Pressure Vessel Design as Per ASME Section VIII Division 2 and Its Optimization

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Abstract

Designing a pressure vessel using a handbook is troublesome and not interactive. Therefore computer aided software is created to assist the users, the computer aided software for designing pressure vessel. This project is to develop an interactive system to design pressure vessels besides the understanding of the algorithm in designing pressure vessel. Results generated are compared with manual calculations as per ASME VIII-2 design code. In addition, the finite element model was created using the results obtained from the system and the maximum stress value in finite element analysis was to compare with theoretical calculation. This project includes comparative studies to compare self-defined material versus material library, for self-defined load versus load from substance library and for substance library liquid with substance library gas. Computer Aided Design of Pressure Vessel Design has potential to produce robust design which would beneficial to the human kind. The analysis is carried out based on three different cases and results are compared by using Materials SS310 with permissible stress of 240 MPa. Applied inside pressure 1.3 MPa and both side wall fixed. Various type five case considering, 10 mm thickness, 9.5 mm, 9 mm, 8.5 mm, 8 mm and its von-misses stress and total deformation find same all boundary condition. Last case 8 mm thickness wall model on same material stiffener fitted by welding.

Keyword: ASME, Creo, Simulation, Pressure Vessel

1. Introduction

Vessels, tanks, and pipelines that carry, store, or receive fluids are called pressure vessels. Pressure are used to store and transmit liquids, vapours, and gases under pressure in general [2]. A pressure vessel is defined as a container with a pressure differential between inside and outside. The inside pressure is usually higher than the outside, except for some isolated situations. The fluid inside the vessel may undergo a change in state as in the case of steam boilers, or may combine with other reagents as in the case of a chemical reactor. Pressure vessels often have a combination of high pressures together with high temperatures, and in some cases flammable fluids or highly radioactive materials. Pressure vessels are used in a number of industries; for example, the power generation industry for fossil and nuclear power, the petrochemical industry for storing and processing crude petroleum oil in tank farms as well as storing gasoline in service stations, and the chemical industry (in chemical reactors). Based on the shape (cylinder) of the vessels, they are called as cylindrical pressure vessel. They are further classified into two types: Horizontal Pressure Vessels and Vertical Pressure Vessels. When the orientation of the vessel is horizontal, that is horizontal pressure vessel[3]. . If the orientation of pressure vessel vertical, that it is cylindrical or vertical type pressure vessel. Advantages of cylindrical pressure vessels: 1. It is easier to fabricate. 2. They are probably cheaper to construct. 3. They pack more efficiently into rectangular structures such as boxes and buildings.

2. Literature Survey

Analysis on thick cylinder pressure vessel. Buckling is a critical failure phenomenon in the columns and pressure vessels subjected to external pressure and axial compressive loads. The cylinders the buckling load will be affected by many factors such as length, thickness, diameter, cross section and temperature etc. Typically fluids will be stored in the pressure vessels and then exposed to ambient environment or customized environment[4]. In the present work real life conditions are applied as inner fluid temperature (T1), external convective heat transfer (h). Buckling load of cylinder subjected to combined axial compressive load and external pressure was studied by varying the length to thickness ratio(L/T), inner fluid temperature(T1), convection heat transfer co-efficient(h), ambient temperature(T2). Ambient temperature plays vital role in buckling load[5]. The buckling load was increased up to 80 C and then decreased in the considered range. Fracture mechanics is focuses on the analysing the structures containing initial cracks that can affect the load carrying capacity of an engineering structures. The effect of sliding mode is investigated due to rotating the crack orientation and the load capacity of vertical crack is the most critical one among others[6]. The difference between elastic-plastic and elastic analyses is not significant due to the small plastic zone in the crack tip. The property of FGMs is assumed to be exponential function form. The problem is reduced to solve an ordinary differential equation numerically. Stress distributions along the radial direction are studied. The obtained result shows that the property of FGMs has a significant influence to the stress distribution along the radial direction[7]. In the homogeneous medium case, for a given loading the stress distribution in an elastic body will be determined uniquely. The failure pressures of thick and thin walled cylindrical pressure vessels considering the Voce hardening law and plastic orthotropic effect are obtained. The solution presented is used to compare the failure pressures of copper and brass cylindrical pressure vessels[8].

3. Problem Definition

1. Thickness of pressure vessel more so weight of pressure vessel more.
2. More materials used, more cost of pressure vessel.
3. More labour work cost.
4. Transportation cost more.
5. Poor quality fabrication like welding; heat treatment or forming methods etc.
6. Inexperienced person operations or maintenance of pressure vessel.

