEAT EXCHANGER WITH CUPRONICKEL TUBES [WITHOUT BAFFLES]



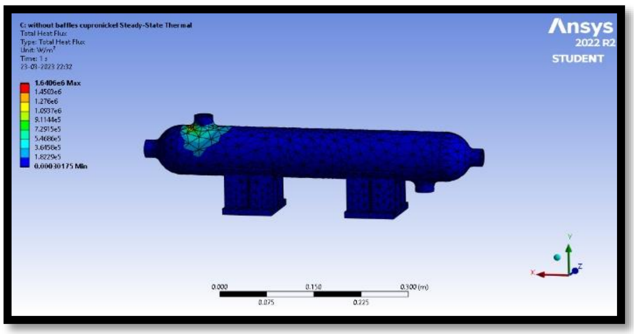


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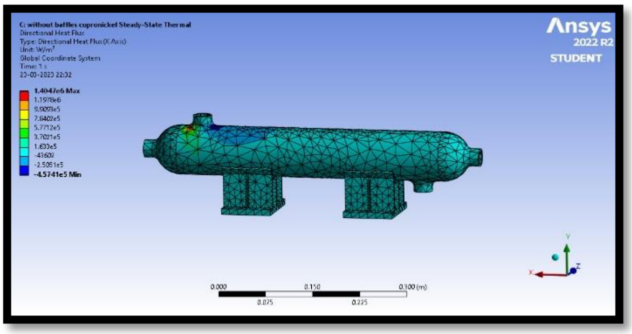
Fig. 24: Variation of Temperature

Fig. 25:Variation of Heat Flux



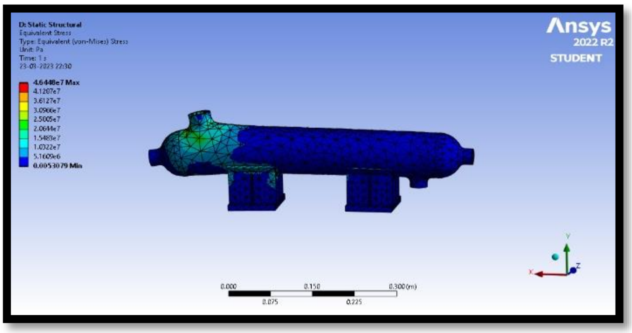


Fig. 26: Variation of Directional Heat Flux

Fig. 27: Variation of Von-Mises Stresses

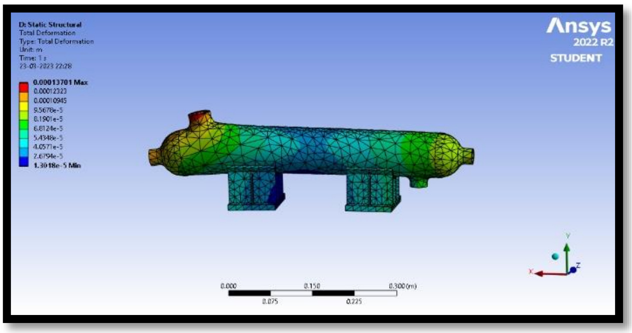
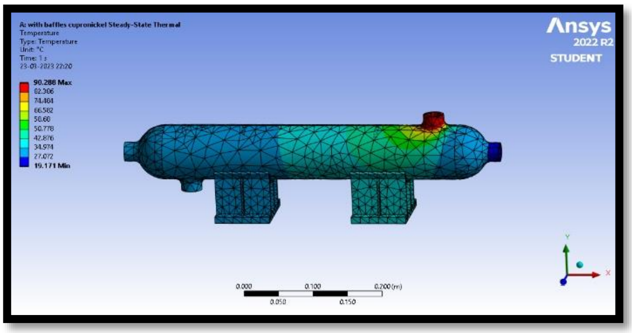


Fig. 28: Variation of Deformation

CASE 6 : SHELL AND TUBE HEAT EXCHANGER WITH CUPRONICKEL TUBES [WITH BAFFLES]



