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MODELLING AND ANALYSIS OF HEAT EXCHANGER

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Abstract - Shell and tube heat exchangers in their various construction modifications are probably the most widespread and commonly used basic heat exchanger configuration in the process industries. The modelling of the heat exchanger has done by using the advanced design software CATIA. In this project the Heat Exchanger is modelled and assembled with the help of CATIA and the component is meshed and analysis is done in ANSYS software and the thermal and static behaviour is studied and the results are tabulated. The various stresses acting on the Heat Exchanger under various loading conditions has been studied. In the preset work has been taken up on the following aspects to cover the research gaps and to present the results based on the systematic studies. Temperature distribution and heat flow through the Heat Exchanger. FEA analysis of the Heat Exchanger to measure temperature at the points where it is not possible to find out practically and to observe the heat flow inside the Heat Exchanger.

Key Words: Shell and Tube Heat Exchanger, Catia,and Ansys Softwares, Static and Thermal behavior, and FEA Analysis.

1.INTRODUCTION:

A heat exchanger is essentially a device that transfers heat from one fluid to another. Imagine it like a middleman for temperature. Hot fluids can warm up cooler fluids, and vice versa. They don't necessarily have to be liquids, they can also be gases. These exchangers are important for many things in our world, from heating buildings to cooling car engines.

Heat exchangers, despite their efficiency, face challenges during design and operation. Finding the right balance between maximizing heat transfer and minimizing pressure drop within the exchanger is crucial. Additionally, material selection is vital to ensure durability against corrosion and withstand temperature extremes. Even with careful design, issues like fouling (accumulation of unwanted material) and leakage can occur, impacting performance and requiring maintenance. Optimizing these factors is key to creating a reliable and efficient heat exchanger. Heat exchangers are classified based on the way fluids flow within them. Common types include shell and tube, where one fluid flows through tubes housed inside a shell containing the other fluid. Plate heat exchangers use thin, corrugated plates to create alternating channels for hot and cold fluids. Challenges arise during both the design and analysis phases. Designers must balance factors like heat transfer efficiency, pressure drop, and cost. Thermal analysis aims to predict temperature distribution and heat transfer rate, but complexities like fouling (accumulation of unwanted material on surfaces) can make this difficult.

Structural analysis ensures the heat exchanger can withstand internal pressure and external loads without failure. Here, factors like vibration and thermal expansion need to be considered. By carefully navigating these challenges, engineers can create effective and reliable heat exchangers.

2.METHODOLOGY:

The Methodology for the modelling and analysis of Heat Exchanger involves the following steps:

2.1 Development:

The first step is to develop a concept for the Modelling and Analysis of Heat Exchanger this involves identifying the requirements for the Modelling and Analysis of Heat Exchanger Shape, such as Size, Material Composition and Performance Specifications.

2.2 Designing 3D Model:

Once the concept has been developed, the next step is to create a 3D model of the Heat Exchanger using Catia software. This involves creating a detailed model of the design.

2.3 Design Validation:

The 3D model is then validated using simulation software to ensure the design meets the required performance specifications. This may include stress analysis, fatigue testing, and other simulation.

2.4 Analysis:

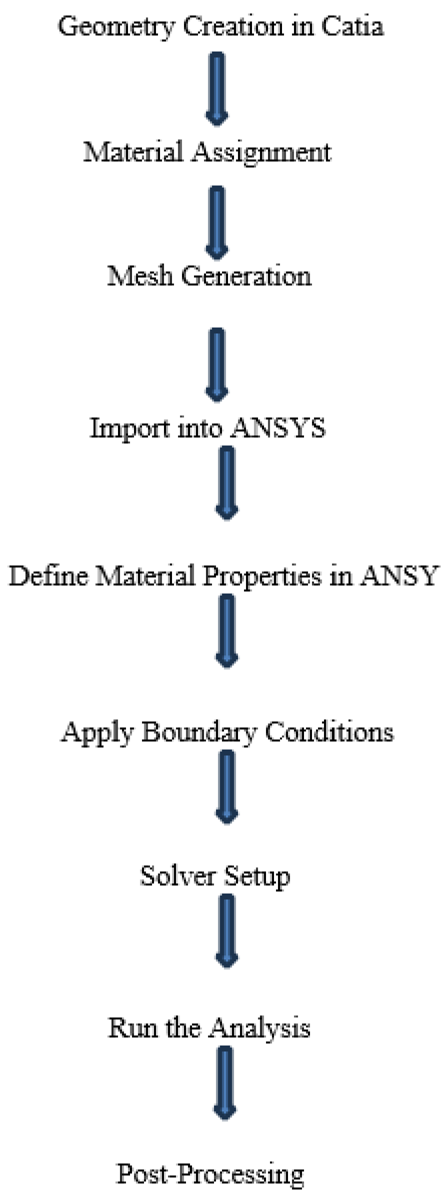
After the creation of 3D model, the analysis is performed on the Heat Exchanger by using the ANSYS software. Temperature distribution is performed.