4. Objective

The main object is design pressure vessels as per ASME section VIII division 2 [1]. First model 10 mm wall thickness model design then reduced thickness 2 mm of vessel up to wall thickness 8 mm.Find deformation and equivalent stress of 10 mm, 9.5 mm, 9 mm, 8.5 mm, 8 mm thickness vessel. Last case 8 mm thickness with stiffener analysis.

5. Research Methodology

ASME code and related research paper read to pressure vessel. Select design in ASME section VIII division 2 [1] of pressure vessel. Analysis of pressure vessel done by ANSYS software and find out deformation and working stress. Second case in reduce thickness by 2 mm and find result and third case in stiffener fitted on pressure vessel again find deformation and working stress. Concluding that thickness reduced that preferable or not.

6. Pressure Vessel Design Criteria

ASME section VIII division-2 [1] have been establishment to identify the components and parameters that considered in formulating the rules and regulation. All rules and regulation issue by municipality, state government, federal or other enforcement or regulatory bodies have jurisdiction at the location of installation establish mandatory application of the code rules. ASME section VIII division-2 contains mandatory requirements, specific prohibitions and non-mandatory guideline for design materials, fabrication, examination, inspection, testing and certificates of pressure vessel and their associated pressure relief device.

The requirements of this Division are contained in the nine Parts listed below [1]

- The general requirements that provides the scope of this division and establishes the extent of coverage’s.
- Responsibilities and Duties, that sets for the responsibilities of user and Manufacturer, and the duties of Inspector.
- Materials Requirements, provides the permissible materials of construction, applicable material specification and physical properties, special requirements, allowable stresses, and design fatigue curves.
- Design by Rule Requirements that provides the requirements for the design of vessels and its components using these rules.
- Design by Analysis Requirements, provides requirements for design of vessels and its components using the analytical methods.
- Fabrication Requirements, provides requirements of governing the fabrication of vessels.
- Examination and Inspection Requirements, provides requirements governing the examination and inspection of vessels and parts.
- Pressure Testing Requirements, provides pressure testing requirements.
- Pressure Vessel Overpressure Protection, provides rules for pressure relief devices.

Table 1 Pressure Vessel Design Parameter

Parameters	Thickness (mm)	Outer diameter (mm)	Inner diameter (mm)	Length (mm)
Case 1	10	1405	1385	3838
Case 2	9.5	1404	1385	3838
Case 3	9	1403	1385	3838
Case 4	8.5	1402	1385	3838
Case 5	8	1401	1385	3838
Case 6	8 with stiffener	1401	1385	3838

7. Pressure Vessel Analysis

ASME section VIII division 2 code per design pressure vessel and that analysis done by ANSYS Workbench software. Inside wall applied pressure 1.3 MPa and both side wall fixed as shown in figure 1. Here three difference case consider in analysis. First analysis in 10 mm wall thickness and continue reduce 0.5 mm thickness up to wall thickness 8 mm. find total deformation and von-misses equivalent stress.

7.1 Analysis at 10 mm wall thickness of pressure vessel

Design of pressure vessel as per ASME section VIII division-2, shown in dimension table 1 those dimension consider in model analysis. Shown in figure 1 CAD model of pressure vessel at 10 mm wall thickness. Simulation in applied 1.3 MPa internal pressure and both side fixed joint applied boundary condition shown in figure 2. Analysis for used ANSYS workbench software. Before pre-process generate mesh model because accurate result. Show in figure 3, maximum equivalent stress around 98 MPa but here, consider average stress around 55 MPa that stress less then materials yield stress so deformation take place within elastic region not plastic region. Pressure vessel after release stress complete arrival original position. Shown in figure 4, total deformation around 0.59 mm that very small deformation.

