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Stress Analysis of Pressure Vessel

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Abstract:- Tanks, vessel and pipelines that carry, store or receive fluids are called Pressure vessel. A pressure vessel is defined as a container with a pressure differential between inside and outside. The inside pressure is usually higher than outside. The fluid inside the vessel may undergo a change in state as in case of a steam boiler or may combine with other reagent as in the case of chemical reactor. Pressure vessel often has a combination of high pressure together with high temperature and in some case flammable fluids or highly radioactive material. Because of such hazards it is imperative that the design be such that no leakage can occur. In addition, vessel hat to be design carefully to cope with the operating temperature and pressure.

In this paper, the analysis on pressure vessel with variation of hole and outside temperature variation is carried out to find the stresses in pressure vessel. First, the finite element approach is used to evaluate the stresses in the closed pressure vessel and with varying material and outside temperature. Further the finite element approach is used to evaluate the stresses in the pressure vessel with holes on circumference and with varying material and outside temperature.

Keywords:- *Pressure Vessel, Fluid, Stresses, Circumference, Temperature, Material.*

I. INTRODUCTION

Tanks, vessel and pipelines that carry, store or receive fluids are called Pressure vessel. A pressure vessel is defined as a container with a pressure differential between inside and outside. The inside pressure is usually higher than outside.

The fluid inside the vessel may undergo a change in state as in case of a steam boiler or may combine with other reagent as in the case of chemical reactor. Pressure vessel often has a combination of high pressure together with high temperature and in some case flammable fluids or highly radioactive material.

Pressure vessel 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 station, and the chemical industry.

II.OBJECTIVE

- Analytical design of pressure vessel having stress distribution over closed pressure vessel.
- To analyze the stress contour on pressure vessel with holes on cylinder and cover plate

III.PROBLEM STATEMENT

- In this paper, the analysis on pressure vessel with variation of hole and outside temperature variation is carried out to find the stresses in pressure vessel.
- The various geometric ratios considered for analysis are as follows,
- Length of pressure vessel, L = 500 mm
- Diameter of pressure vessel, D = 250 mm
- Test pressure, p = 2 MPa
- The various material used for the analysis are:
- Mild Steel
- Stainless Steel
- Aluminum
- Copper
- Gray Cast Iron
- Titanium
- The finite element approach is used to evaluate the stresses in the closed pressure vessel and with varying material and outside temperature.
- Secondly, the finite element approach is used to evaluate the stresses in the pressure vessel with holes on circumference and with varying material and outside temperature.
- Variation of hole number on circumference: 1, 2, 3.
- Variation of diameter (mm): 10, 20, 30, 40.

IV.DESIGN CALCULATIONS OF A PRESSURE VESSEL

- Yield tensile stress, σ_{yt} =250 MPa
- Design tensile stress, σ_{dt} = 0.8 σ_t =196.8 MPa (For steel or ductile material)
- Standard thickness, t_b=5mm

The hoop of circumferential stress is,

σ_h = $P_T \times D_i / 2 \times t \times \eta$
= (2×240)/(2×5×0.95)
= 50.52 MPa

The Longitudinal stress is,

σ_L = $P_T \times D_i / 4 \times t \times \eta$
= (2×250)/(4×5×0.95)
= 25.26 MPa

Maximum sheer stress,

$\Gamma'_{max} = (\sigma_{t1}-\sigma_{t2})/2$
$= (50.52-25.26)/2$
$= 12.63$ MPa

The increase in diameter of the cylindrical shell due to an internal pressure is,

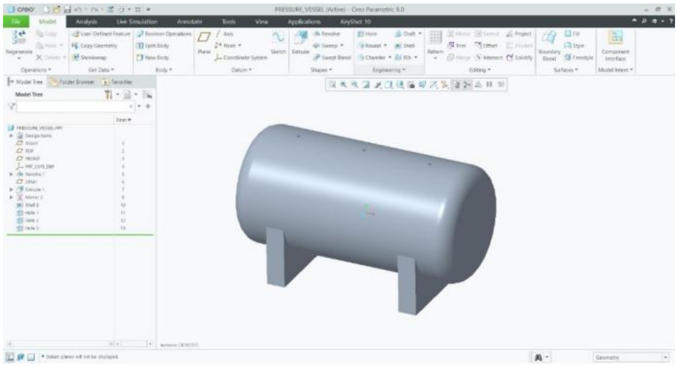
$\Delta d = P_T \times D_i^2/2\times t.E\ (1- \mu/2)$
$= (4\times250\times205)/(2\times5\times200\times1000)(1-0.3/2)$
$=0.106$mm

Table 4.1: Analytical results for stresses on pressure vessel

SR. NO.	Type of stress	Magnitude (MPa)
1	Hoop Stress	50.52
2	Longitudinal stress	25.26

V. MODELING AND ANALYSIS OF PRESSURE VESSEL

The 3D model of pressure vessel is created using a CAD software Creo Parametric.