2.5 Post-Processing:

After the analysis based on the report, we can find out the capability of the Heat Exchanger and in which conditions it can be used.

2.6 Design Optimization:

Based on the results of testing and evaluation, any necessary modifications can be made to the design in the SolidWorks software and to the material selection in Ansys software, and the process can be repeated until the final design meets all the requirements.



3.MODELLING USING CATIA:

3.1 INTRODUCTION TO CATIA:

CATIA: Computer Aided Three-Dimensional Interactive Application. It was developed by Dassault Systems in 1981 and it is located in French. Versions of CATIA are V1, V2, V3, V4, V5 and V6 more companies are using from V4 only. Now in the market many companies are using V5R16 and in V5 we have many versions from V5R1 to V5R21It is a tool based software these tools we call as features, so it is a feature based software. It is a parametric software, parametric mean while designing or after completing the design we can change the parameters of the component. It is a advanced designing software compared to AutoCAD, and in AutoCAD we can complete all the tasks in single window, but in this we have different windows those windows we call as modules, the main modules in designing are

1.Sketcher:(To know about 2d tools only)

2.Part modelling:(To create any solid models)

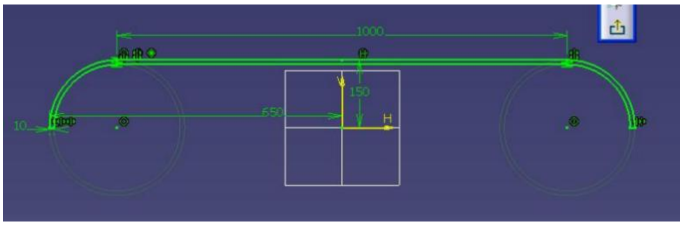
3.Assembly:(In this just we insert the components already created in part)

4.Drafting:(To generate the views with projections, dimensions, BOM, etc.)

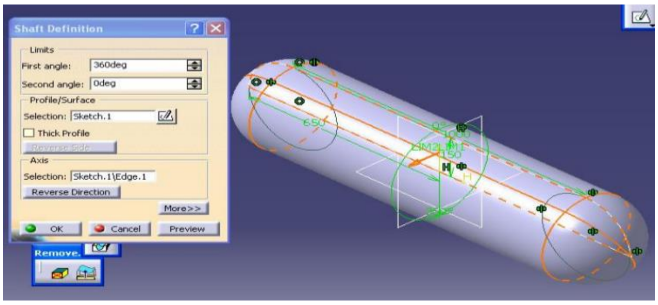
5.Wireframe and surface designing:(To create the surfaces only without thickness)

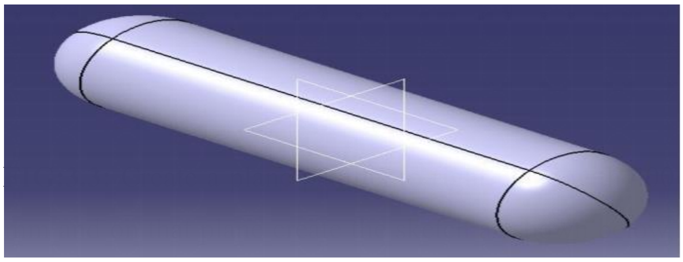
6.Generative Sheet metal Design:(Total design follows the fixed thickness)

Open CATIA Software go to Start menu and Mechanical Design – Part Design – It opens part module, now select front plane - select sketch tool – now selected plane will be rotated towards parallel to the screen, now draw the required cross section to create the shell cylinder with required dimensions as shown below.

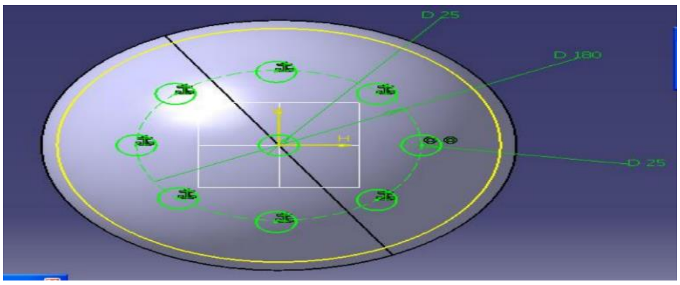


select horizontal axis and give the angle 360, the cylinder will be created as shown below.





then exit work bench use the pad tool to add the material with 10mm thick plate with holes and mirror it with right plane to create one more plate other side



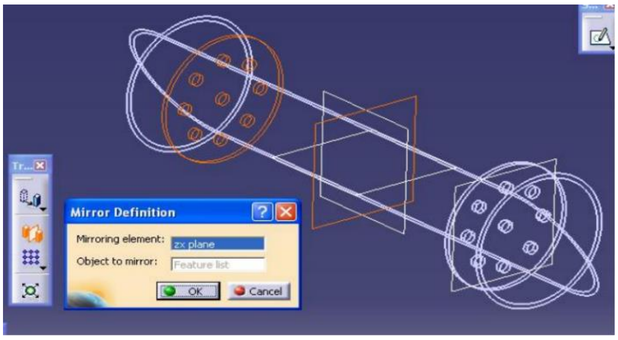


FIG:3.5: Create the sketch on plate to create the tubes with required dimensions between two plates, and use the pad tool to add the material to the sketch