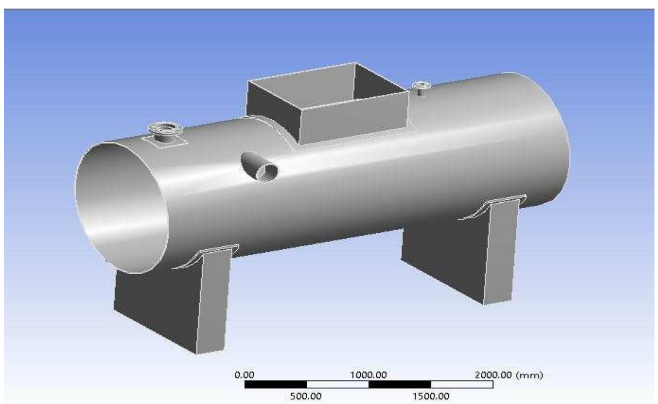

Figure 1 Pressure Vessel Model Geometry

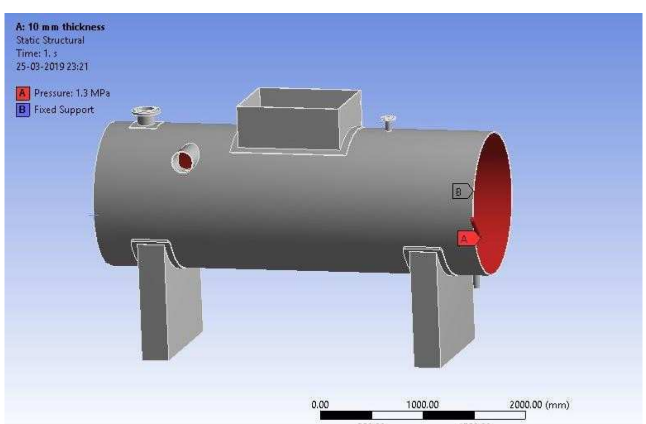

Figure 2 Boundary Condition

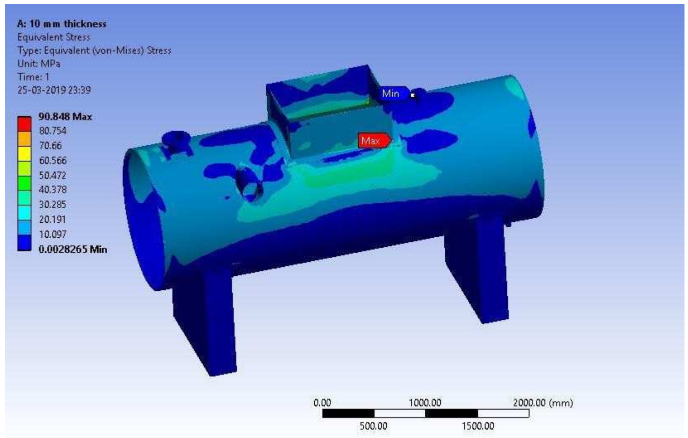

Figure 3 Equivalent stress (10 mm wall thickness)

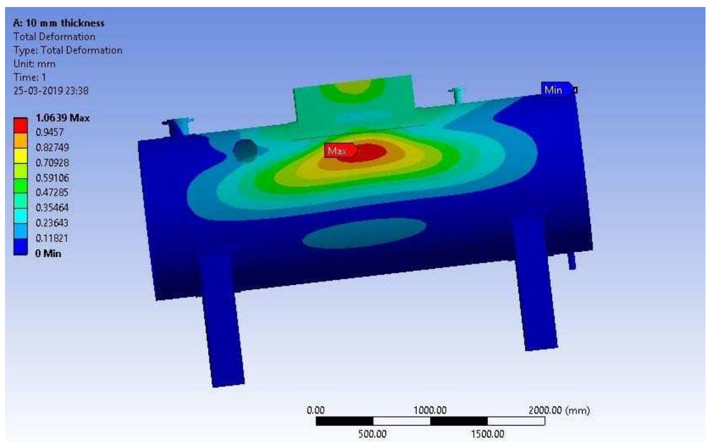

Figure 4 Total Deformation (10 mm wall thickness)

7.2 Analysis at 9.5 mm wall thickness of pressure vessel

In that case reduce 0.5 mm wall thickness applied same boundary condition as case 1. Shown in figure 5, von misses equivalent stress around 81.5 MPa reduce thickness 0.5 mm stress increase 15-30 MPa but not more then yield limit so those safe zone condition. Total deformation around 0.8 mm shown in figure 6.