3D Model of Pressure Vessel

VI. STRESS ANALYSIS OF PRESSURE VESSEL WITH HOLES ON CYLINDER AND COVER PLATE

The finite element approach is used to evaluate the stresses in the pressure vessel with holes on circumference and with varying material and outside temperature.

- Variation of hole number on circumference: 1, 2, & 3.
- Variation of diameter (mm): 10, 20, 30, 40.

i. STRESS ANALYSIS OF PRESSURE VESSEL WITH ONE 10 MM DIAMETER HOLE

The stress analysis of pressure vessel with one hole of 10 mm diameter is carried out for various material. The pressure vessel is subjected to structural and thermal load.

Table 6.1. Stress Analysis of Pressure Vessel with One 10 mm Diameter Hole

Material	Von Misses Stress (MPa)	Total Heat Flux (W/mm^2)	Max. Principle Stress (MPa)	Min. Principle Stress (MPa)
Aluminum	178.73	2.63 e^{-13}	159.88	10.89
Copper	202.76	6.89 e^{-13}	161.13	13.03
Gray Cast Iron	155.4	8.93 e^{-14}	157.83	8.52
Mild Steel	240.93	1.02 e^{-13}	161.69	14.18
Stainless Steel	306.01	2.61 e^{-14}	164.54	18.78
Titanium	144.38	3.75 e^{-14}	158.13	12.53

ii. STRESS ANALYSIS OF PRESSURE VESSEL WITH TWO 10 MM DIAMETER HOLE

The stress analysis of pressure vessel with two hole of 10 mm diameter is carried out for various material. The pressure vessel is subjected to structural and thermal load.

Table 6.2. Stress Analysis of Pressure Vessel with Two 10 mm Diameter Hole

Material	Von Misses Stress (MPa)	Total Heat Flux (W/mm^2)	Max. Principle Stress (MPa)	Min. Principle Stress (MPa)
Aluminum	146.65	2.55 e^{-13}	158.7	11.02
Copper	161.15	2.54 e^{-14}	159.47	12.58
Gray Cast Iron	146.74	8.86 e^{-14}	156.96	8.97
Mild Steel	193.92	1.02 e^{-13}	159.07	9.74
Stainless Steel	246.31	2.54 e^{-14}	160.57	12.58
Titanium	145.26	3.68 e^{-14}	158.43	12.50

iii. STRESS ANALYSIS OF PRESSURE VESSEL WITH THREE 10 MM DIAMETER HOLE

The stress analysis of pressure vessel with three hole of 10 mm diameter is carried out for various material. The pressure vessel is subjected to structural and thermal load.

Table 6.3. Stress Analysis of Pressure Vessel with Two 10 mm Diameter Hole

Material	Von Misses Stress (MPa)	Total Heat Flux (W/mm^2)	Max. Principle Stress (MPa)	Min. Principle Stress (MPa)
Aluminum	177.33	2.30 e^{-13}	159.97	9.92
Copper	201.77	6.02 e^{-13}	160.81	11.04
Gray Cast Iron	153.55	7.80 e^{-14}	158.19	8.70
Mild Steel	239.57	9.13 e^{-14}	160.69	11.69
Stainless Steel	305.01	2.26 e^{-14}	163.34	15.22
Titanium	146.41	3.33 e^{-14}	159.44	11.22

iv. STRESS ANALYSIS OF PRESSURE VESSEL WITH ONE 20 MM DIAMETER HOLE

The stress analysis of pressure vessel with one hole of 20 mm diameter is carried out for various material. The pressure vessel is subjected to structural and thermal load.

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Table 6.4. Stress Analysis of Pressure Vessel with One 20 mm Diameter Hole

Material	Von Misses Stress (MPa)	Total Heat Flux (W/mm^2)	Max. Principle Stress (MPa)	Min. Principle Stress (MPa)
Aluminum	168.35	$2.004e^{-13}$	180.41	7.17
Copper	174.93	$5.26\ e^{-13}$	181.35	7.52
Gray Cast Iron	168.03	$6.84\ e^{-14}$	178.86	6.03
Mild Steel	207.93	$7.95\ e^{-14}$	181.71	8.56
Stainless Steel	263.74	$1.98\ e^{-14}$	183.8	11.29
Titanium	166.6	$2.87\ e^{-14}$	179.26	6.37

v. STRESS ANALYSIS OF PRESSURE VESSEL WITH TWO 20 MM DIAMETER HOLE

The stress analysis of pressure vessel with two hole of 20 mm diameter is carried out for various material. The pressure vessel is subjected to structural and thermal load.