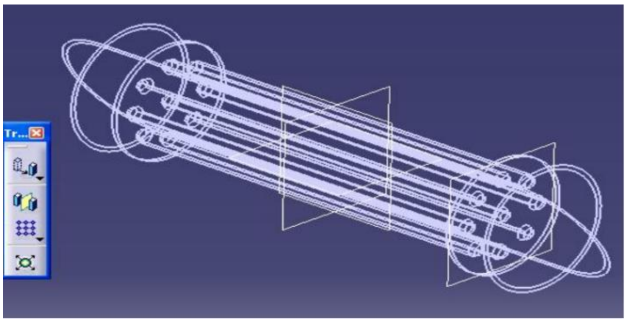


FIG: 3.6: To see the internal geometry clearly split the model up to half towards front side it looks as below.

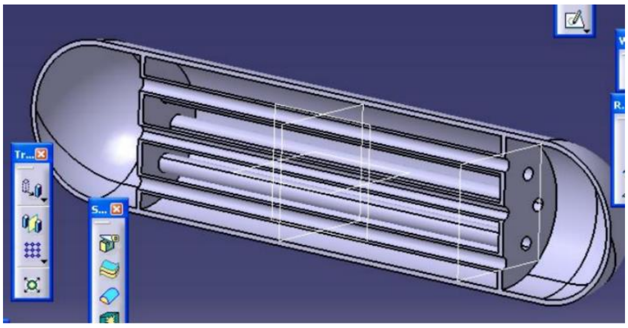


FIG 3.7: Create a plane above top plane with required dimension, create a circle on the new plane and pad it with up to next.

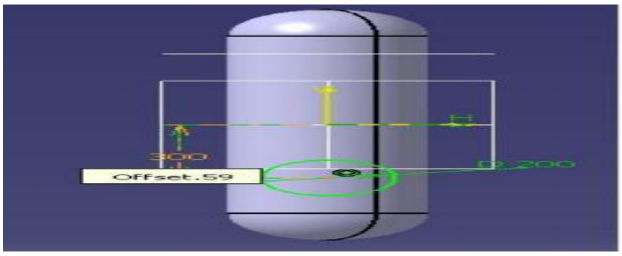
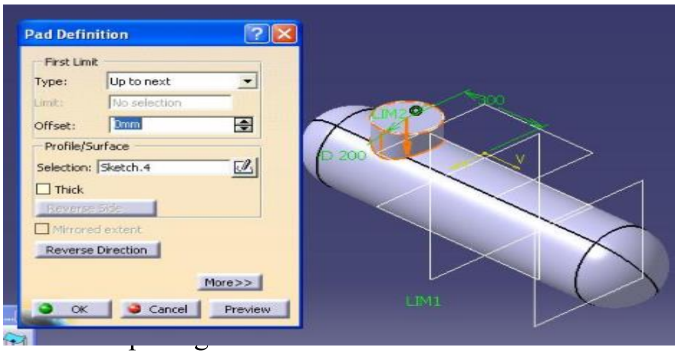


FIG 3.8: Offset



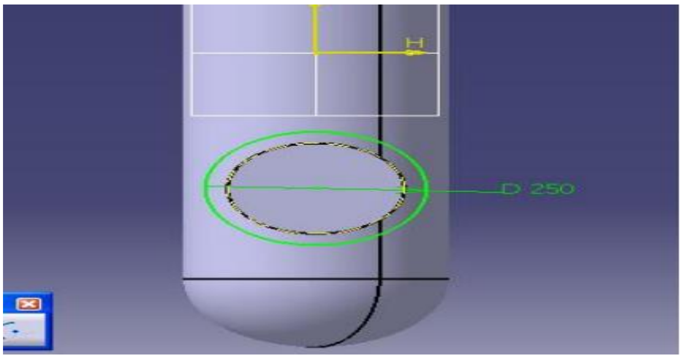


FIG 3.10: Draw a sketch on the flange and use pocket tool to remove the material as shown below.

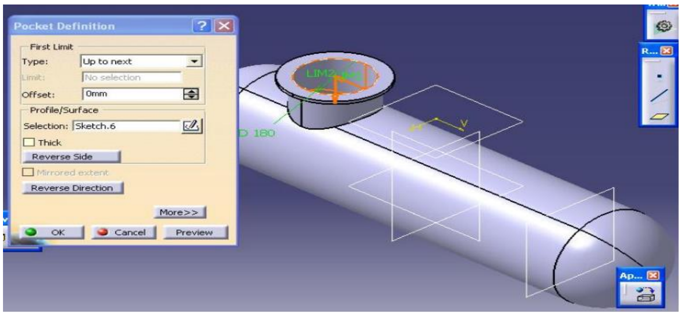


FIG: 3.11: Create a point at origin and create a line perpendicular to front plane and select the part as shown below and pattern it as shown below.