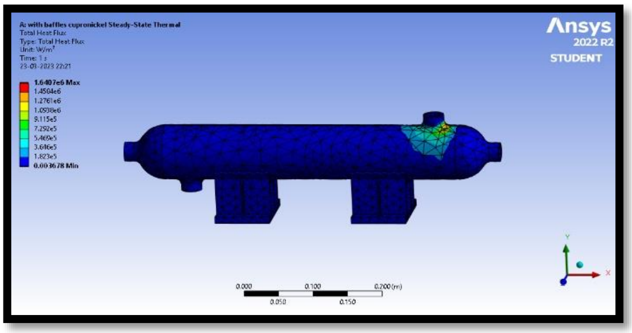


Fig. 29: Variation of Temperature

Fig. 30: Variation of Heat Flux

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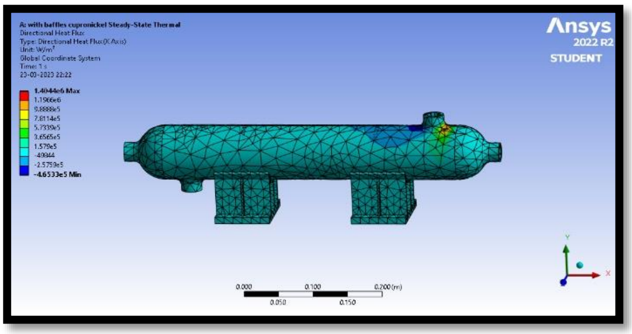

Fig. 31: Variation of Directional Heat Flux

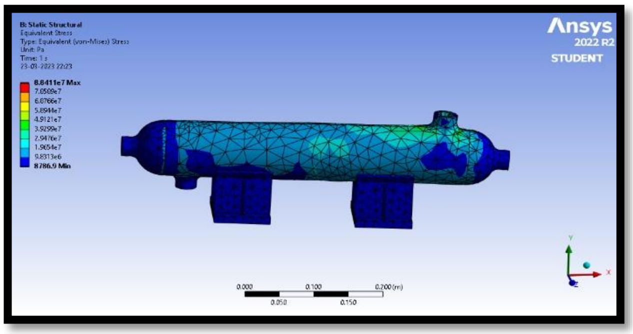

Fig. 32: Variation of Von-Mises Stresses

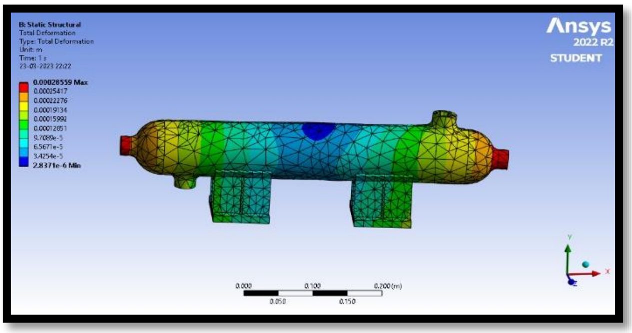

Fig. 33: Variation of Deformation

IV. RESULTS

The observations are tabulated and the various cases are analysed and compared by respective criteria by comparing each other.

Table 2: Comparison of Parameters from all cases

PARAMETERS		**Temperature (Celsius)**	**Total Heat Flux (W/m²)**	**Directional Heat Flux (W/m²)**	**Von Mises Stress (Pa)**	**Total Deformation (m)**
Copper Tubes	**Without Baffles**	94.944	$4.9397*10^6$	$2.1993*10^6$	$4.8575*10^8$	$1.1346*10^{-4}$
	With Baffles	94.942	$4.9555*10^6$	$2.2*10^6$	$5.1724*10^8$	$2.3149*10^{-4}$
Hastelloy Tubes	**Without Baffles**	116.49	$2.6462*10^6$	$1.824*10^6$	$3.4288*10^8$	$2.029*10^{-4}$
	With Baffles	93.314	$2.2827*10^6$	$1.2833*10^6$	$5.1321*10^8$	$1.6149*10^{-4}$

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Cupro Nickel Tubes	**Without Baffles**	90.288	$1.6406*10^6$	$1.4047*10^6$	$0.46448*10^8$	$1.3701*10^{-4}$
	With Baffles	90.288	$1.6407*10^6$	$1.4045*10^6$	$0.88411*10^8$	$2.8559*10^{-4}$

