International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 3, March - 2013

Determination of Effect Angular Poisoning of Legs on the Structural Stability of Pressure Vessel by Using Non-linear Finite Element Analysis (FEA)

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Abstract

The objective of the pressure vessel is to have production of phenol and acetone. Cumene process is an industrial process of producing phenol (C_6H_5-OH) and acetone (CH_3-CO-CH_3) from benzene (C_6H_6) and propene (C_3H^6). The term stems from isopropyl benzene or cumene (C_6H_5-CH (CH_3)2), the intermediate material during the process. With the help of this process two relatively cheap materials, benzene and propene are converted into two more valuable products such as phenol and acetone. For this process other required reactants are oxygen from air and small amounts of a free radical initiator. Most of the worldwide production of phenol and acetone are now based on this method.

The pressure vessel is being designed to implement the cumene process. The process is extremely sensitive to pressure and temperature conditions and requires a lot of control systems to monitor it. These control systems are to be placed below the vessel for effective monitoring. The current range of Pressure Vessels in the market of 'AZ' series come either in skirt support or supported by 8 legs equidistance from each other. However, a custom made pressure vessel has been ordered for the cumene process. The custom made vessel has to have a lot of controls for the cumene process; hence 8 legs are not feasible. Six legs support with a non- symmetric distribution was tried out initially. However the current requirement is to have more floor space.

1. Introduction

Type of support used depends on the orientation and pressure of the pressure vessel. Support from the pressure vessel must be capable of withstanding heavy loads from the pressure vessel, wind loads and seismic loads. Pressure on pressure vessel design is not a consideration in designing support. Temperature can be a consideration in designing the support from the standpoint of material selection for the different thermal expansion.

2. Need of Work

It is observed that although a lot of work has been done in the field of pressure vessel. The current range of Pressure Vessels in the market of 'AZ' series come either in skirt support or supported by 8 legs equidistance from each other. Six legs support with a non- symmetric distribution was tried out initially. However the current requirement is to have more floor space.

It is decided to improvise on the design and introduce angular supports. It has an advantage of increased floor space to mount the controls**.**

3. Objective of Work

Typically most of the pressure vessel are either skirt or leg supported and observation is that legs are primarily vertical. However in case vertical expansion of the vessel either due to thermal expansion or due to vertical loading the legs are susceptible to buckling.

Hence, objective of this work is to determine whether creating an angle in the legs in combination with unsymmetrical distribution affects the structural stability of the system.

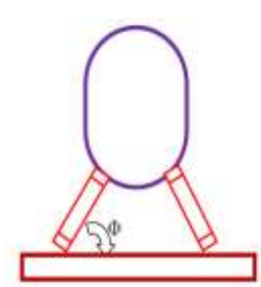

Figure 1 Vertical drum on inclined leg support

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4.Methodology

4.1 Material Selection

According to ASME code for manufacturing of pressure vessel number of materials are specified but the selection depends purely upon nature of application. In accordance with number of material selection factors and rules and regulation led down by ASME code specifications material need to be decided. Since this work primarily focus on the analysis of vertical leg supports. Finally end user will decide which material to be used. The material used for this vessel is structural steel and its properties are listed below.

Table 1

Sr . No.	Material	Structural Steel
1	Youngs Modulus (Mpa)	2e5
2	Density Kg/ m3	7850
3	Poissons Ratio	0.3
4	Yield Strength (Mpa)	250
5	Tensile Strength (Mpa)	460

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4.2 Geometry Modelling

The vessel geometry modelling has been done in Ansys 12.01 workbench itself.

