# Finite Element (FE) Analysis of Pressure Vessel with Embedded Heat Treatment Pipes

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*Abstract*— In chemical processes viscosity of fluid is important fluid property. To maintain viscosity of the fluid stored heat is used. The viscosity of the fluid varies with temperature. If the temperature drops the fluid becomes viscous and can cause considerable damage to the system. However if we heat from below, at time surface cooling occurs and this makes natural convection stop, and the heat never reaches the Top layers. Hence to avoid this heat pipes are inserted from top to ensure efficient distribution of heat. Heat is supplied in these pipes itself so that maximum benefit of heat transfer is achieved. The main objective of paper is finite element analysis of pressure vessel at different boundary condition. The stresses developed in pressure vessel are analyzed by using ANSYS.

***Key words:*** Pressure vessel, FEA

## I. INTRODUCTION

Chemical engineering involves the application of sciences to the process industries, which are primarily concerned, with the conversion of one material into another by chemical or physical means. These processes require the handling or storing of large quantities of materials in containers of varied constructions, depending upon the existing state of the material, it's physical and chemical properties and the required operations, which are to be performed. For handling such liquids and gases, a container or vessel is used. It is called a pressure vessel, when they are containers for fluids subjected to pressure. They are leak proof containers. The fluid is to be stored in pressure vessel is heavy oil which is used distillate naphtha. The first unit process in a petroleum refinery is the crude oil distillation unit. The overhead liquid distillate from that unit is called virgin or straight-run naphtha and that distillate is the largest source of naphtha in most petroleum refineries. To maintain required viscosity of fluid stored temperature is required to maintain above 40℃ for this heat pipes are inserted from top. The main purpose of paper is to design and analysis of pressure vessel and its safety at various conditions.

## II. DESIGN CALCULATIONS FOR PRESSURE VESSEL

Pressure vessels are design in accordance with ASME code. The code gives for thickness and stress of basic components of pressure vessel .The input parameters which are given for design of pressure vessel are tabulated in Table I. from input parameters the vessel will be characterized as low pressure Process reactionary vessel.

| No. | Parameter Description | Parameter Code | value |
|---|---|---|---|
| 1 | Specific gravity Of Fluid | $S_f$ | 1.125 |
| 2 | Operating Pressure | P | 0.05MPa |
| 3 | External Pressure | $P_o$ | Atm |
| 4 | Process Volume | $V_p$ | $205m^3$ |
| 5 | Expected Stagnant | $V_S$ | $57m^3$ |
| 6 | Buffer Volume | $V_b$ | $50m^3$ |
| 7 | Vessel radius | R | 2.5m |
| 8 | Tube porosity volume | $T_p$ | 25 |
| 9 | Radius of tube sheet | R | 2.5m |
| 10 | Tube diameter | $T_d$ | 200mm |
| 11 | Corrosion allowance | CA | 6mm |

Table 1: Input Data

### A. *Internal Dimensions Calculations*

Internal dimensions of pressure vessel are calculated from input parameters which are shown in fig.1

Where,

L0 = Main stock cylinder length =13m

L1 = Buffer stock cylinder length =6.645m

NTD= Main Nozzle to Nozzle centre distance (inlet/outlet) =12.823m

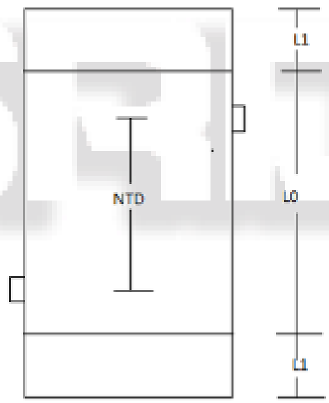


Fig. 1: 2D Pressure vessel

| Description | Values |
|---|---|
| Material | SA 516 Grade 70 |
| Modulus of elasticity | 200 GPa |
| Poisson's ratio | 0.29 |
| allowed stress | 138 |

