IOSR Journal of Mechanical & Civil Engineering (IOSRJMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X
PP 24-31
www.iosrjournals.org

Design Optimization of Shell an Tube Heat Exchanger for Tube Failure Prevention

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Abstract : *In this paper a simplified approach to optimize the design of Shell Tube Heat Exchanger [STHE] by using Finite Element Analysis [FEA]. The FEA of STHE helps in achieving optimization in design by prevention of tube failure caused due to FEA.The main reason for design of STHE is to optimize the heat exchanger for safer design. Firstly, take the detailed design from Alfa-Laval (India), Ltd., Pune-10. then make the model in 3-D software and convert this model into ANSYS for analysis and after these calculate the stress strain value by using numerical method. These shows that software and numerical stress, strain values are same therefore design is safe, also find frequencies at different modes.*

Keywords*- Heat Exchanger, FEA, Stress, TEMA, HTRI*

I. INTRODUCTION

Engineering materials are evolving faster and the choice is wider than ever before [1]. Many industries have transformed significantly over the past few decades. This is mainly because of the advancement in materials, processes, and computational capabilities. Advanced high – tech industries adopted new materials and processes; replacement of mild steel with high strength steel, lighter non – ferrous alloys, such as aluminium and magnesium alloys, plastics, and composites. Many industries developing high strength, low weight materials for wide applications such as composite materials [2]. Heat exchangers are commonly used to transfer heat from steam, water, or gases, to gases, or liquids. Some of the criteria for selecting materials used for heat exchangers are corrosion resistance, strength, heat Conduction, and cost. Corrosion resistance is frequently a difficult criterion to meet. Damage to heat exchangers is frequently difficult to avoid. The tubes in a heat exchanger transfer heat from the fluid on the inside of the tube to fluid on the shell side (or vice versa). Some heat exchanger designs use fins to provide greater thermal conductivity. To meet corrosion requirements, tubing must be resistant to general corrosion, pitting, stress-corrosion cracking (SCC), selective leaching or dealloying, and oxygen cell attack in service.

II. PROBLEM STATEMENT

To design and develop a shell and Tube heat exchanger to meet the functional requirements as per Table1, Table 2 and Table 3 to satisfy company requirement as per ASME code & TEMA standards. The scope was limited to analyze the stress variation at Shell Tube Heat Exchanger. The objective of this work is to find stresses on Heat Exchanger by numerical and software basis and modal analysis is done. Also done modal analysis for finding out natural frequency of Heat Exchanger.

TABLE 1: Design Data ASME section 8 div.1

Design Data		
Design Code: ASME Sec. Viii Div. 1 Ed. 2007 Ed 2009/ Tema Cl R, 9th Edition. Type Bem		
	Shell Side	**Tube Side**
Design Pressure Bar	5.2	5.2
Design Temperature C^o	150	150
Operating Pressure bar	0.965	0.409
Operating Temperature C^o	89.78/73.99	72.63/72.63
Hydro Test Pressure bar	7.8	7.8
Hydro Test Temperature C^o	Ambient	Ambient

M.D.M.T. C°	-29	-29
Mean Metal Temperature C°	81.89	72.644
Corrosion Allowance mm	0	0
Radiography	Nil	Nil(Rt4)
Joint Efficiency	0.7	0.7
Content Fluids	Water/Ethanol/Co_2	Thin Stillage
Specific Gravity	0.83	0.97
Heat Transfer Area Sq.m	781.4	-
Basic Wind Speed M/Sec	42	-
Seismic Criteria	Ubc-1997	-
Insulation mm	75 Mm Fiberglass	-
Empty Weight Kg	21000	-
Hydro Test Weight Kg	42500	-
Bundle Weight Kg	94000	-
Inspection Authority	Alil/Tuv	-
Equipment Quantity	1	-
P & Id No.	8455001-4100-25-R4102	

