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Finite Element Analysis of Tube Sheet

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***Abstract*—Tubesheet is the major element for the industriel purpose for engineering department.in many condition to apply for tubesheet for number of stresses and pressureintubesheet.in these condition static and dynamic analysis of tubesheet for stressesand and deformation of tubesheet is major area for resherch for work.**

I. Introduction

A tube sheet is a plate, sheet, or bulkhead which is perforated with a pattern of holes designed to accept pipes or tubes. These sheets are used to support and isolate tubes in heat exchangers and boilers or to support filter elements. Depending on the application, a tube sheet may be made of various metals or of resin composites or plastic.

However tube sheet design is very complex, because of its interaction with the Pressure Vessel & the stresses it generates. The location where the tube sheet is attached, radial expansion of the vessel is halted; this creates bending stress in the vicinity of the tube sheet.

Generally, Holes arranged in the uniform pattern are in a plate is popularly known as tube plate or tube sheet. Holes in the tube sheet can be arranged in three different patterns.

- Equilateral Triangular Pattern
- Square Pattern
- Staggered Square Pattern

Out of these patterns, the equivalent triangular arrangement is the most widely used as it is the most effective packing arrangement.

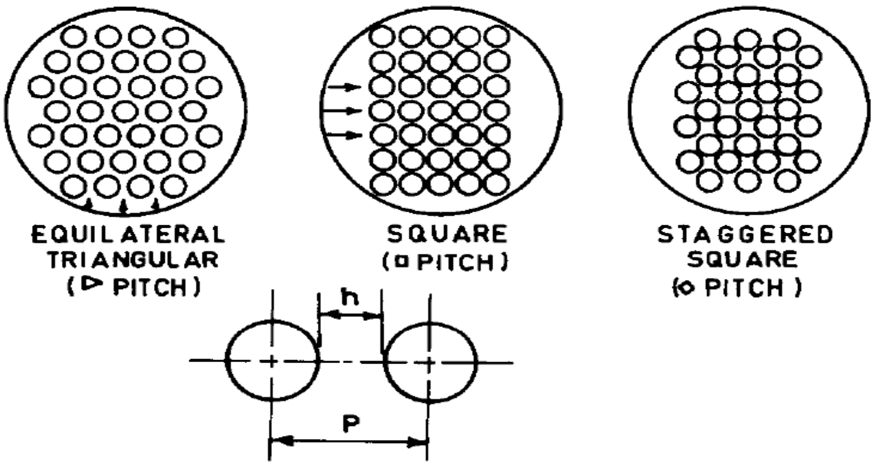


Figure 1.1 Three Different types of hole patterns

The main objective of this research work is to minimize the stress, deformation of tubesheet by using the static and dynamic analysis of ansys. An extensive research work has been carried out on the Shell and Tube heat exchangers by changing different parameters to meet the industrial requirements.

H.F. Li at al. (2010)[1], investigate the possible mechanical causes of a real tubesheet cracking by simulate the tube sheet under different loading condition. They took three different loading conditions, namely residual expansion stress, crack face pressure and transverse pressure, and three crack growth patterns were considered.

V. G. Ukadgaonker et al. (1996) [2], works on review of analysis of tube sheets. They analyze for the different types of hole pattern in the tube sheet. They use Analytical technique, Experimental Technique as well as Numerical technique to analyze the tube sheet. And also compare the stress concentration factor for three patterns of holes. Chi Bum Bahn at al. (2013)[3], address concerns about excessive leakage from through wall cracks in nuclear reactor tube-to-tubesheet joints under accident conditions, leak rates were measured experimentally by using tube-to-collar joint specimens and nitrogen gasK.Behseta at al. (2006) [4], works on the design of the tubesheet and the tubesheet-to-shell junction Of a fixed tubesheet heat exchanger. Ravivarma.R at al. (2014)[10], investigate in two parts; first one is linear Static analysis of conventional equivalent Modulus of elasticity & Poisson's ratio method, which is recommended by ASME (American Society of Mechanical Engineers) Sec. VIII, Division-1. Second is a new and realistic approach of linear Static analysis by considering the perforations of tube holes in the Tubesheet with pressure acting at inside tubes. Research paper indicates that the analysis of tube sheet is attempted by various investigations for various conditions as well as for highly stressed assembly like tube to tuebsheet joint. Literature survey shows that there are so many analyses observed with tube sheet & tube to tubesheet joint but there is no attempt made with analysis and optimization of spaced sequential tubesheet. Hence FEA based Analysis and Optimization of spaced sequential Tubesheet is an interesting area for investigation

II. OBJECTIVE

The literature survey carried out during the present course of work clearly shows that there is scope for analysis and optimization of spaced sequential tubesheet using Finite element analysis.