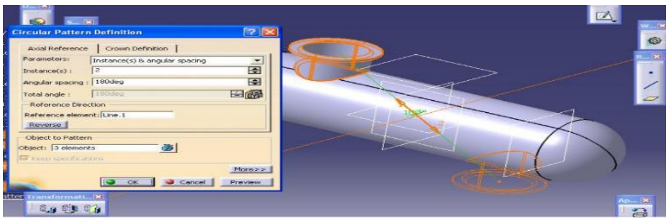


FIG:3.12: After patterning the part hide the planes whichever we do not required, it looks finally as below.

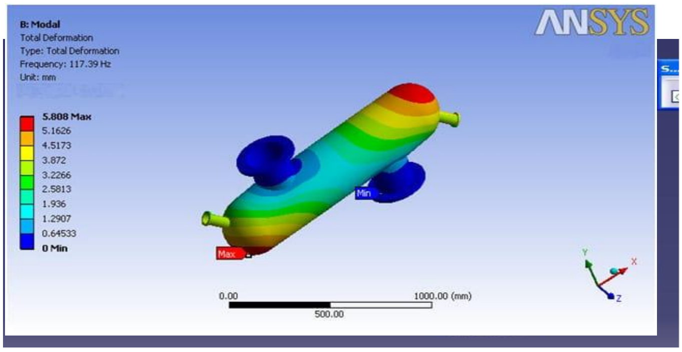


FIG 3.13: Create a plane as shown below and offset one more with required distance, on the newly created plane create the extension portion as shown below same as above method.

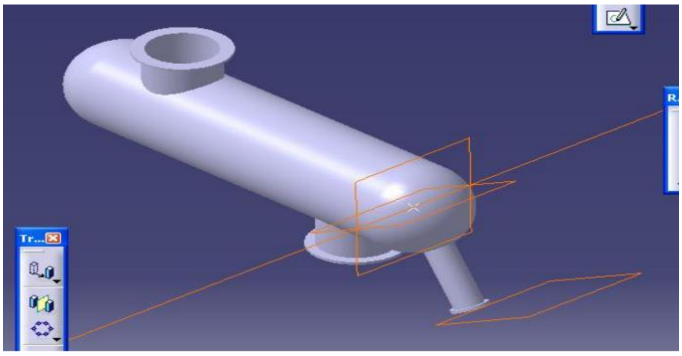


FIG 3.14: Create a point at origin and create a line perpendicular to front plane and select the part as shown below and patter After patterning the part hide the planes whichever we do not required, it looks finally as below.

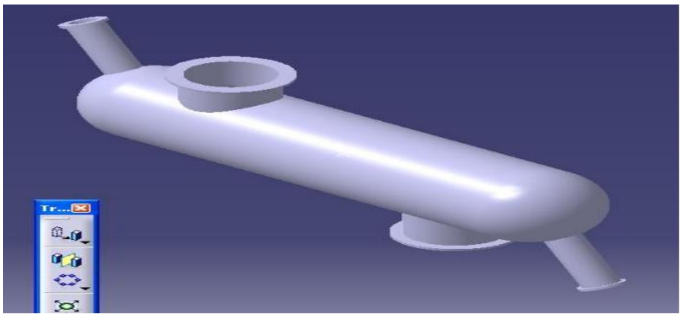


FIG 3.15: Split the model with split tool to see the component as below with respect to front plane.

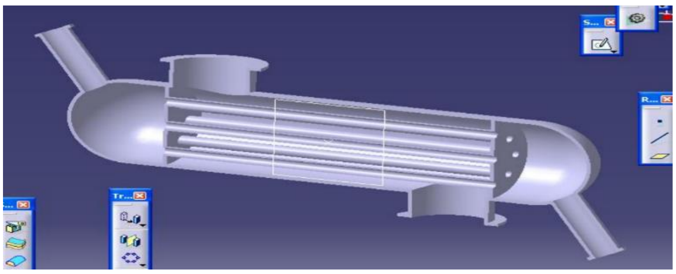


FIG 3.16: Final Stage

4.INTRODUCTION TO ANSYS:

ANSYS is a comprehensive engineering simulation software widely used across industries for its ability to tackle complex engineering challenges. With its intuitive interface, engineers can seamlessly navigate through geometry creation, meshing, simulation setup, and post-processing. The software covers a broad spectrum of physics, including structural mechanics, fluid dynamics, electromagnetics, and more. Its robust solvers ensure accurate and efficient simulations, while powerful post-processing tools enable thorough analysis and visualization of results. ANSYS is a key tool for design optimization, product performance evaluation, and virtual prototyping, empowering engineers to innovate faster and more cost-effectively.

