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Von Mises Analysis of Truck Tanker for Various Materials

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Abstract:– It is clearly known to all that the transportation of fluids is so difficult and dangerous. To make the transportation easier and safer the designing of the fluid container is such that the container can withstand on any situation. Therefore to maintain the demand of it in the industry the most important thing should be consider in the industry is the selection of materials. Because the better will be the material's properties the stronger will be the container of the fluid. In this paper the suggestion is given to select the best suited material with the help of von mises stress analysis. The analysis is performed to consider the von mises criteria on different materials. This analysis has done on the COMSOL MULTYPHYSICS version 6.0, the designing of the container has done in the CATIA V-5 R18 software, and the analytical graph has plotted with the help of MATLAB R2021a. Shape of the container has taken as cylindrical. The dimensions of the cylinder are taken in such a way that the internal diameter of the cylinder is 135mm; outer diameter is 150mm, length of the cylinder is 300mm and therefore the thickness is 9mm. These are arbitrary dimensions which have taken for the analysis. The materials selected to the analysis are mild steel, stainless steel, and hastelloy.

Keywords:- *Thick cylinder; Von Mises Criteria; Truck Tanker;*

I. INTRODUCTION

The truck tankers are most commonly used to transport the petroleum product from one place to other. Since the petroleum are highly difficult and dangerous to transport. Therefore to see the safety and ease of transportation the designing of container or we can say that the tanker must be considerate. Because there has been noted for so many explosion during transportation of petroleum product. The main factor to design a tanker is the selection of materials. The design of the tanker has been done on the standards of ASME BPVC section-III which consist three divisions –

- Division – I : Design by rule;
- Division – II : Design by analysis;
- Division – III: Design by that requires internal or external pressure operating at above 10,000 psi.

[1] Oluleke Oluwole has done the analysis of the ellipsoidal and cylindrical petroleum tankers with the help of MATLAB programming he found that when the tank is loaded the von mises stress increases and when it is unloaded then the von mises stress decreases. [2] It also varies with the thickness of the tanker i.e. with increasing the thickness of the tanker the von mises stress decreases. This analysis has performed by FEA method and the load has considered as inside pressure within the tanker. And also dictated that when the pressure inside the cylinder increases the von mises stress also increases by it. [9] W. Zhao analyzes the pressure performance of thick walled cylinder which is subjected to internal pressure by analytical means. [10] The failure of cylinder under internal pressure is calculated by von mises theory which suggest that if the von mises stress of any cylinder is equal to greater than the yield strength the of the material then material will fail under the internal pressure.

The von mises criteria is given following:

$$\sigma_v = \frac{1}{\sqrt{2}}[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2]^{1/2}, 1$$

If yield strength of the material is σy then from von mises criteria

$$\sigma_v \geq \sigma_y$$

[3]A review paper on pressure vessel design and analysis has been done. It has highlighted to the major consideration to designing and also analyzing the performance of a pressure vessel.

[4] To find the burst pressure of a cylinder which is subjected to inside pressure is carried out by finite element method and compared by analytical method.

This paper predicts the material which is best suited for the tanker. And in this paper the finite element method has used to find the von mises stresses of the tanker.

II. ANALYSIS AND DISCUSSION

A. *Design of cylindrical tank:*

The following dimensions has taken to design the tanker which is given below:

Outer diameter of tank (D) = 150mm
Inner diameter of tank (d) = 135mm
Length of the tank (l) = 300mm
Thickness of the tank (t) = 9mm
Pressure inside the cylinder varies from 0 to 32MPa with the difference of 4 each.

Materials selected for the analysis are –

- Mild steel
- Stainless steel 304
- Hastelloy–A

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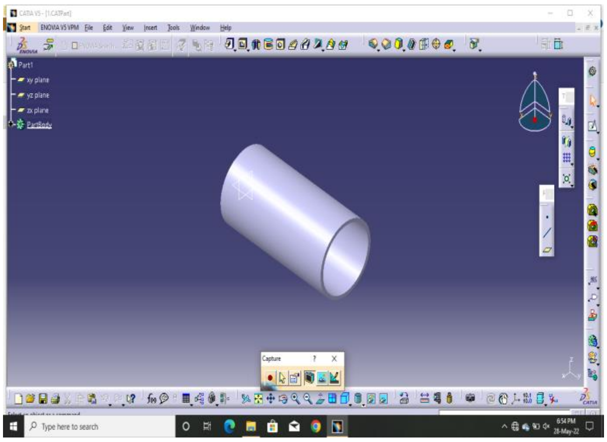

Fig. 1: Screenshot of part design of the cylinder

Source CATIA V-5

Description	Value
Space dimension	3
Number of domains	1
Number of boundaries	6
Number of edges	12
Number of vertices	8

Table 1: Geometrical Statistics

a) Mesh distribution of cylinder:
The diagram shown below represents the mesh distribution of the cylinder. In this the shape of the mesh is tetrahedron and size is finer has taken.