TABLE 2: Nozzle Schedule

Nozzle Schedule								
Nozzle	**Service**	**Size**	**Sch./Thk**	**Flange**				**R/F Pad Odxthk**
				Std	**Rating**	**Type**	**Facing**	
A	Shell Side Vapour Inlet	Dn400	10 Thk	ASME B-16.5	150#	So	Rf	660x8 Thk.
B	Shell Side Liquid Outlet	Dn200	Sck. 40	ASME B-16.5	150#	So	Rf	350x8 Thk.
C1,C2	Manway With Blind & Davit	Dn600	10(8)Thk	ASME B-16.5	150#	So	Rf	1100x8 Thk.
E	Tube Side Inlet	Dn300	10 Thk	ASME B-16.5	150#	So	Rf	500x8 Thk
F	Vapour Outlet	Dn600	10 Thk	ASME B-16.5	150#	So	Rf	1100x8 Thk
H1,H2,H3	View Port	Dn200	-	ASME B-16.5	150#	Pad	-	-
J1,J2	Press. Indicator	Dn50	Sch.160	ASME B-16.5	150#	So	Rf	-
P	Psv	Dn50	Sch.160	ASME B-16.5	150#	So	Rf	-
Q1	Non Condensible Vents	Dn50	Sch.160	ASME B-16.5	150#	So	Rf	-
Q2	Spare With Blind	Dn50	Sch.160	ASME B-16.5	150#	So	Rf	-
R1,R2	Skirt Vent	Dn50	Sch.160	-	-	-	-	-

TABLE 3: Material Specification

MATERIAL SPECIFICATION		
1	Shell/Dish	SA 240 TYPE 304
2	Shell / Tube Side Internals	SA 240 TYPE 304
3	Tubes	SA 249 TYPE 304
4	Nozzle Neck	SA 240 Gr.304/ SA 312 TP 304
5	Flanges	SA 180 F-304
6	Gasket	2 mm thk. PTFE
7	Lug Support	SA-36
8	Skirt / Support	SS-304 + SA – 36
9	Sealing Strip	SA-240-Gr.304
10	Stub End	SA-403-Gr..304
11	Tube Sheet	SA-965-F-304
12	Glass	Boro Silicate
13	Stiffener	SA-240-Gr.304