Table 6.5. Stress Analysis of Pressure Vessel with Two 20 mm Diameter Hole

Material	Von Misses Stress (MPa)	Total Heat Flux (W/mm^2	Max. Principle Stress (MPa)	Min. Principle Stress (MPa)
Aluminum	174.04	$2.60\ e^{-13}$	185.3	8.01
Copper	174.35	$6.89\ e^{-13}$	185.93	7.48
Gray Cast Iron	173.94	$8.86\ e^{-14}$	183.82	6.90
Mild Steel	205.34	$1.03\ e^{-13}$	185.46	9.00
Stainless Steel	259.8	$2.58\ e^{-14}$	186.61	13.36
Titanium	173.02	$3.75\ e^{-14}$	185.3	9.02

vi. STRESS ANALYSIS OF PRESSURE VESSEL WITH THREE 20 MM DIAMETER HOLE

The stress analysis of pressure vessel with three hole of 20 mm diameter is carried out for various material. The pressure vessel is subjected to structural and thermal load.

Table 6.6. Stress Analysis of Pressure Vessel with Three 20 mm Diameter Hole

Material	Von Misses Stress (MPa)	Total Heat Flux (W/mm^2	Max. Principle Stress (MPa)	Min. Principle Stress (MPa)
Aluminum	178.13	$2.60\ e^{-13}$	189.58	7.17
Copper	178.56	$6.78\ e^{-13}$	190.3	7.23
Gray Cast Iron	177.77	$8.63\ e^{-14}$	187.95	6.12
Mild Steel	207.12	$1.00\ e^{-13}$	189.89	9.29
Stainless Steel	261.03	$2.57\ e^{-14}$	191.31	13.58
Titanium	177.03	$3.68\ e^{-14}$	182.42	8.95

vii. STRESS ANALYSIS OF PRESSURE VESSEL WITH ONE 30 MM DIAMETER HOLE

The stress analysis of pressure vessel with one hole of 30 mm diameter is carried out for various material. The pressure vessel is subjected to structural and thermal load.

Table 6.7. Stress Analysis of Pressure Vessel with One 30 mm Diameter Hole

Material	Von Misses Stress (MPa)	Total Heat Flux (W/mm^2	Max. Principle Stress (MPa)	Min. Principle Stress (MPa)
Aluminum	198.72	$2.57\ e^{-13}$	211.85	7.39
Copper	199.22	$6.93\ e^{-13}$	212.55	8.56
Gray Cast Iron	198.68	$8.80\ e^{-14}$	210.86	6.39
Mild Steel	207.16	$1.02\ e^{-13}$	213.18	9.74
Stainless Steel	261.59	$2.61\ e^{-14}$	214.89	12.40
Titanium	196.7	$3.76\ e^{-14}$	210.57	7.35

viii. STRESS ANALYSIS OF PRESSURE VESSEL WITH TWO 30 MM DIAMETER HOLE

The stress analysis of pressure vessel with two hole of 30 mm diameter is carried out for various material. The pressure vessel is subjected to structural and thermal load.

Table 6.8. Stress Analysis of Pressure Vessel with Two 30 mm Diameter Hole

Material	Von Misses Stress (MPa)	Total Heat Flux (W/mm^2	Max. Principle Stress (MPa)	Min. Principle Stress (MPa)
Aluminum	200.58	$2.58\ e^{-13}$	212.11	10.13
Copper	204.96	$6.80\ e^{-13}$	212.45	11.17
Gray Cast Iron	200.77	$9.00\ e^{-13}$	211.43	8.60
Mild Steel	243	$1.02\ e^{-13}$	212.5	12.26
Stainless Steel	308.41	$2.54\ e^{-14}$	213.26	15.76
Titanium	199.62	$3.74\ e^{-14}$	211.72	8.64

ix. STRESS ANALYSIS OF PRESSURE VESSEL WITH THREE 30 MM DIAMETER HOLE

The stress analysis of pressure vessel with three hole of 30 mm diameter is carried out for various material. The pressure vessel is subjected to structural and thermal load.