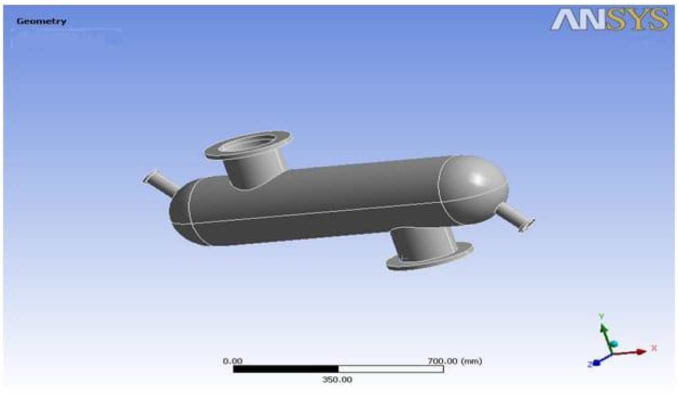


FIG 4.1: GEOMETRY

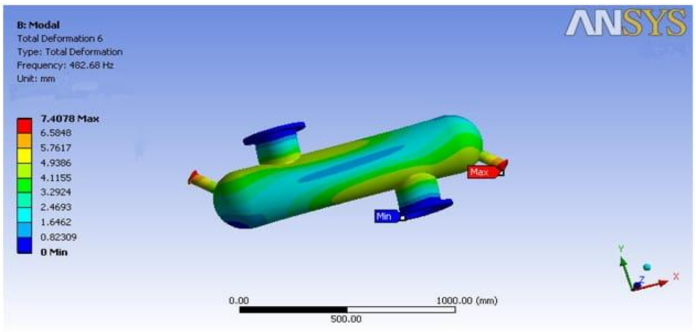


FIG 4.2: FIXED SUPPORT

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FIG 4.3: TOTAL DEFORMATION (MODE SHAPE 1)

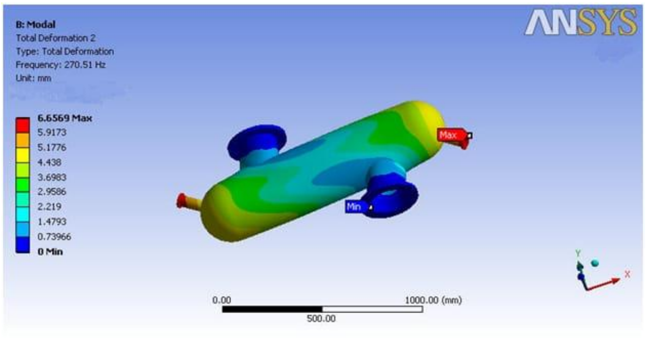

FIG 4.4: TOTAL DEFORMATION (MODE SHAPE 2)

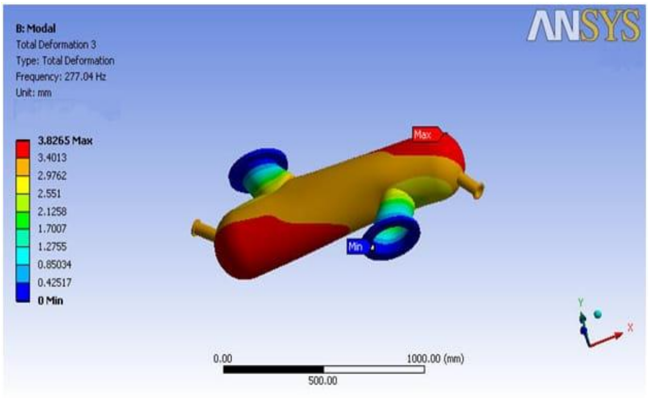

FIG 4.5: TOTAL DEFORMATION (MODE SHAPE 3)

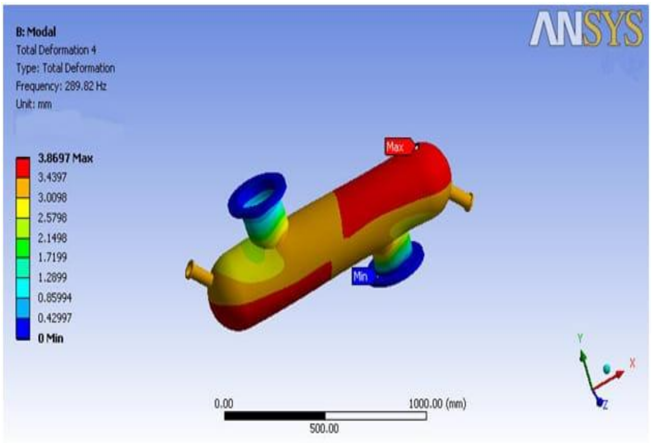

FIG 4.6: TOTAL DEFORMATION (MODE SHAPE 4)