4.3 Mesh Generation

Meshing has been done by using the method of Tetrahedron. In Tetrahedron method the component is been divided into small triangle on its surface which gives no of nodes and elements of that component. The meshing has been done by changing the mesh size of the various component of the pressure vesssel. Due to change in the density of the meshing, it results in the variation of the no of nodes and elements of the meshed parts.
The result of this mesh density change affects the value of the stress and deformation of the component. For fine meshing that is for small mesh size the values of no of nodes and elements are high but as the element size is gradually increased it result in increase in the value of no of nodes and elements. For small variation in mesh size that is of 1E-03 m the values are showing small variation in no of nodes and elements and also it shows the same amount of variation in the values of stress and deformation for the given mesh size. But for large variation in mesh size the values of no of nodes and elements are also vary in large amount.

4.4 Boundary Condition

In case of FEA analysis on has to make sure that the boundary condition applied for particular analysis must be correct or it may cause misleading results.
The nature of analysis will decide the boundary conditions need to be applied. As in this work the leg supports are more important from analysis point of view and sine pressure vessel is vertically standing on ground the following boundary conditions were applied.

1 .Wind load acting on the vessel
2. Internal pressure of the vessel
3. All the supports need to be fixed to the ground

4.5 Structural Analysis

The Ansys 12.01 workbench will give the results in terms of the maximum deformation as well as the stress subjected by the pressure vessel assembly.
Here, in this work there will be small increment in the angular positioning of legs by 1 degree upto 30 degree. This increment will result in the considerable amount of deformation as well as stress in the leg supports. The tabular results for stress and deformation for 1 to 30 degree are as shown in Table 2. The nature of this analysis is based upon Section VIII Division 1 for the targeted compliance of the stress values in the pressure vessel assembly.