Hence the objectives of the present work are decided as under:

Mechanical Design of Tubesheet using ASME code.

To create analysis of Tubesheet in Ansys.

To optimize the thickness of Tubesheet.

To study the effect of tube sheet spacing on stress profile.

To optimize the structure with the Spacing Distance between tube sheet.

III. SIMULATION METHODOLOGY

Parameters for Tubesheet Calculations:-

Sr. No.	Parameter Description	Notations	Given Value
1	Internal Pressure	P	0.14 MPa
2	External Pressure	P0	Atmospheric
3	Process Volume	Vp	126 cu m
4	Expected Stagnant Volume	Vs	Not Specified
5	Buffer Volume Requirement	Vb	Not Specified
6	Tube Porosity Volume	Tp	70
7	Tube Length	TL	5.5m
8	Radius of tube sheet	R	2m
9	Tube Diameter	Td	0.15m

A 5% Gap will be maintained on the Tube Sheet radius to allow for welding.

Tubes shall be spaced in a manner such that they form a 60 deg Equilateral Triangle.

Mathematical Formulation for unknown parameters:

Total volume = Pressure Volume + Expected Stagnant Volume + Buffer Volume

V = Vp + Vs + Vb……………………… (1)

Here buffer volume is not specified; hence it has to be considered 0.01 of total volume or stagnant volume whichever is higher.

Also stagnant volume is not specified; hence it should be taken as 0.1 of total volume.

Therefore, above equation 1 becomes,

V = Vp + 0.1V + 0.01V…………………(2)

∴ V (1 - 0.1 – 0.01) = Vp

∴ V (0.89) =126 x 109.

∴ V = 1.415730 x 1011mm3

∴ Buffer Volume = Vb = 0.01V = 1.415730 x 109mm3

∴ Stagnant Volume = Vs = 0.1V = 1.415730 x 1010mm3

Here, Vs> 0.1Vp

Hence, the vessel is characterized as a full process reactionary vessel.

Referring A2209, for full process reactionary vessel,

Vp = (0.90NTD) x (πr2) (NTD is nozzle to nozzle distance in meters).

126 x 109= 0.90 x NTD x π x (20002)

NTD = 11146.4968 mm

i.e. NTD = 11.146 metres

Now, Vs + Vb = (0.82L1) x (π r2)
Here, Vs>Vb, hence considering Vb = Vs
2 x 1.415730 x 1010 = (0.82L1) x (π x 20002)
Gives, L1 = 2749.203 mm.
i.e. NTD = 2.7492 metres

Calculations for Tube sheet volume (Tv):

Tv = $\frac{\pi}{4} D^2 \times T_t$

Where, Tt = Tube sheet thickness
Tv = Total volume of the tube sheet

∴ Tv = $\frac{\pi}{4}(3800)^2 \times T_t$

Assuming Tt = 1mm
Tv = 11341.1494 x 103
The above volume is reduced value of actual tube sheet volume by 5% for welding space.
4.4 Calculation for tube volume:
Now, tube diameter (Td) is 0.15m =150mm.
Considering length of the tube = length of the tube sheet.

Total volume = $\frac{\pi}{4} T_d{}^2 \times T_L \qquad ....T_L = Tt$

TL = Tube length.
Tv = 17671.458mm3
Calculations for 'n' no of holes,
Volume of holes = (total volume) x n
∴ Residual volume = Tube sheet volume – Tube volume
∴ TR = Tv – Tube volume

But T ^{R} / Tv = 0.3

∴ 0.3 = 1- $\frac{Tube\ volume}{Tube\ sheet\ volume}$

∴ 11341.1494 x 103 x 0.7 = 17671.458 x n
∴ n = 449.244 nos ≅ 450 number of holes.

Calculations for ligament efficiency

Ligament efficiency (η) = $\frac{Area\ remaining\ after\ drilling\ holes}{area\ before\ drilling\ the\ holes} = \frac{D - nd}{D}$

$$= \frac{4000 - (22 \times 150)}{4000} = 0.175.$$

The figure below shows the pattern of holes in the tubesheet.