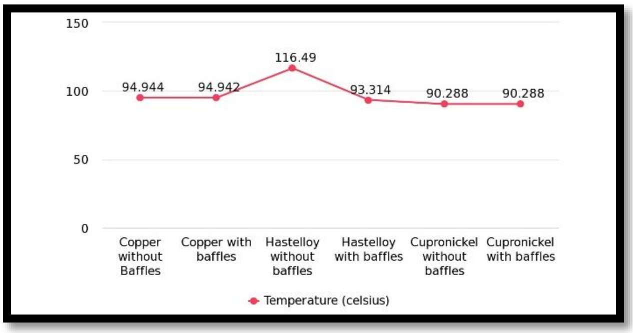

Fig. 34: Temperature Plot

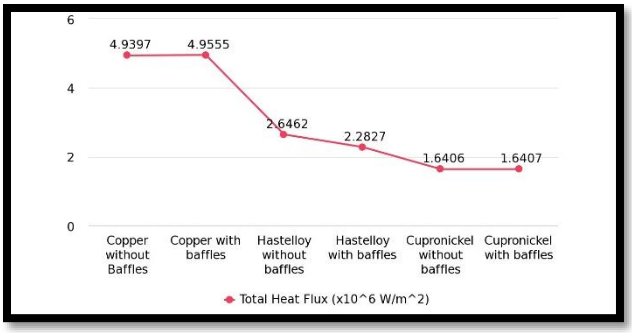

Fig. 35: Total Heat Flux Plot

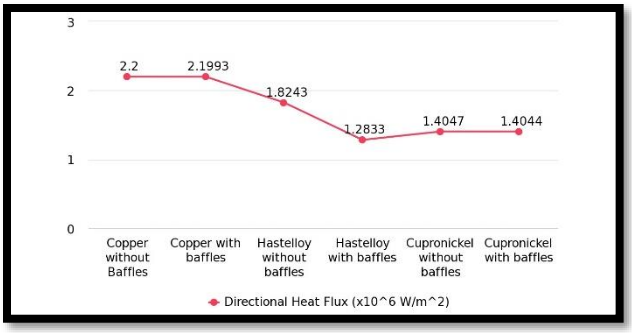

Fig. 36: Directional Heat Flux Plot

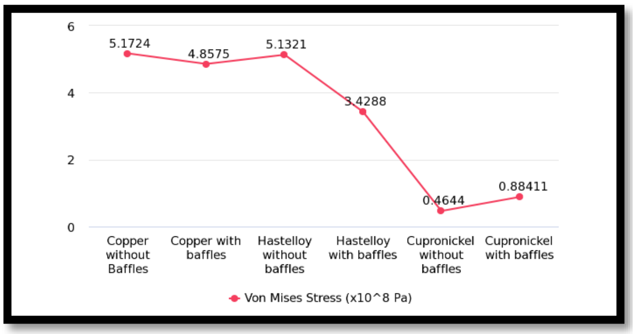

Fig. 37: Von-Mises Stress Plot

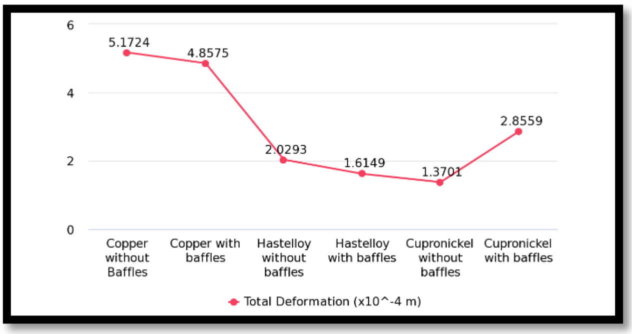

Fig. 38: Total Deformation Plot

V. CONCLUSION

- By comparing the results of all 6 cases, the temperature of Hastelloy tubes with baffles is more.
- By observing the thermal analysis result, we can say that the heat flux is more when Hastelloy is used rather than cupronickel.
- When we observe the structural analysis result the total deformation is decreased when baffles are used.
- The shell and tube made of cupronickel has performed better as compared to Hastelloy .Also, cupronickel has high corrosion resistance.

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