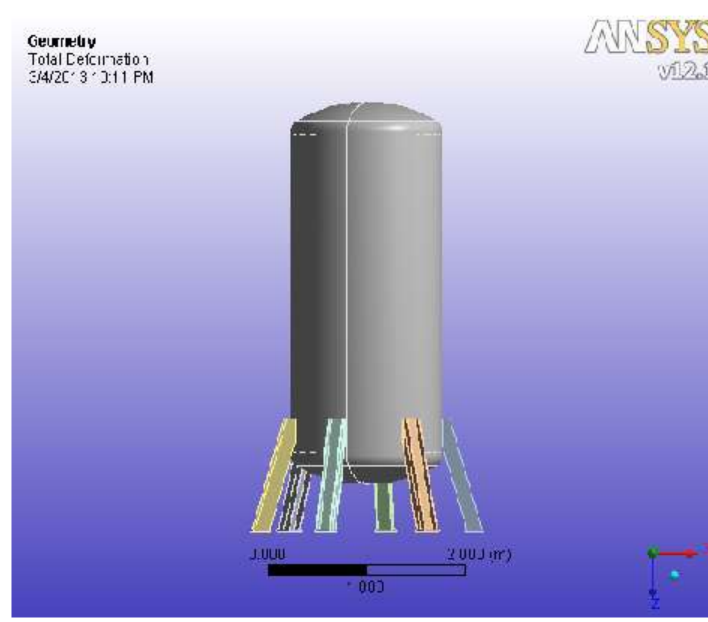

Figure 2 3D Model

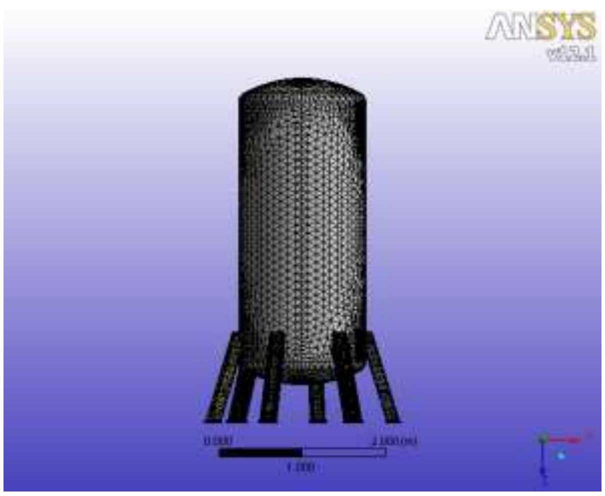

Figure 2 Meshing

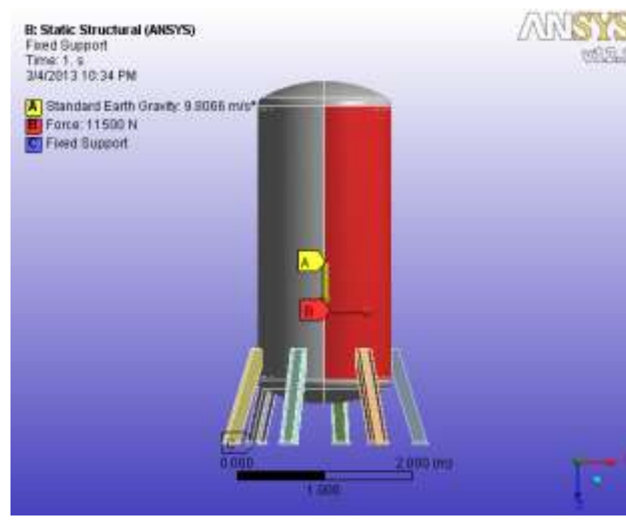

Figure 3 Boundary Condition

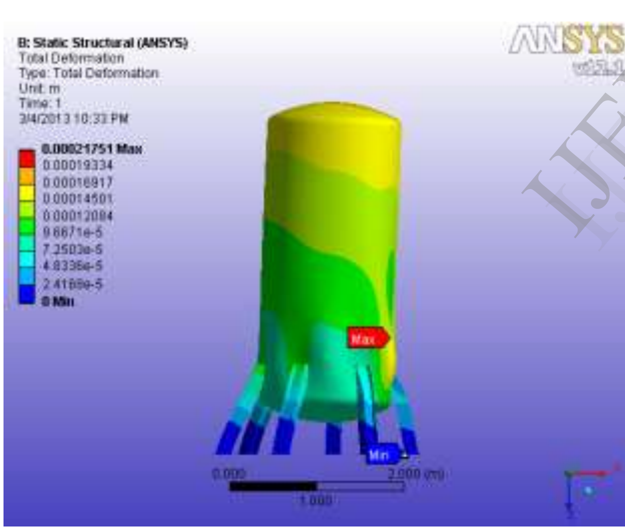

Figure 4 Total Deformation

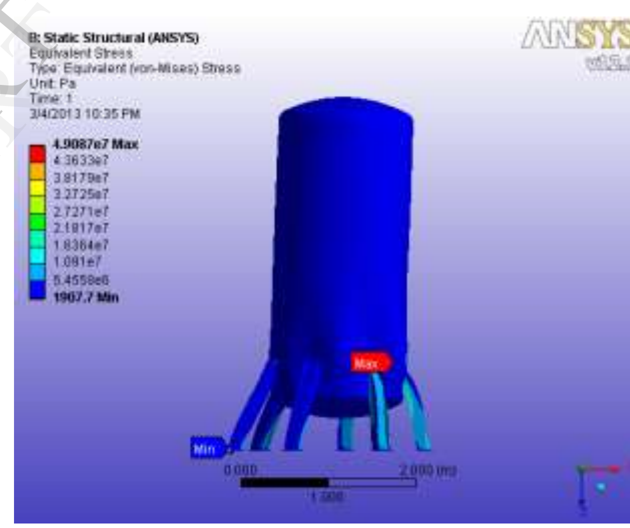

Figure 5Von Mises Stress

International Journal of Engineering Research & Technology (IJERT)
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Table 2 Stress and deformation values for no. of angles