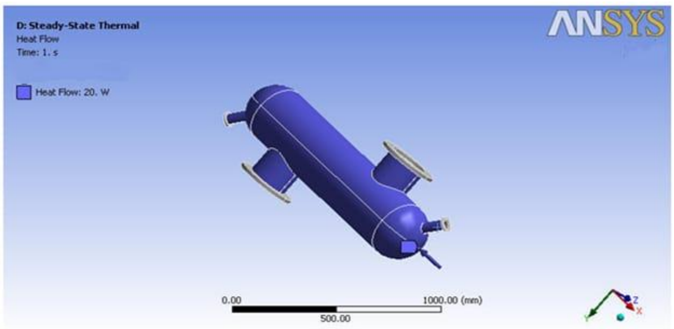

FIG 4.7: TOTAL DEFORMATION (MODE SHAPE 5)

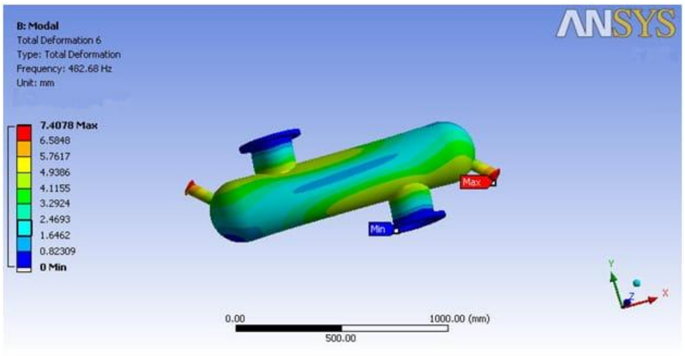

FIG 4.8: TOTAL DEFORMATION (MODE SHAPE 6)