III. DESIGN AND ANALYSIS RESULTS

A. Analysis of Heat Exchanger

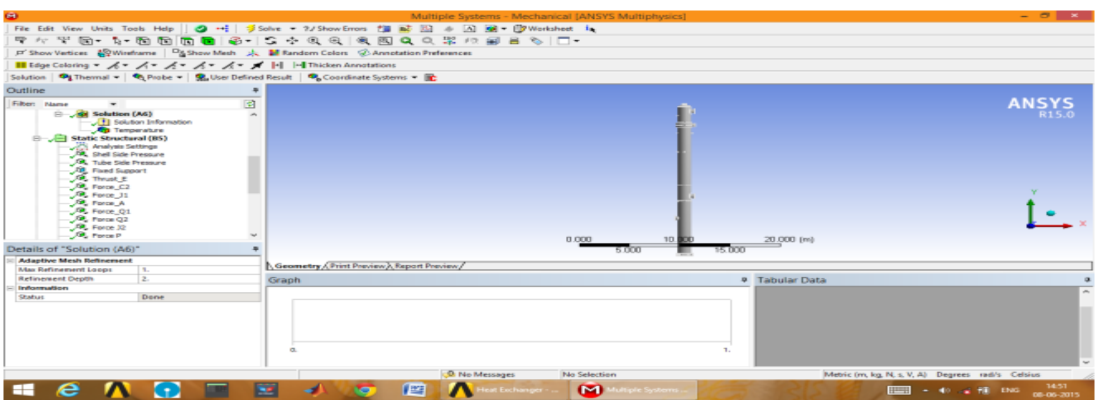

Fig. 1 Geometry of Heat Exchanger

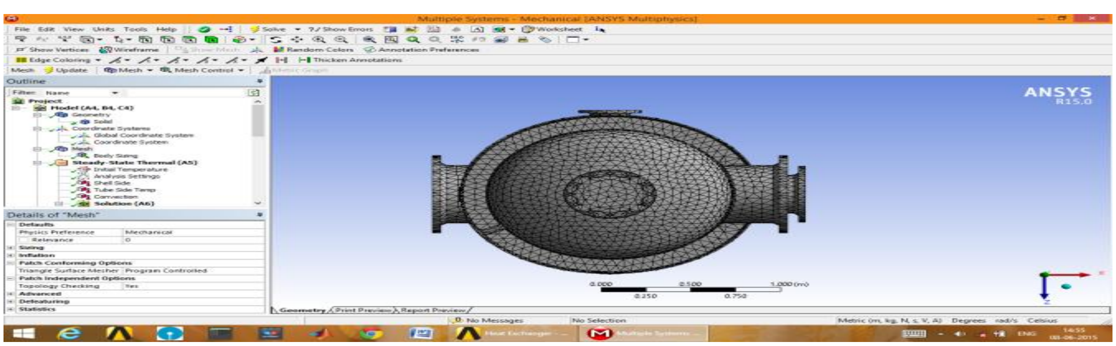

Fig.2 Meshing of Heat Exchanger

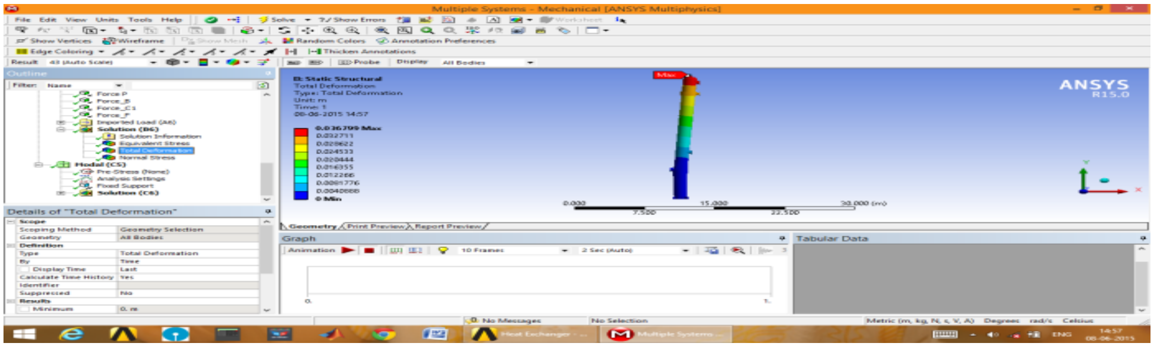

Fig.3 Total deformation of Heat Exchanger

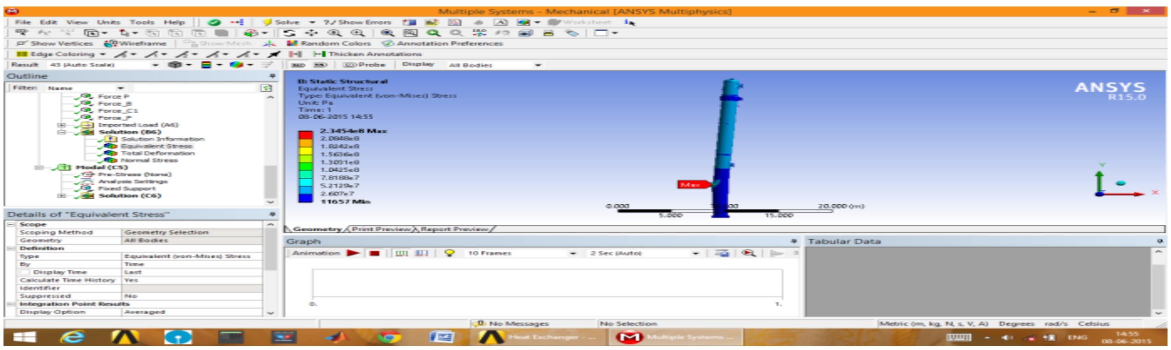

Fig. 4 Equivalent stress plot of Heat Exchanger

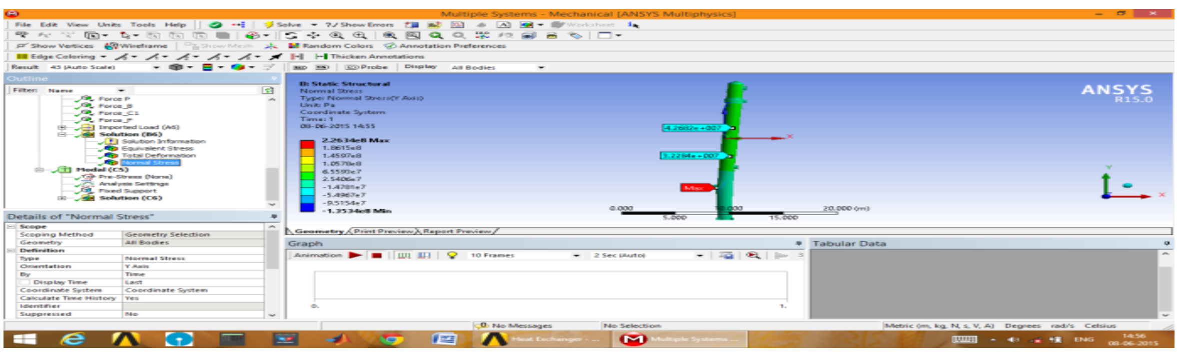

Fig.5 Normal Stress plot of Heat Exchanger

B. Numerical Design of Heat Exchanger

1. Thickness of HE Shell = 8 mm.
2. Thickness of Semielliptical Head=8 mm.
3. Inside Corner Radius = 126 mm.
4. Straight Flange Length = 50 mm.
5. Storage Capacity of HE = 2.293 $mm^{3.}$
6. Ro = Outer radius of shell = 683 mm
   Ri = Inner radius of shell = 675 mm
   P = 0.52 MPa

Results are verified for stress due to pressure as follows:

Hoop stress in shell away from discontinuity

$$\sigma_\phi = \frac{P * {R_i}^2}{({R_o}^2 - {R_i}^2)}\left(1 + \frac{{R_o}^2}{{R_i}^2}\right)$$

$$\sigma_\phi = \frac{0.52 * 675^2}{(683^2 - 675^2)}\left(1 + \frac{683^2}{675^2}\right)$$

$$\sigma_\phi = 44.136531 \text{ N/mm}^2$$

As per IS code and ASME code, the allowable stress is based on ultimate tensile strength and as per DIN code, the allowable stress is based on the yield strength.

Allowable stress, $\sigma_{all} = \frac{S_{ut}}{3.0} = \frac{505}{3.0} = 168.33\text{MPa}$

Or $\sigma_{all} = \frac{S_{yt}}{1.5} = \frac{215}{1.5} = 143.33\text{MPa}$

For further reference take the minimum value of Allowable Stress.
From above result the Normal Hoop's Stress using analytical method is 42.68N/mm^2 and numerical solution is 44.13N/mm^2.and Allowable stress is 143.33/mm^2.
Therefore, both the stresses are within the limit of Allowable stress.