Table 2: Material Properties

### B. *Final Dimensions of Pressure Vessel*

Final dimensions of pressure vessel are calculated using ASME SECTION VIII DIVISION 1 codes

| | |
|---|---|
| Thickness of shell | 18mm |
| Diameter of shell | 5000 mm |
| Thickness of nozzle | 18 mm |
| Diameter of nozzle | 200 mm |
| Thickness of reinforcing pad | 9 mm |
| Diameter of reinforcing pad | 300 mm |
| Thickness of Flat head | 200 mm |

Table 3: Dimensions of Pressure Vessel

 

## III. MODELLING

3-D model of the given component is created in ANSYS Design modeler. which is compatible to import in the solver. The 3-D model of the Pressure vessel is created in Ansys 15 work bench . Fig.2 shows The modeling of pressure vessel . These files were used for analysis further process.

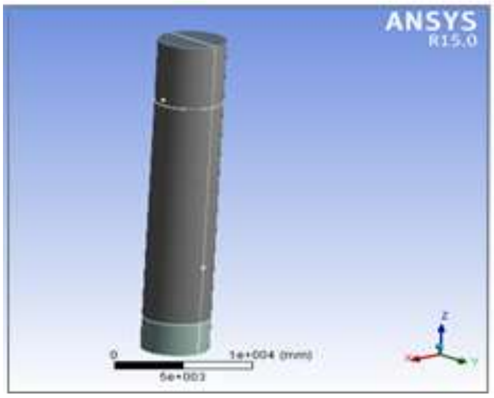


Fig.2 3D Model of Pressure Vessel

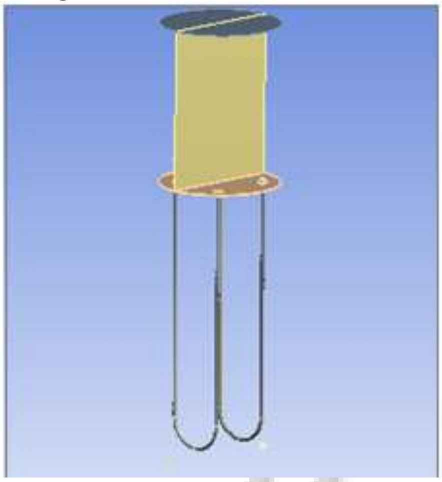

Fig. 3 Detail 3D model of pressure vessel

## IV. MESHING

The meshing is done with mesh size of 75mm for cylinder, tubesheet, skirt support and 50mm mesh size for other parts such as all nozzle, pipes and reinforcement pad. Also Map faced meshing is done for removing non regularity in meshing which affects the end results. Fig. 4 shows Meshed model,

Type of mesh : Quadrilateral
number of Nodes : 152407
number of Elements :114811

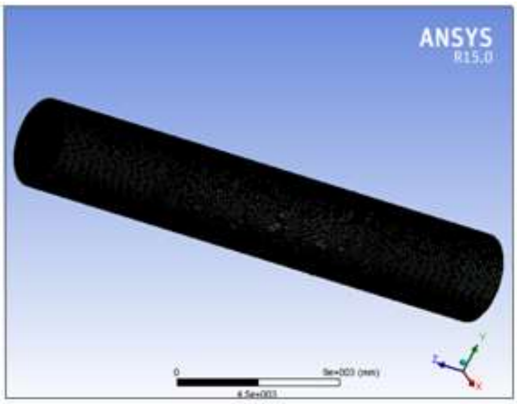


Fig. 4: Meshed model of pressure vessel

## V. STATIC ANALYSIS

### A. *Self weight loading conditions:*

The vessel was analyzed with dead weight loading. The load by acceleration due to gravity is aplied to find the total deformation and equivalent stress. As shown in figure the standard earth gravity 9806.6 mm/s2 is applied downward. The fixed support is given to skirt support.