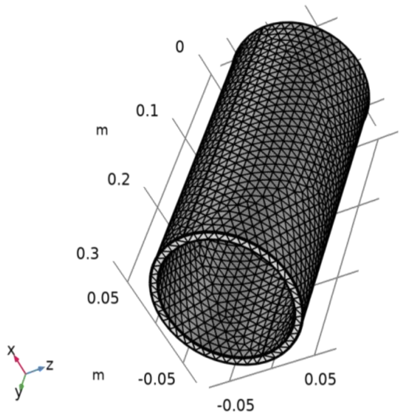

Fig. 2: Mesh distribution on the cylinder

Source COMSOL MULTYPHISICS 6.0

Description	Value
Status	Complete mesh
Mesh vertices	2880
Tetrahedron	8387
Triangles	5760
Edge elements	280
Vertex elements	8
Number of elements	8387

Description	Value
Minimum element quality	0.4382
Average element quality	0.6779
Element volume ratio	0.34751
Mesh volume	0.001007 m³
Maximum element size	0.0165
Minimum element size	0.0012
Curvature factor	0.4
Resolution of narrow regions	0.7
Maximum element growth rate	1.4
Predefined size	Finer

Table 2: Mesh Statistics

B. Analysis

a) Mild steel
Mild steel also known as low carbon steel is a type of carbon steel which is classified on the basis of % of carbon in the steel. This % of carbon in the mild steel is 0.05% to 0.25% of carbon by weight. [5] Due to less % of carbon in it, makes it popular type of steel to the various application in the industries. It contains various properties such as high strength, less hardness, less brittle, more ductility which makes it to deform easily in any shape, high machinability makes it better surface finish and last but not the least toughness makes it absorb more and more energy up to fracture.

The following material parameters have used in this paper to analyze the behavior of mild steel subjected to internal pressure:

Name	**Value**	**Unit**
Density	7850	kg/m³
Young's modulus	200	GPa
Poisson's ratio	0.303	1
Yield strength	250	MPa

Table 3: Material Parameters

C. FEA Analysis of mild steel

a) Von mises stress distribution of mild steel:

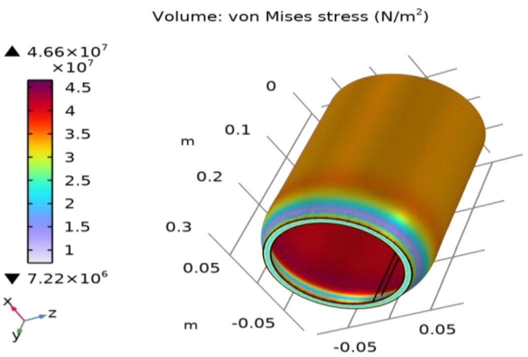

Fig. 3: Von mises stress distribution on mild steel tanker

Source COMSOL MULTYPHYSICS 6.0

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S. No.	Internal Pressure (MPa)	Von Mises Stress (MPa)
1.	4	46.6
2.	8	93.1
3.	12	140
4.	16	186
5.	20	233
6.	24	279
7.	28	326
8.	32	373

Table 4: Von Mises Stresses On Mild Steel For Various Pressure Values

As we can see that in the above table increasing the pressure value, the von mises stress will also increase. Since the yield strength of mild steel is 250MPa therefore from the above table it is clear that material will fail between pressure values 20-24 MPa. Or material will start deform plastically after 20MPa.

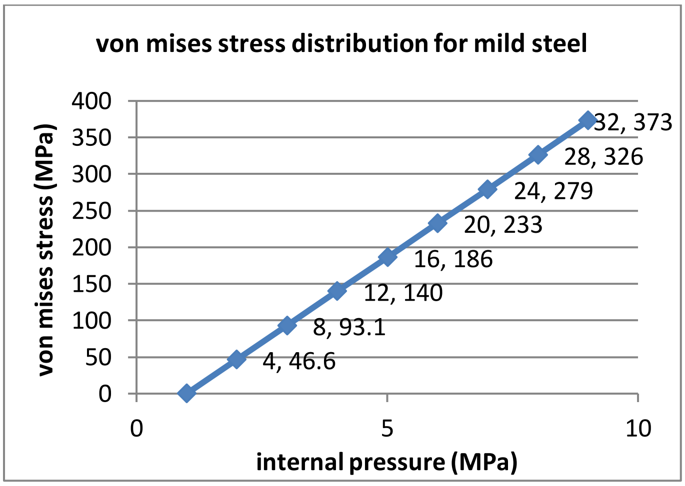

Fig. 4: Graphical representation of von mises Vs internal pressure

D. *Stainless Steel*

It is a type of steel which uses chromium to reduce the corrosion of the material which is experienced by most of the iron based materials. [6] It contains 0.08% of carbon, 18 – 20 % of chromium, 66 – 74 % of iron, 2% of manganese and other elements as well. The corrosion resistance and temperature resistance is quite high as compared to other iron based alloy. It has high strength, more ductile in nature, less brittle and hard.