C. Modal Analysis of Heat Exchanger

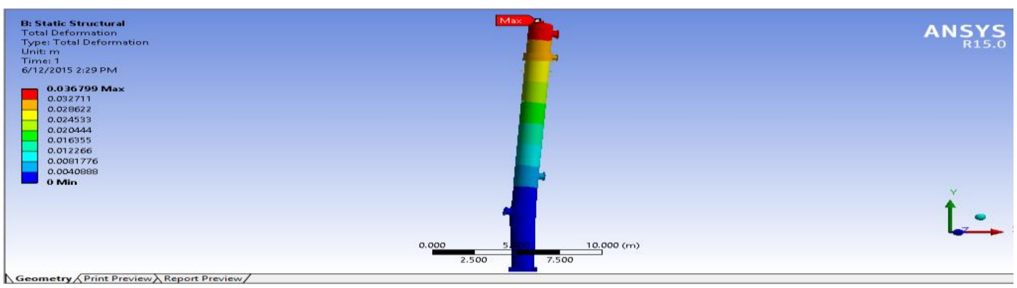

Fig.6 Total deformation 1

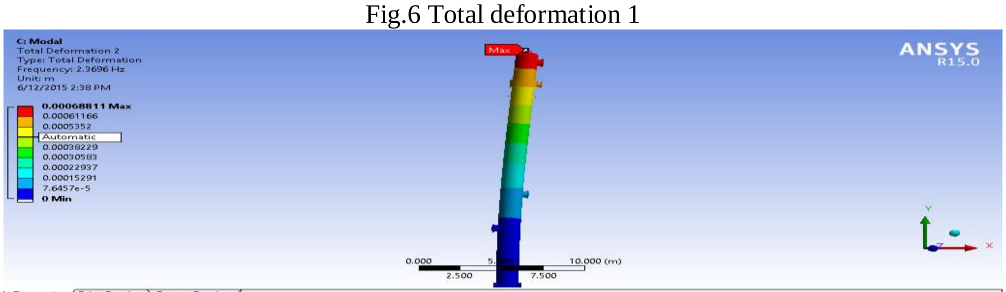

Fig.7 Total deformation 2

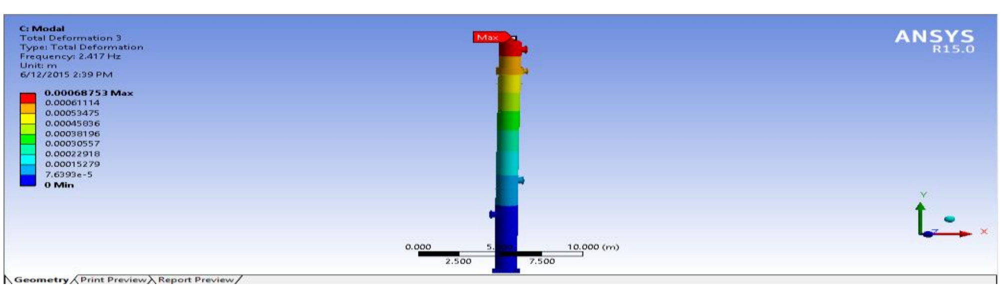

Fig.8 Total deformation 3

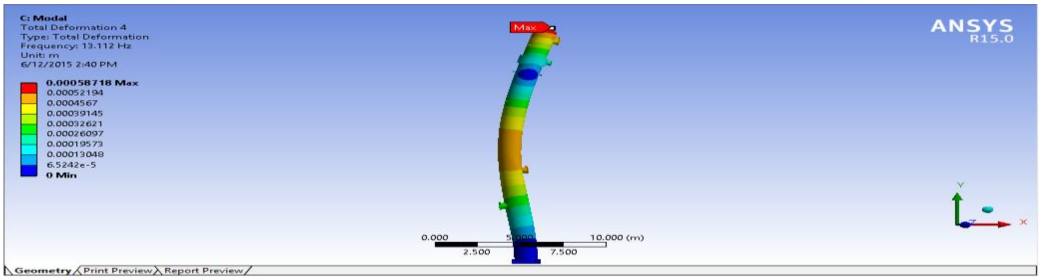

Fig.9 Total deformation 4

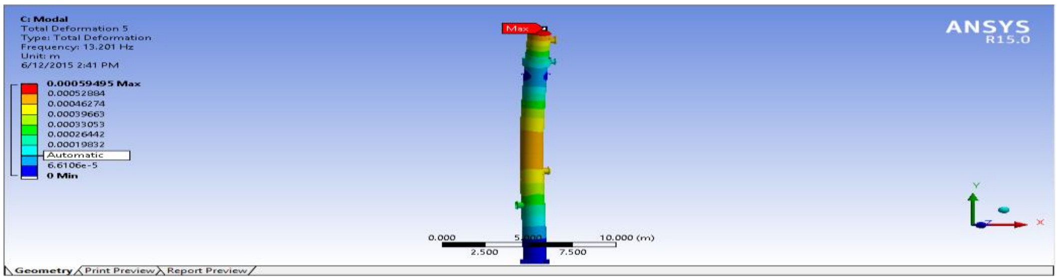

Fig.10 Total deformation 5

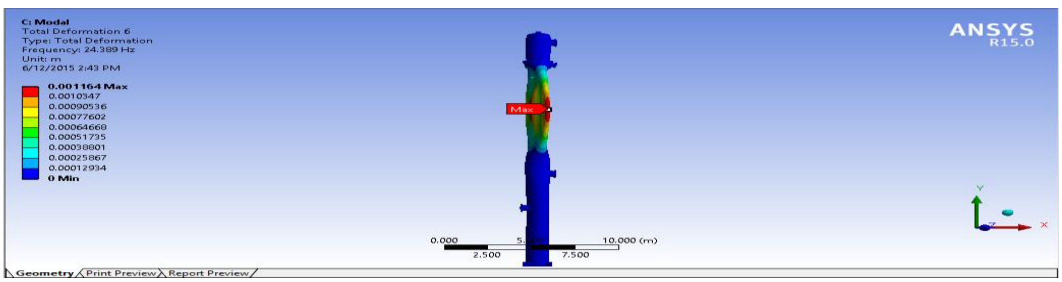