Final Dimension: -

In this chapter all the dimensions of the vessel component as well as the tubesheet were calculated, also the dimensions were modified according to ASME standards.
The final modified dimensions are as follows:-

Thickness of Tubesheet – 150 mm
Ligament Efficiency – 0.16
Number of Holes on the tubesheet - 49

IV. ANALYSIS

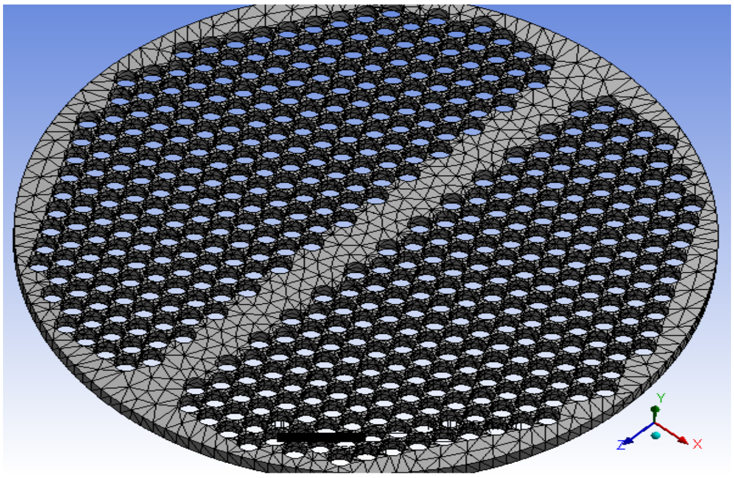
Finite element analysis is one of the finest methods to get the solutions for some of themost complexengineering problems. In finite element analysis, the boundary conditions are of the prime importance. The correctness of results is intensely dependent on the applied boundary conditions. Further the type of loading classifies theproblem into different modules of analysis viz. static analysis, dynamic analysis, modal analysis, transient analysis, etc. For the application considered in this project, transient dynamic analysis is being used.

Boundary Conditions for Convergence:

Case 1: Tubesheet analysis with self-weight and gravity acting downwards.
Case 2: Tubesheet analysis with gravity acting downwards and design load (0.175 Mpa) acting in opposite direction of gravity.
Case 3: Tubesheet analysis with gravity acting downwards and back pressure (0.145 Mpa) acting in the direction of gravity.
Case 4: Tubesheet analysis with both positive and negative pressures acting on it.

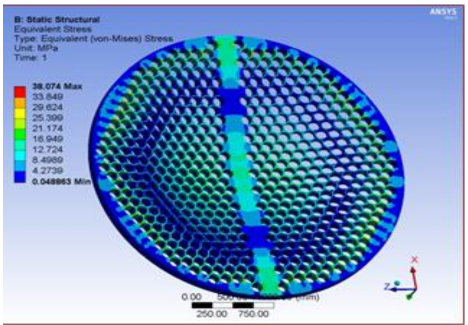
Tetrahedron Element

Figure below shows the actual meshing of the tubesheet using Tetrahedron element for 2.5 Lakh nodes.

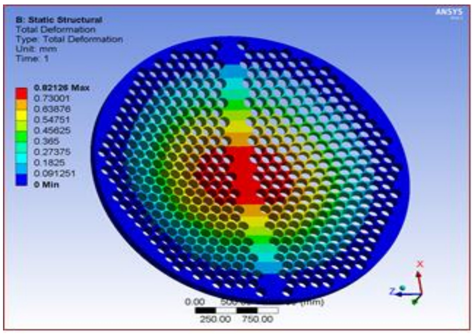


Meshing with Tetrahedron Element

Case 1: Tubesheet analysis with self-weight and gravity acting downwards.



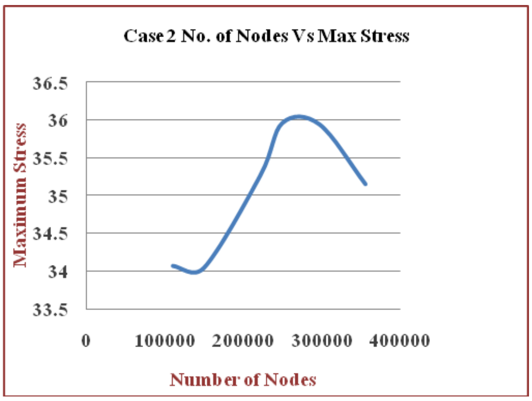
(a) Maximum Stress (Case 1)



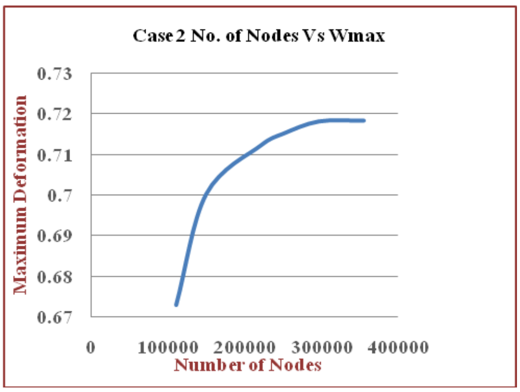
(b) Maximum Deformation (Case 1)