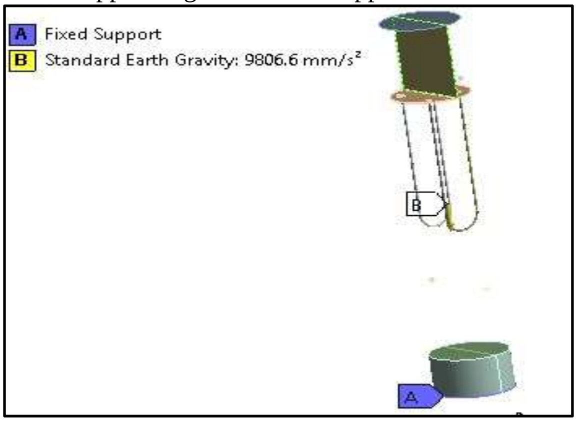


Fig. 5: self-weight boundary conditions

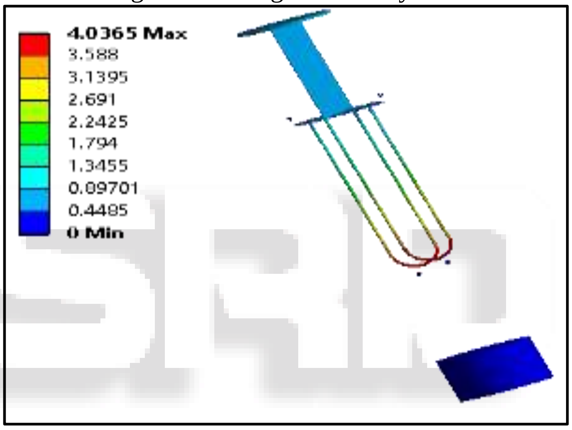


Fig. 6 Total deformation (self weight condition)

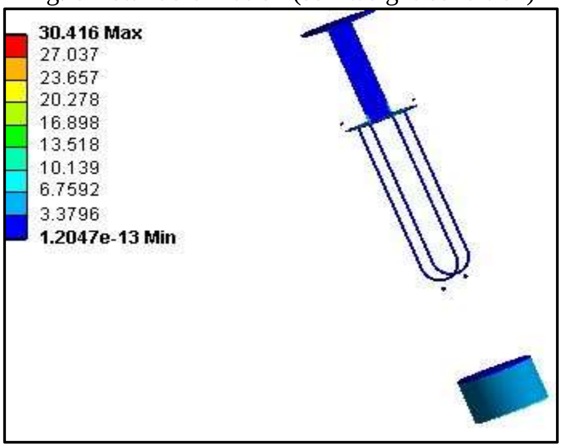


Fig. 7 von misses stress (self-weight condition)

### B. *Internal pressure loading condition at Upper chamber:*

A pressure of 0.05 MPa is applied to all internal surfaces of one section of upper chamber and 0.04 Mpa is applied to other section of chamber. Standard earth gravity is applied and fixed support is given to skirt support.

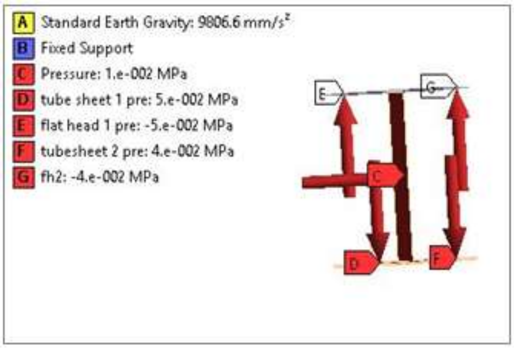


Fig. 8: Internal pressure loading condition at upper chamber

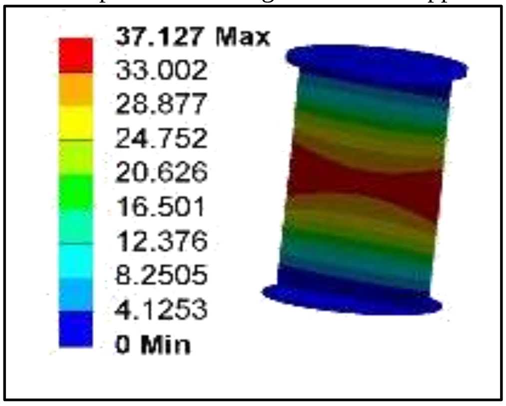


Fig. 9: Total deformation (Internal pressure loading condition)