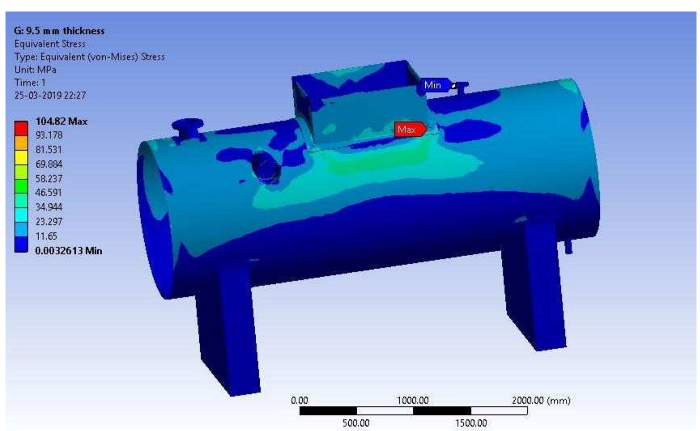

Figure 5 Equivalent stress (9.5 mm wall thickness)

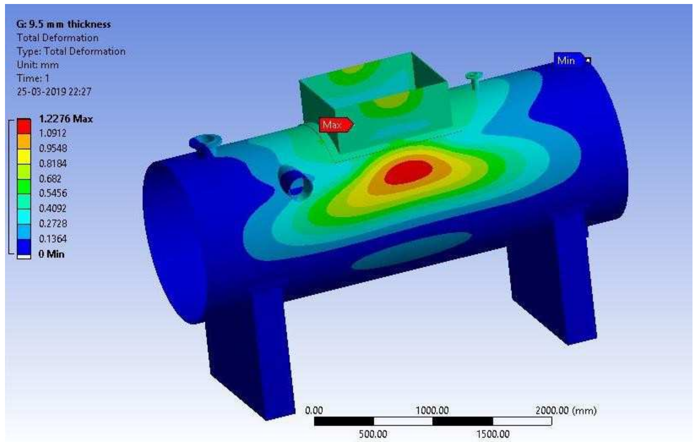

Figure 6 Total Deformation (9.5 mm wall thickness)

7.3 Analysis at 9 mm wall thickness of pressure vessel

In that case reduce 1 mm wall thickness (9 mm wall thickness) applied same boundary condition as case 1. Shown in figure 7, von misses equivalent stress around 400 MPa reduce thickness 1 mm stress increase 150-200 MPa that more than yield limit so pressure vessel plastic deformation zone. Total deformation around 5-7 mm shown in figure 8. Stress increase yield limit so after realise pressure not comes to original position.

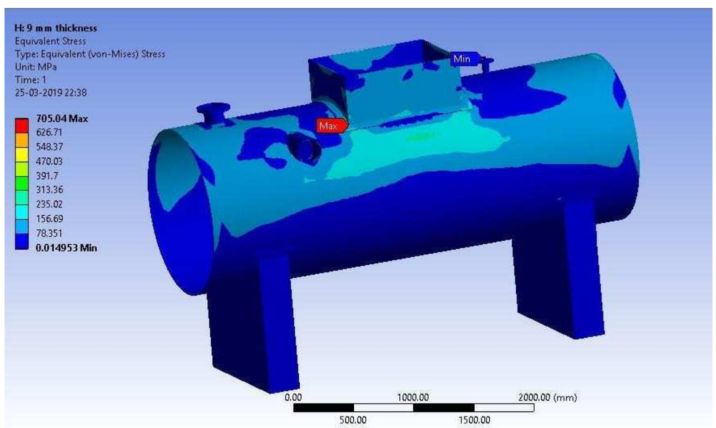

Figure 7 Equivalent stress (9 mm wall thickness)

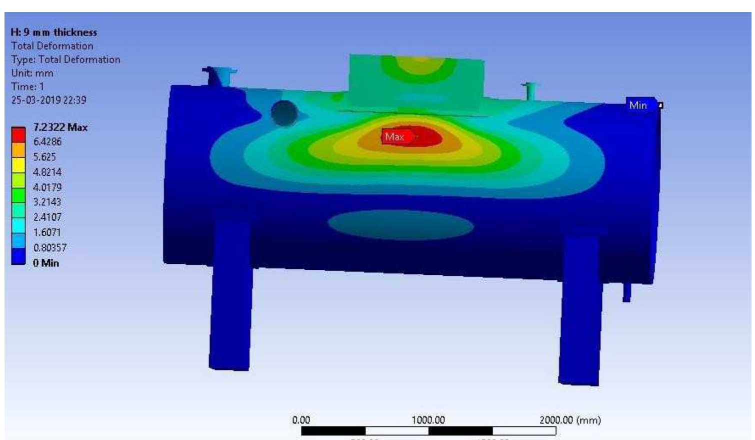

Figure 8 Total Deformation (9 mm wall thickness)

7.4 Analysis at 8.5 mm wall thickness of pressure vessel

In that case reduce 1.5 mm wall thickness (8.5 mm wall thickness) applied same boundary condition as case 1. Shown in figure 9, von misses equivalent stress around 800 MPa reduce thickness 1.5 mm stress increase 350-400 MPa that more than yield limit so pressure vessel plastic deformation zone. Total deformation around 9-10 mm shown in figure 10. Stress increase ultimate limit so pressure permanent deformation.