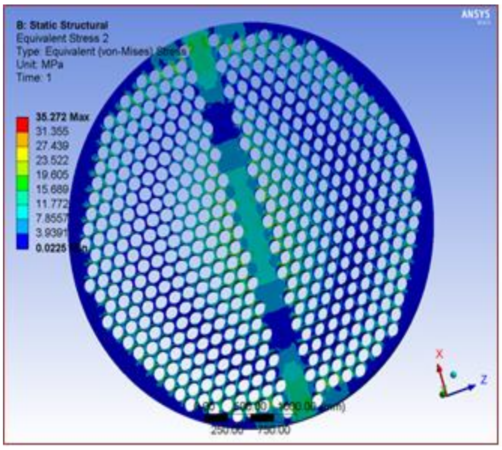
Case 2: Tubesheet analysis with gravity acting downwards and design load (0.175 Mpa) acting in opposite direction of gravity.

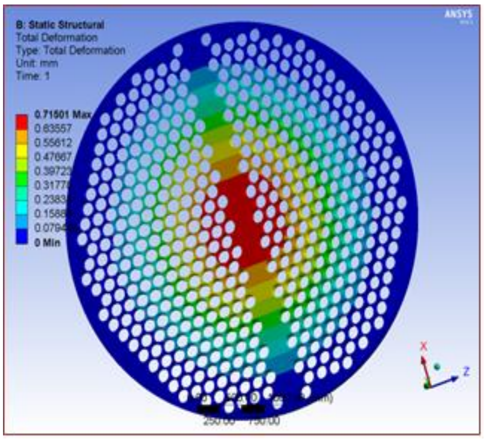
(a) Nodes Vs Max Stress



(b) Nodes Vs Max Deformation



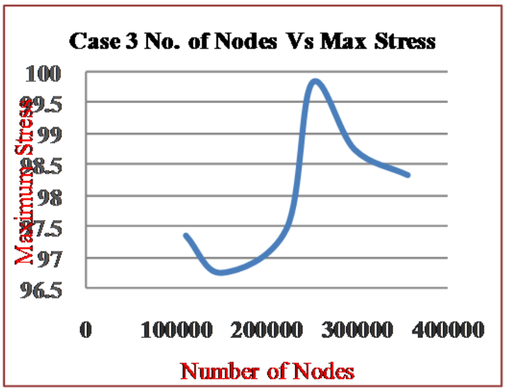


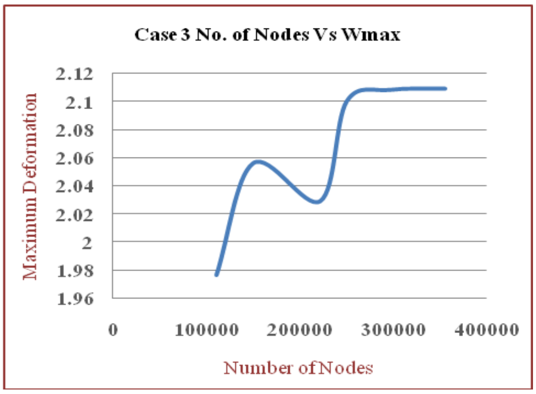


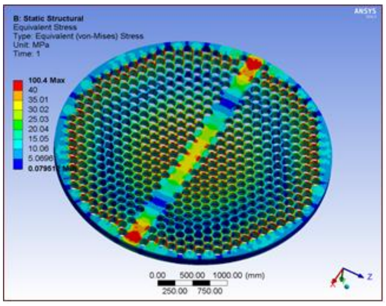
(c) Maximum Stress (Case 2) (d) MaximumDeformation(Case 2)

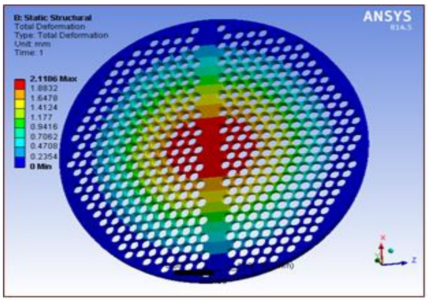
Case 3: Tubesheet analysis with gravity cting downwards and back pressure (0.145 Mpa) acting in the direction of gravity.

(a) Nodes Vs Max Stress (b) Nodes Vs Max Deformation









(c) Maximum Stress (Case 3) (d) Max Deformation (Case 3)

V. Conclusion

In this chapter the transient dynamic analysis of tubesheet was carried out for different loading conditions of tubesheet. Below are the results of the analysis in terms of fatigue life of the Tubesheet.

a) Tubesheet with 150mm thickness and 1,00,000 nodes:-
Maximum deformation – 0.252 mm
b) Tubesheet with 150mm thickness and 2,50,000 nodes:-
Maximum deformation – 1.0372 mm
Fatigue Life – 1.0E11 number of cycles

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