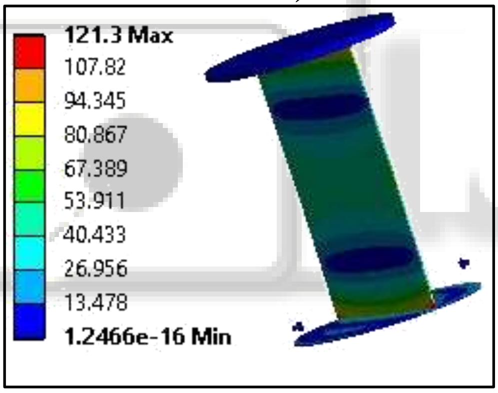


Fig.10 von misses stress (Internal pressure loading condition)

*C. Tube at 60 ℃ and internal pressure 0.05Mpa with Buoyancy force 14690:*

The temperature condition i.e. 60℃ on pipes with internal pressure 0.05 MPa given and buoyancy force .

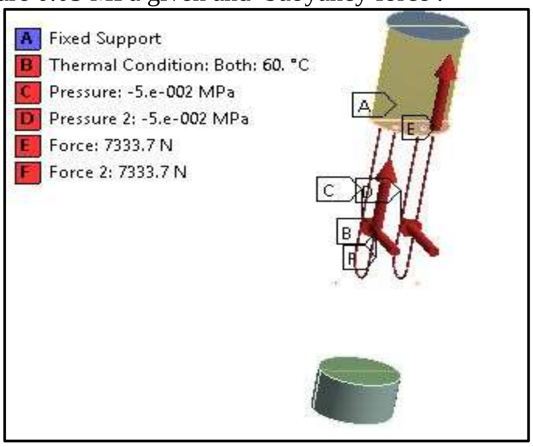


Fig. 11 Temperature condition of 60℃

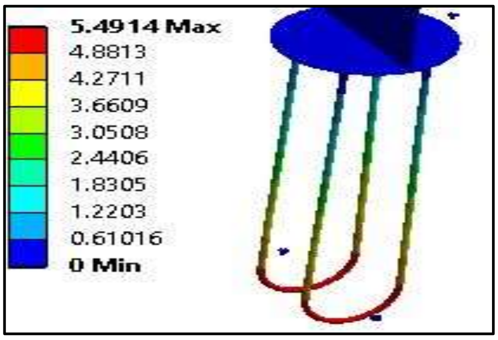


Fig. 12 Total deformation conditions (Temperature condition of 60℃)

*D. Wind load*

By fixing skirt support wind load is applied on outer surface of pressure vessel.