7.5 Analysis at 8 mm wall thickness of pressure vessel

In that case reduce 2 mm wall thickness (8 mm wall thickness) applied same boundary condition as case 1. Shown in figure 11, von misses equivalent stress around 800 MPa reduce thickness 1.5 mm stress increase 350-400 MPa that more than yield limit so pressure vessel plastic deformation zone. Total deformation around 9-10 mm shown in figure 12. Stress increase ultimate limit so pressure permanent deformation.

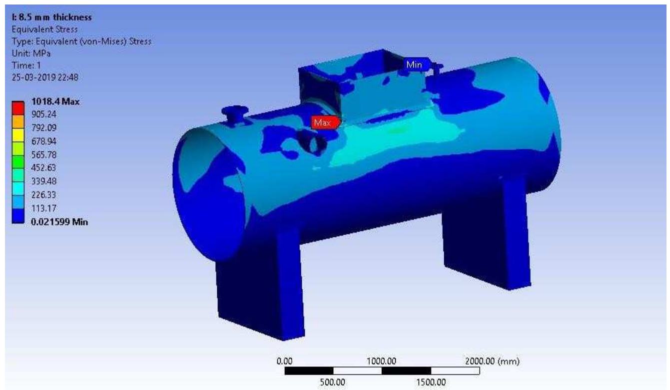

Figure 9 Equivalent stress (8.5 mm wall thickness)

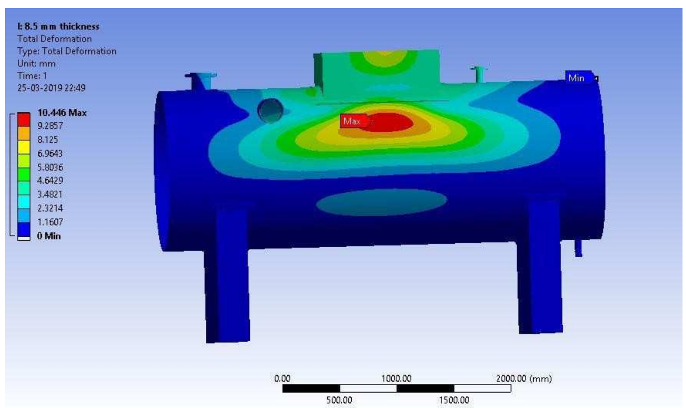

Figure 10 Total Deformation (8.5 mm wall thickness)

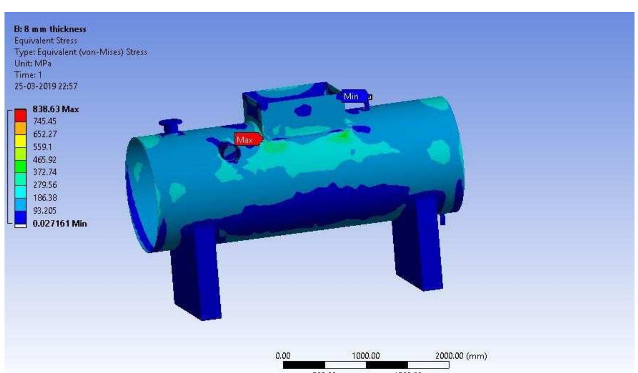

Figure 11 Equivalent stress (8 mm wall thickness)

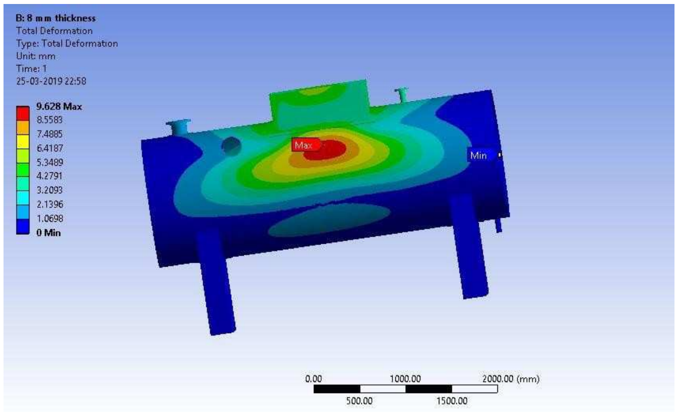

Figure 12 Total Deformation (8 mm wall thickness)

7.6 Analysis at 8 mm wall thickness with stiffener

In that case reduce 2 mm wall thickness (8 mm wall thickness) applied same boundary condition as case 1 but outer body stiffener place. Shown in model figure 13. Shown in figure 14, von misses equivalent stress around 57 MPa reduce thickness 2 mm stress increase 350-400 MPa but stiffener applied equivalent stress again reduce comes to safe zone. Total deformation around 0.7-1 mm shown in figure 15.