4.2 Static Structural Analysis

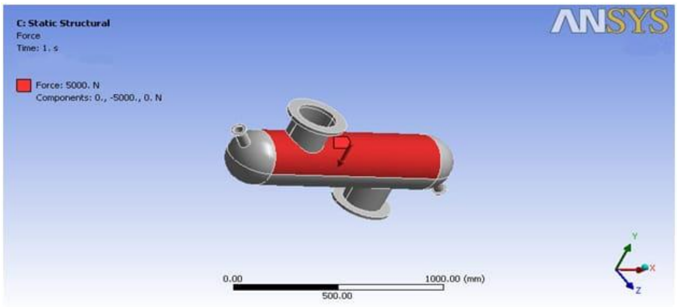

FIG 4.9: Force

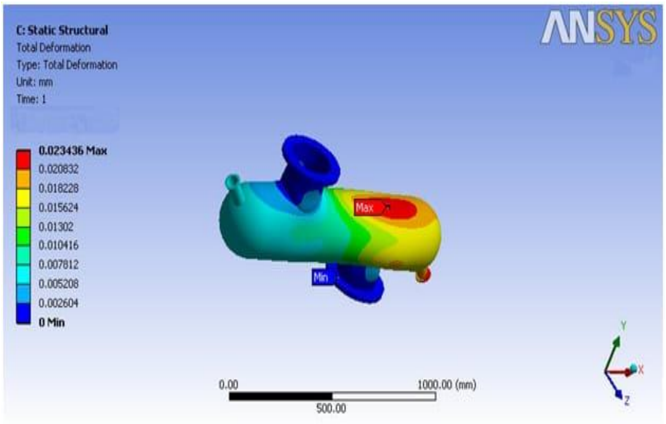

FIG 4.10: Equistress

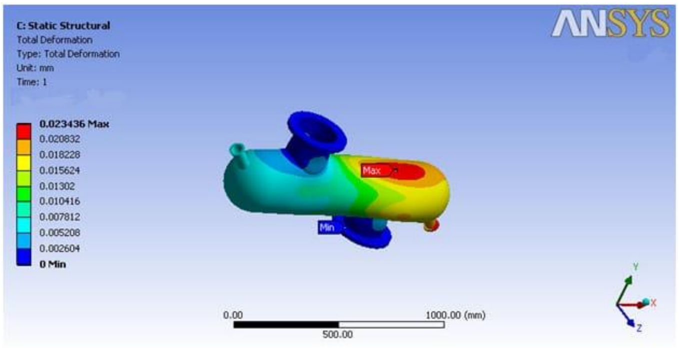

FIG 4.11: Total Deformation

4.2 Thermal Analysis

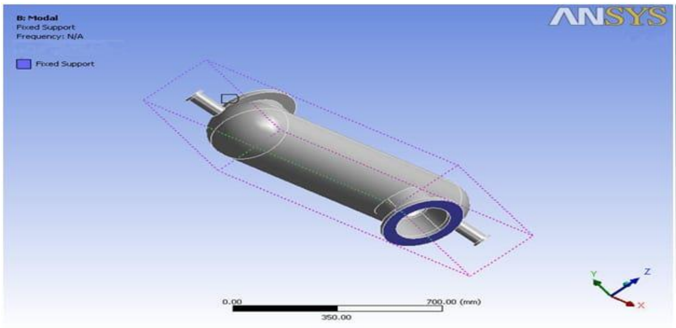

FIG 4.12: Temperature Application

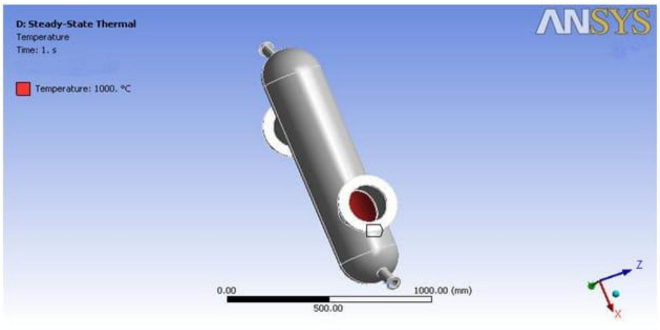

FIG 4.13: Heat flow

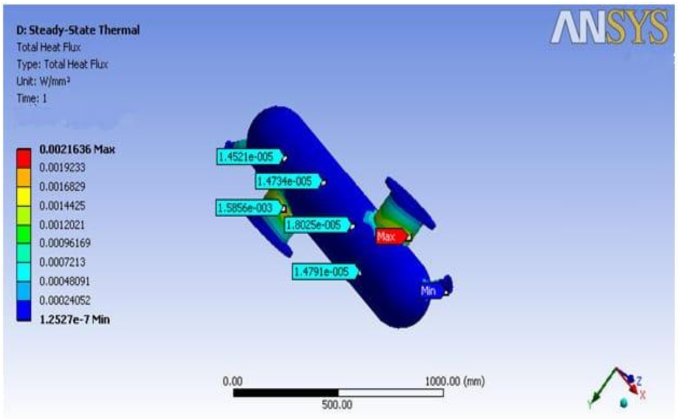

FIG 4.14: Total heat flux

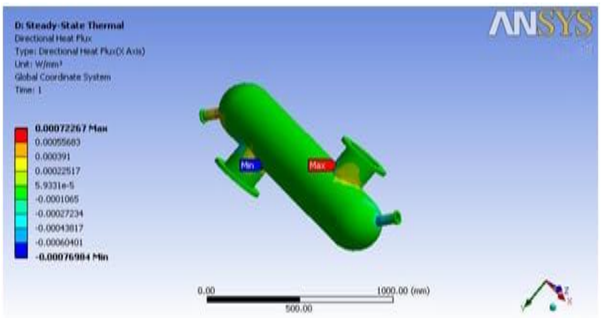

FIG 5.15: Directional heat flux

Table No-4: Results:

S.No	TOTAL DEFORMATION	FREQUENCIES
1	5.808	117.39
2	6.6569	270.51
3	3.8265	277.04
4	3.8697	289.82
5	5.4906	330.98
6	7.4078	482.68

	STRUCTURAL ANALYSIS		
S.no	FORCE	EQUISTRESS	TD
1	5000	8.3617	0.023

	THEREMAL ANALYSIS			
S.no	TEMP	HEAT FLOW	TOTAL HEAT FLUX	DIRECTIONAL HEAT FLUX
1	1000	20	0.00216	0.000722

6.RESULT:

6.1 Constructional details

- Inside diameter of the tube 'd'
- Thickness of the tube
- Outside diameter of the tube 'does'
- In side diameter of the shell
- Number of the tubes
- Number of the pass

2. Details of hot oil

- Dynamic viscosity
- Density
- Thermal conductivity
- Specific heat

3.Details of aromatic hydrocarbons

- Dynamic
- Viscosity
- Density

4. Length of the tube of existing heat exchanger and the new heat exchanger

- Total length=6689mm
- Average length of the tube=6.689mm
- Length new heat exchanger=800mm
- Average length of new heat exchange=160mm

5. Operating conditions of existing heat exchanger and new heat exchanger

- Mass flow rate of hot oil 'mh'
- One time oil passes 120 tubes Mass flow=66173kg/hr
- of aromatic hydro carbons 'mc" Inlet temperature=64708 kg/hr.
- of hot oil 'Thi'=320°c
- Out let temperature of hot oil 'tho* =270°c
- Inlet temperature of aromatic hydro carbons 'Tcj'=217°c
- Outlet temperature of aromatic hydro carbons 'Tco'=230°c

New heat exchanger

- Mass flow rate of hot oil 'mh'
- One time oil passes 5 tubes Mass flow rate=2757.208kg/hr
- of aromatic hydro carbons 'mc" Inlet temperature=2696.166
- of hot oil ‘Thi’=320°c
- Out let temperature of hot oil ‘tho’=270°c
- Inlet temperature of aromatic hydro carbons ‘Tcj’=217°c
- Outlet temperature of aromatic hydro carbons Tco’=230°c