The following mechanical properties have used to analysis which is given below –

Name	Value	Unit
Density	rho(T)	kg/m³
Young's modulus	200	MPa
Poisson's ratio	0.29	1

Table 6: Materisl Parameters

E. *FEA Analysis of stainless steel*

- Von mises stress distribution:

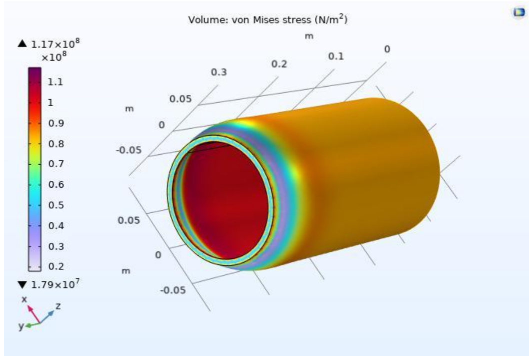

Fig. 5: Von mises stress distribution on stainless steel tanker

Source COMSOL 6.0

S. No.	Internal pressure (MPa)	Von mises stress (MPa)
1.	4	42.9
2.	8	85.8
3.	12	129
4.	16	172
5.	20	234
6.	24	281
7.	28	300
8.	32	343

Table 5: Von Mises Stresses On Stainless Steel For Various Pressure Values

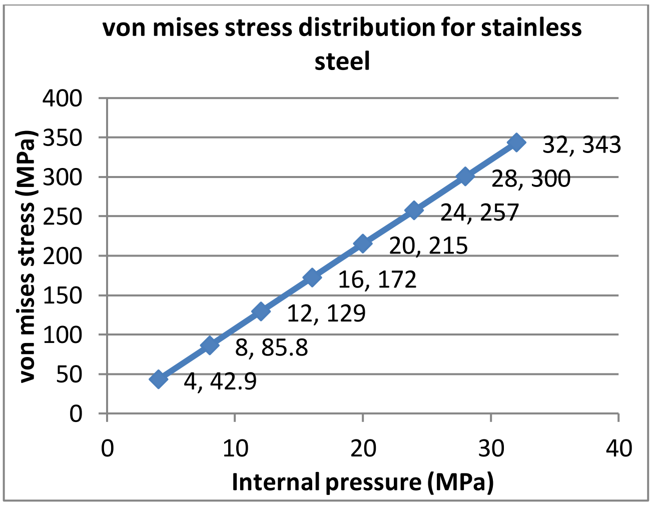

Fig. 6: Graphical representation of Von mises Vs internal pressure

- *Hastelloy–A*
- It is a type of No based alloy material. [7] It contains chromium and molybdenum which are resistance to corrosion. It has high metallurgical stability. [8] It is also called as super alloy due to their outstanding properties related to corrosion and temperature. Its strength is very high, less hard and less brittle, and has high malleability

which makes it to deform in any shape by impacting on it. It contains chromium, molybdenum, carbon, aluminum, manganese, tungsten, copper, cobalt etc.

The following mechanical properties have used to analysis of von mises stress

Name	Value	Unit
Density	rho(T)	kg/m³
Young's modulus	205	MPa
Poisson's ratio	0.307	1

Table 6: Material Parameter

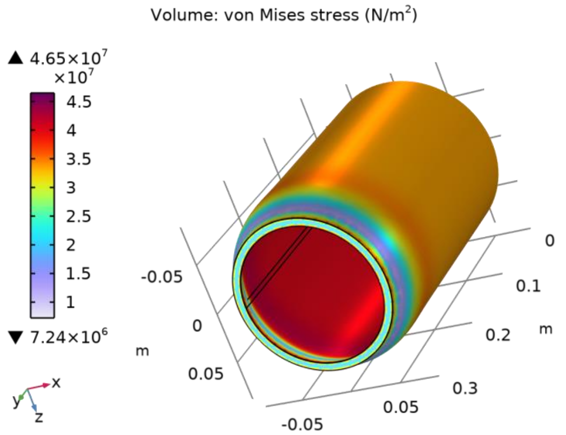

Fig. 7: Von mises stress distribution on hastelloy
Source COMSOL 6.0

S. No.	Internal pressure (MPa)	Von mises stress (MPa)
1.	4	46.5
2.	8	92.6
3.	12	139
4.	16	186
5.	20	232
6.	24	279
7.	28	325
8.	32	372