Fig.11 Total deformation 6

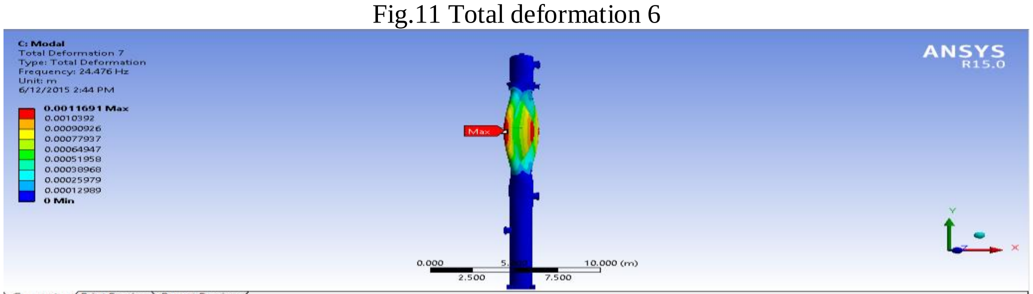

Fig.11 Total deformation 7

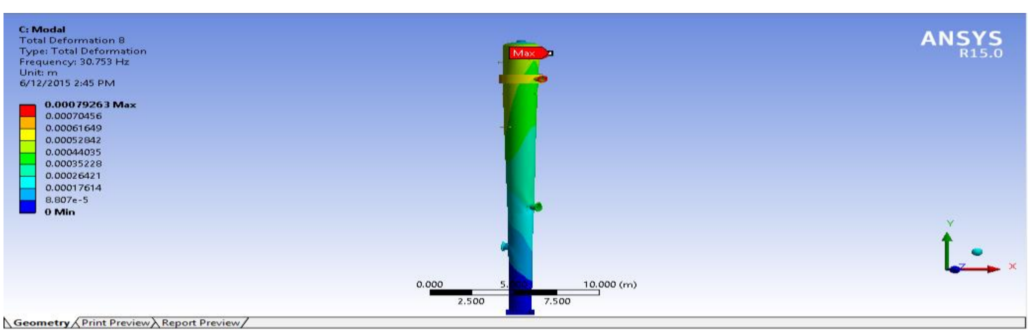

Fig.12 Total deformation 8

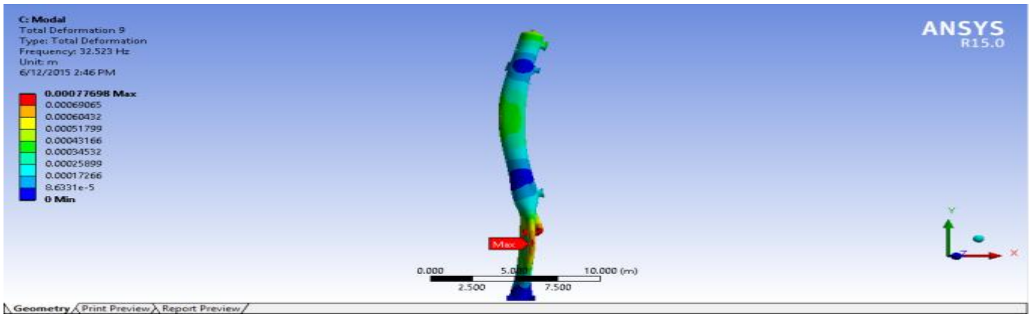

Fig.12 Total deformation 9

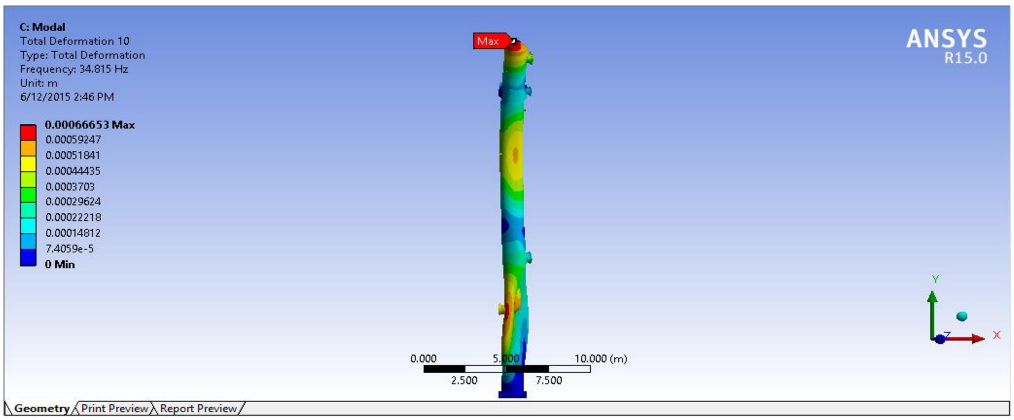

Fig.13 Total deformation 10

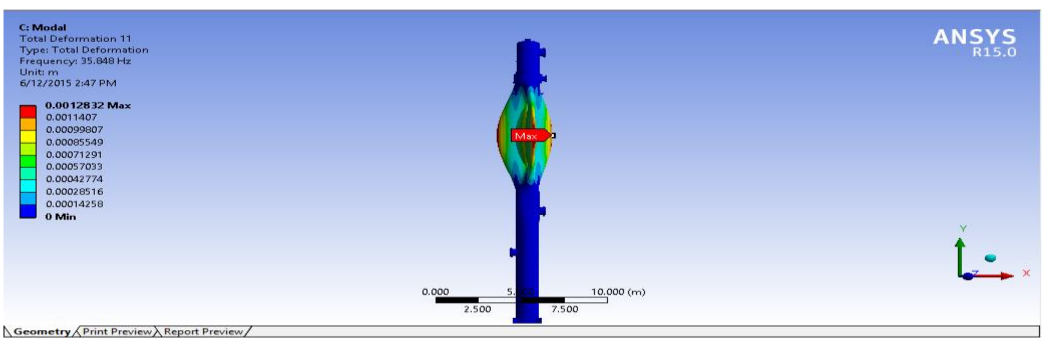

Fig.14 Total deformation 11

Table: 4 Modal analysis results

Sr. No.	Mode	Frequency(Hz)
1	1	2.3696
2	2	2.3696
3	3	2.417
4	4	13.112
5	5	13.201
6	6	24.389
7	7	24.476
8	8	30.753
9	9	32.523
10	10	34.815
11	11	35.848

IV. CONCLUSION

As per customer requirement we have analyzed and design Heat Exchanger under structural condition for normal stress and compare with numerical hoops stress, both stresses are within the limit of allowable stress Also find Frequency using Modal Analysis.

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