Graph-1: Analysis of shell using convection T.H.F and D.H.F

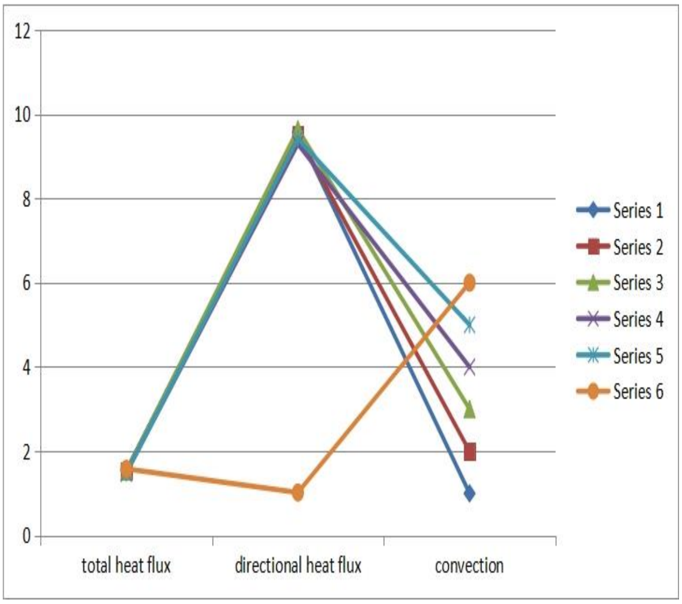

Table No-1: Analysis of Shell of a Heat Exchanger

S.NO	CONVECTION	INPUT TEMP	OUT-PUT TEMP	TOTAL HEAT FLUX	DIRECTIOAL HEAT FLUX
1	1	22	22	$1.5397x10^{-7}$	$9.5606x10^{-8}$
2	2	22	22	$1.5281x10^{-7}$	$9.5065x10^{-8}$
3	3	22	22	$1.5183x10^{-7}$	$9.645x10^{-8}$
4	4	22	22	$1.4825x10^{-7}$	$9.2908x10^{-8}$
5	5	22	22	$1.4769x10^{-7}$	$9.4146x10^{-8}$
6	6	22	22	$1.5819x10^{-7}$	$1.0209x10^{-7}$
7	7	22	22	$1.5266x10^{-7}$	$9.5986x10^{-8}$
8	8	22	22	$1.5495x10^{-7}$	$9.4229x10^{-8}$
9	9	22	22	$1.5067x10^{-7}$	$9.29x10^{-8}$
10	10	22	22	$1.4892x10^{-7}$	$9.6833x10^{-8}$

Table No-2: Analysis of tube of an heat exchanger

Convection	Heat Flow	Heat Flux	Meshing	Temperature		Total Heat Flux		Directional Heat Flux	
				Max	Min	Max	Min	Max	Min
1	10	10	0.005	131.47	131.47	103.08	98.691	101.87	-102.25
2	15	15	0.006	104.11	104.1	153.2	148.95	153.2	-153.2
3	20	20	0.007	94.983	94.981	208	196.72	204.43	-204.42
4	25	25	0.008	90.422	90.42	257.59	247.21	255.75	-256.13
5	30	30	0.009	87.794	87.58	332.75	281	323.88	-324.34
6	35	35	0.010	85.91	85.79	392.3	333.99	373.63	-373.78
7	40	40	0.011	84.55	84.55	438.34	386.89	418.12	-408.36
8	45	45	0.012	83.605	83.532	481.74	430.93	466.84	-469.91
9	50	50	0.013	82.83	82.77	535.16	484.98	520.46	-524.28
10	55	55	0.014	82.22	82.19	580.7	530.23	569.07	-570.81

7.CONCLUSION:

Advanced design software CATIA V5 is used to model and analyze electrical components and finite element an analysis software ANSYS v23 is used for analysis. Tardr um reboiler E4509 has been found to fail in service and each failure is costly as it affects production.During the design review, one of the tubes was tested with both SS3 16 and incoloy825 tubing and was found to be the only suitable one.

Vibration of the pipe is also the element of pipe failure a nd can be prevented by installing DTS strips on the pipe, and changing the design of the reboiler bottle can also extend the life of the returning material when the bag is full. It's all in the liquid. They do this by lowering all temperatures during operation. Therefore, it is recomme nded to use incoloy825 tube packing made of DTS strip for the tube stuffing box of electrical equipment, and rep lace the heat transfer box housing according to the relev ant results and results specified.

8. ACKNOWLEDGEMENT

We would like to say sincere thanks to our guide **Mr. V. SHYAMU, Assistant Professor,** Department of Mechanical Engineering for Coordinating Projects for the suggestions and constant guidance in every stage of the project, we also like to thank all our lecturers helping us in every possible way. On a more personal note, we thank our beloved parents and friends for their moral support during our project. We place on record our sincere thanks to **Dr. A. RAJ KUMAR, Professor and Head of the Department**, Mechanical Engineering for their wholehearted co-operation, providing excellent lab facility, constant encouragement, and unfailing inspiration.

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