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Table 6.9. Stress Analysis of Pressure Vessel with Three 30 mm Diameter Hole

Material	Von Misses Stress (MPa)	Total Heat Flux (W/mm^2	Max. Principle Stress (MPa)	Min. Principle Stress (MPa)
Aluminum	225.45	2.57 e^{-13}	235.12	6.04
Copper	229.11	6.88 e^{-13}	238.95	11.62
Gray Cast Iron	226.25	9.11 e^{-14}	235.04	5.64
Mild Steel	230.53	1.05 e^{-13}	239.56	12.51
Stainless Steel	257.7	2.63 e^{-14}	241.27	14.22
Titanium	226.61	3.70 e^{-14}	236.94	9.45

x. STRESS ANALYSIS OF PRESSURE VESSEL WITH ONE 40 MM DIAMETER HOLE

The stress analysis of pressure vessel with one hole of 40 mm diameter is carried out for various material. The pressure vessel is subjected to structural and thermal load.

Table 6.10. Stress Analysis of Pressure Vessel with One 40 mm Diameter Hole

Material	Von Misses Stress (MPa)	Total Heat Flux (W/mm^2	Max. Principle Stress (MPa)	Min. Principle Stress (MPa)
Aluminum	239.69	2.65 e^{-13}	254.33	9.08
Copper	240	6.99 e^{-13}	254.8	10.47
Gray Cast Iron	239.84	9.11 e^{-14}	253.66	7.26
Mild Steel	241.27	1.05 e^{-13}	255.33	10.75
Stainless Steel	254.28	2.60 e^{-14}	256.55	13.74
Titanium	238.04	3.78 e^{-14}	253.29	9.15

xi. STRESS ANALYSIS OF PRESSURE VESSEL WITH TWO 40 MM DIAMETER HOLE

The stress analysis of pressure vessel with two hole of 40 mm diameter is carried out for various material. The pressure vessel is subjected to structural and thermal load.

Table 6.11. Stress Analysis of Pressure Vessel with Two 40 mm Diameter Hole

Material	Von Misses Stress (MPa)	Total Heat Flux (W/mm^2	Max. Principle Stress (MPa)	Min. Principle Stress (MPa)
Aluminum	233.7	1.68 e^{-13}	248.62	8.98
Copper	233.8	4.52 e^{-13}	248.96	9.78
Gray Cast Iron	233.82	5.88 e^{-14}	247.87	7.24
Mild Steel	234.50	6.79 e^{-14}	248.99	10.35
Stainless Steel	235.18	1.71 e^{-14}	249.79	13.42
Titanium	232.94	2.46 e^{-14}	248.19	8.55

xii. STRESS ANALYSIS OF PRESSURE VESSEL WITH THREE 40 MM DIAMETER HOLE

The stress analysis of pressure vessel with three hole of 40 mm diameter is carried out for various material. The pressure vessel is subjected to structural and thermal load.

Table 6.12. Stress Analysis of Pressure Vessel with Three 40 mm Diameter Hole

Material	Von Misses Stress (MPa)	Total Heat Flux (W/mm^2	Max. Principle Stress (MPa)	Min. Principle Stress (MPa)
Aluminum	258.59	1.75 e^{-13}	274.91	9.68
Copper	258.84	4.65 e^{-13}	275.33	10.86
Gray Cast Iron	259.26	5.95 e^{-14}	274.64	7.87
Mild Steel	260.67	6.95 e^{-14}	276.37	11.56
Stainless Steel	261.81	1.72 e^{-14}	277.68	14.20
Titanium	256.44	2.50 e^{-14}	273.34	7.94

VII. CONCLUSION

- It is observed that stresses are increasing when the number of holes is increased & diameter kept constant. Minimum number of holes lower the stresses and maximize the number of holes increases the stresses.
- The analysis of pressure vessel is performed by changing the material. It is found that the von misses stress generated in the Titanium is lower than the material selected for the study. The von misses stress generated in the Stainless steel is maximum for the selected material. Below are the materials arranged in the increasing order of stress generated. Titanium > Gray Cast Iron > Aluminum > Copper > Mild Steel > Stainless steel
- The analysis of pressure vessel is conducted considering the thermal temperature. The heat flux generated in Aluminum is lesser than the material considered for the study. The maximum heat flux is generated in Gray Cast Iron from the material considered for the study. Below materials are arranged in increasing order of Total Heat Flux generated.

Aluminum > Copper > Mild Steel > Stainless Steel > Titanium > Gray Cast Iron

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