Table 7: Von Mises Stresses On Hastelloy For Various Pressure Values

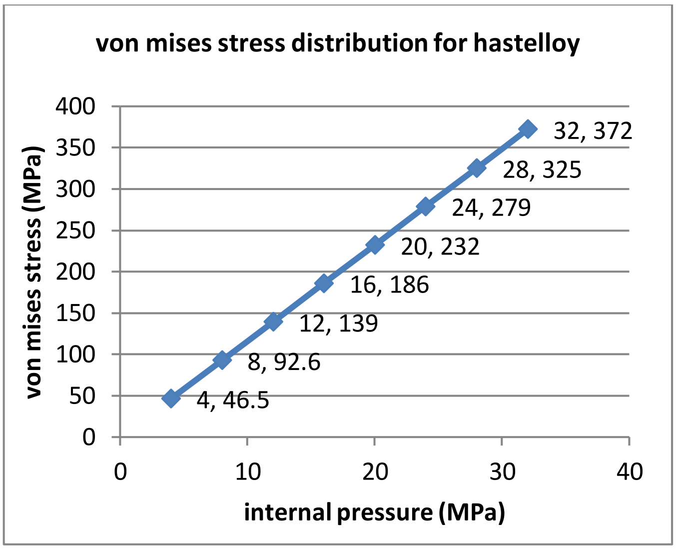

Fig. 8: Graphical representation of Von mises Vs internal pressure

III. RESULT

As we can see that in the above diagrams fig.4, fig.6, and fig.8 represents the von mises distribution on the materials. Fig.4. shows the von mises on mild steel, Fig.6. Show the von mises on stainless steel, and Fig.8. Show the von mises on hastelloy.

The following diagram shows the comparison between these materials. And it has to be found that among mild steel, stainless steel and hastelloy; mild steel withstand on higher pressure because the von mises stress for 32MPa pressure is greater that both of the materials.

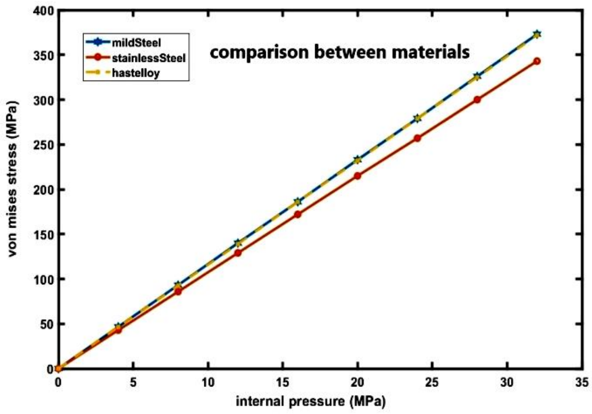

Fig. 9: Comparison between materials

Source MATLAB R2021a

From the FEA method it has to be found that with increasing the value of pressure von mises stress also increases therefore for the validation they have compared with the analytical von mises stress and from there it has shown that from both the methods the von mises stress will increase with increasing the value of pressure which is represented in fig.10.

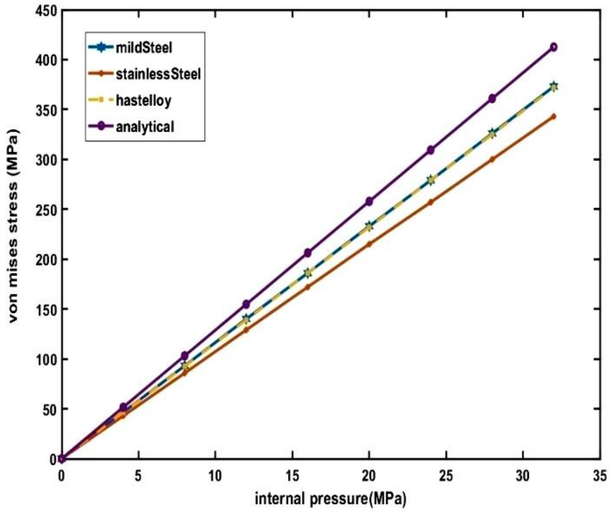

Fig. 10: Validation with analytical von mises stress

Source MATLAB R2021a

IV. CONCLUSION

From these discussions it has been clear that mild steel will be fine for the truck tanker. Since the performance of mild steel over von mises stress is good. The behavior of hastelloy is also high as compared to stainless steel but it is low from mild steel. Although it has high resistance to corrosion and can withstand on high temperature but its strength over pressure is not good as compared to mild steel.

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