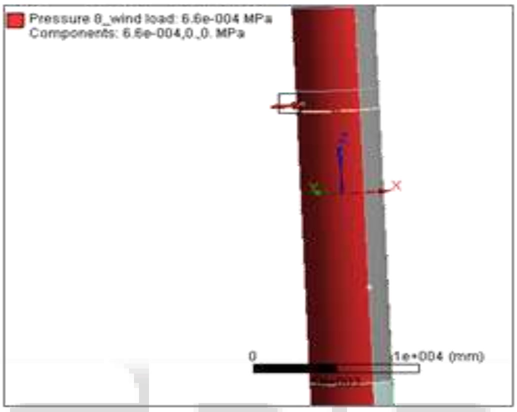


Fig. 13 wind load condition

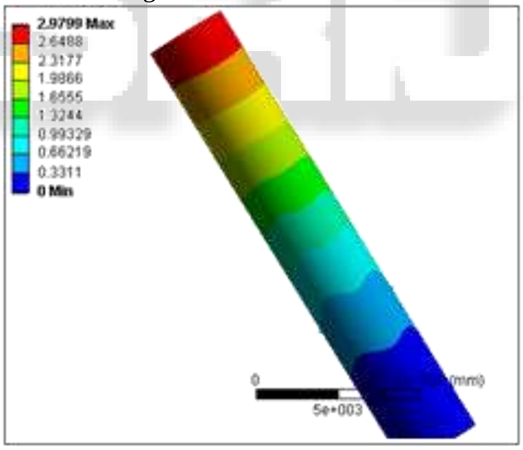


Fig. 14 Total deformation

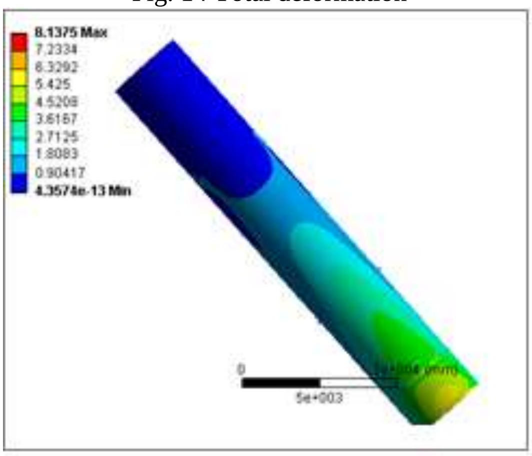


Fig. 15 von misses stress

 

### E. Hydrostatic Loading:

Fluid filled at a height of 13760mm and pressure vessel is fixed at skirt support.

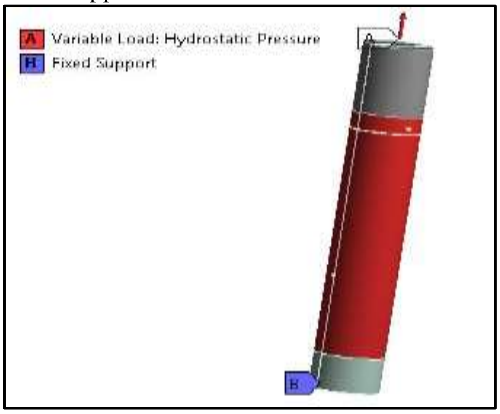


Fig.16.hydrostatic boundary condition

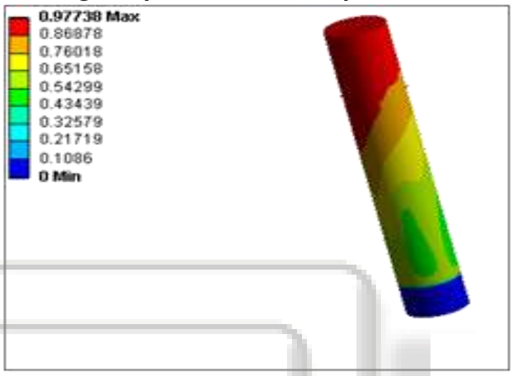


Fig.17 Total deformation

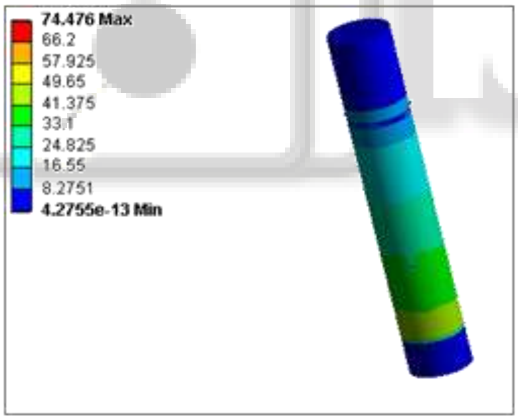


Fig.18 von misses stress

## VI. Conclusions

Finite element analysis of pressure vessel with heat treatment pipes has been done using ANSYS Workbench and are tabulated in table

| Sr. no | Analysis | Deformation | Stress |
|---|---|---|---|
| 1 | Self-weight | 4.0365mm | 30.416MPa |
| 2 | Internal pressure Loading condition at Upper chamber | 37.127mm | 121.3MPa |
| 3 | Tube at 60 ℃ and internal pressure 0.05Mpa with Buoyancy force 14690N | 5.4914mm | 95.359MPa |
| 4 | Wind load | 2.9799mm | 8.1375MPa |
| 5 | Hydrostatic | 0.97738mm | 74.476MPa |

Table 4: Conclusions

From the above table of static analysis, the stress induced at different boundary conditions using ANSYS is less than the material allowable limit of stress. So the model presented here is well for safe design under given loading conditions.

## References

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