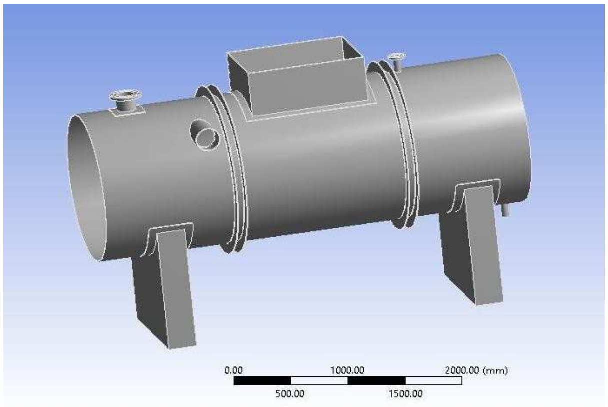

Figure 13 geometry 8 mm wall thickness with stiffener

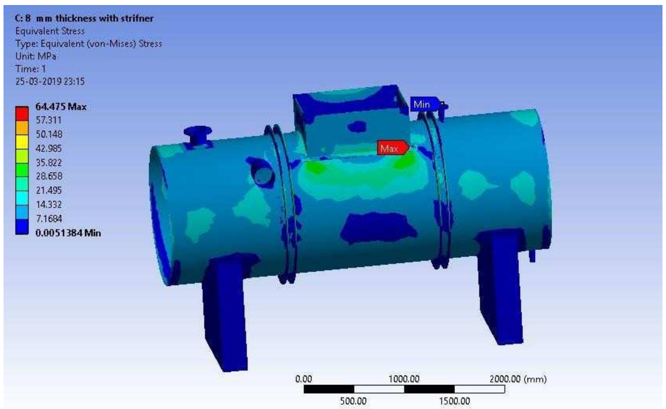

Figure 14 Equivalent stress (8 mm wall thickness with stiffener)

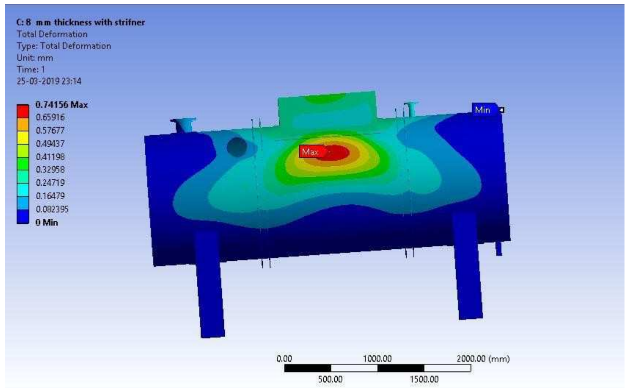

Figure 15 Total Deformation (8 mm wall thickness with stiffener)

Table 2 Result Analysis

CASE	Element quality	Weight (kg)	Von misses stress	Total deformation	Factor of safety
1	0.8165	2894.7	85-45	0.99-0.5	10-15
2	0.8565	2701.6	99-60	1-0.5	10-12
3	0.8265	2689.2	200-150	5-3	5-7
4	0.8265	2456.6	450-350	7-6	1-3
5	0.8523	2241.1	500-450	9-8	0.5
6	0.8613	2360.9	100-80	1-0.7	10-15

8. Conclusion

Design of pressure vessel as per ASME code is successful. The analysis is performed on six different case and results are compared. By result we observed that stress and deformation value of modified model. In first case von misses stress 85 MPa, second case 10 MPa, third case stress 200 MPa, fourth case stress 400 MPa, Fifth case stress 500 MPa and sixth case stress 100- 80 MPa. In result thickness reduce as per stress increase up to 500 MPa so, pressure vessel break 8 mm wall thickness. Total deformation in first case around 0.7 mm and fifth case deformation 9-10 mm. in last case 8 mm thickness with stiffener again deformation reduced.

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