Angle	Von Mises Stress (Mpa)	Total Deformation(mm)	No. of Nodes	No.of Elements
1	25.702	0.125	99795	48693
2	28.709	0.158	99635	48700
3	29.127	0.140	95532	46172
4	33.312	0.178	99909	48907
5	39.280	0.147	99514	48584
6	40.827	0.144	100505	49023
7	44.336	0.149	99807	48784
8	48.757	0.151	100373	48982
9	48.188	0.155	99928	48816
10	47.196	0.158	101329	49619
11	52.103	0.165	100512	49345
12	54.729	0.172	101560	49783
13	58.183	0.166	100882	49291
14	65.696	0.118	102215	50113
15	49.538	0.196	101291	49571
16	49.282	0.202	101728	49712
17	54.798	0.210	101942	49847
18	49.087	0.217	101902	49750
19	63.028	0.224	102404	50078
20	59.741	0.230	103396	50628
21	70.871	0.237	102390	50134
22	74.037	0.243	103947	51031
23	80.392	0.250	103571	50714
24	82.293	0.257	103721	50681
25	84.569	0.264	104716	51251
26	88.839	0.271	104830	51303
27	92.682	0.278	105381	51571
28	10.95	0.285	105956	51724
29	105.38	0.293	107247	52557
30	107.74	0.301	107039	52327

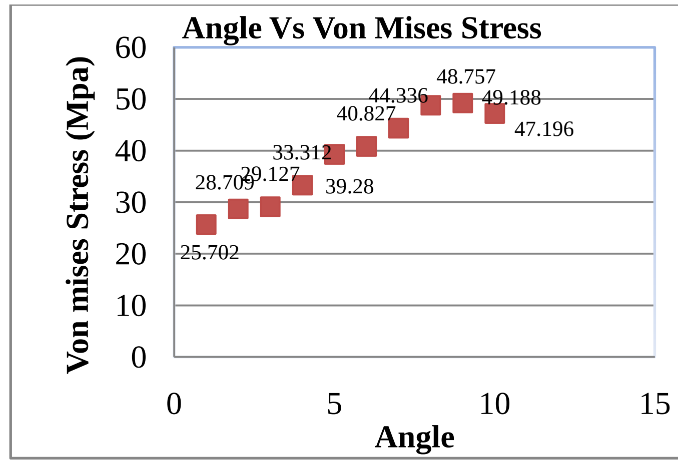

Figure 6 Angle Vs Von Mises Stress

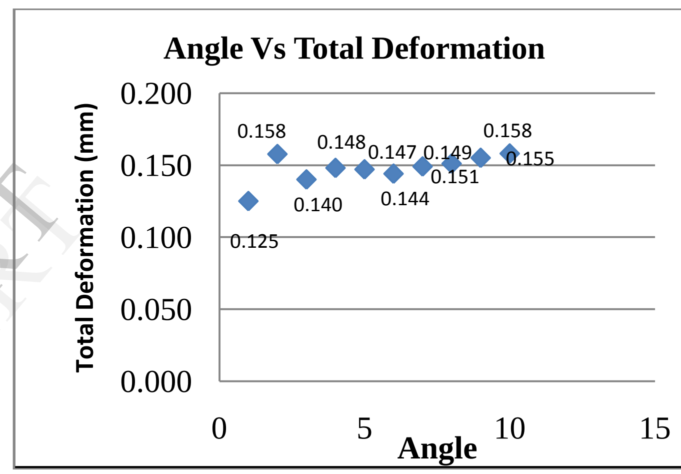

Figure 7 Angle Vs Total Deformation

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5. Conclusion

The table 2 shows the various values of stress and deformation irrespective of the change in the angle. We have plotted 2 graphs as shown in Figure 6 Angle Vs Von Mises Stress and Figure7Angle Vs Total Deformation for a instance both graph are plotted up to first 10 results.

The first graph will lead the information that with corresponding increase in the angle the value of the stress in the vessel is also having gradual increase.

Similarly, for corresponding change in the angle deformation is also increasing. On the other hand if we se e that Table 2 will show that at 30 degree the Von Mises Stress around the leg support is 107.74 Mpa and which is maximum but less than the yield strength and tensile strength resulting into safe design.

6. References

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ISSN: 2278-0181
Vol. 2 Issue 3, March - 2013

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