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DESIGN VERIFICATION OF BOLT PRETENSION AND CONTACT LID OF INFLAMMABLE CONTAINER

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Abstract: ***Inflammable containers are widely used in industries for the storage of highly inflammable liquids and gases. The transportation of these liquids and gases is done either through roadways using Inflammable containers or through pipelines. For the ease of accessibility Inflammable containers are the most preferable mode of transportation. The safety against the failure of these containers due to an internal pressure is a major issue. In this project a detailed stress analysis of contact lid and bolt pretension of the Inflammable container is carried out. A container is designed using ASME codes and the analysis is done using ANSYS. In this project, design modification is made for the base model. The linear static structural analysis is made for each of case of the container to study the stress distribution due to an internal pressure. The result shows that Inflammable container with doubler has better acceptable results compared to the base model. The satellite analysis of bolts, bearing bypass and bilinear analysis are carried out for the container with doubler. The results from this study show that the container with doubler has reduced stresses compared to the base model and it is safer against the maximum allowable working pressure.***

Keywords: Pretension; Contact lid; ASME Codes; Bearing bypass; Doubler.

I. INTRODUCTION

Inflammable containers are widely used in industries for the storage of highly inflammable liquids and gases. An Inflammable container is come under the category of pressure vessel. A pressure vessel is defined as a container with a pressure differential between inside and outside. The pressure vessel mainly consists of centre cylindrical shell with two spherical shell frustum welded through seam welding. The shell is stabilized through an opening which is responsible for the fluid control. The bleed contains a contact lid which assures safety of the fluid inside. These containers are used in many 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. The walls of an ideal thin-wall pressure vessel act as a membrane (that is, they are unaffected by bending stresses over most of their extent). A sphere is the optimal geometry for a closed pressure vessel in the sense of being the most structurally efficient shape. A cylindrical vessel is somewhat less efficient for two reasons: (1) the wall stresses vary with direction, (2) closure by end caps can alter significantly the ideal membrane state, requiring additional local reinforcements. The cylindrical vessels are generally preferred because of the present simple manufacturing problem and make better use of the available space. Boiler, heat exchanger, chemical reactor and so on, are generally cylindrical.

The commonly used cylindrical pressure vessel consists of following components:

- Shell: A shell is a cylindrical member commonly with an opening for providing a Contact lid or bleeder at its side or top. It is made up of seamless pipe or by joining two halves of cylinder.
- Head: The heads are sometimes called as end caps used for closing the two ends of a cylindrical shell. They are joined to the shell through a welded joint. There are several types of heads like hemispherical head, ellipsoidal head, torispherical head, etc.
- Contact Lid: A contact lid system (or a bleeder) consists of the lid, covers for openings in the lid, bolts, the corresponding flange and gaskets. Commonly, two gaskets are positioned in special grooves on lid to establish leak tightness for a long term. The contact lid is an important component of the pressure vessel; it is strong enough to withstand damages from external member. And also it ensure leak proof joint to avoid the leakage of fluids from the container.
- Saddle supports: Commonly, horizontal pressure vessels are supported on saddle supports. They are also called as vertical cradles and it itself has different parts; the web, base plate, ribs and wear plate. Usually two saddle supports are used for supporting the vessels.

II. OBJECTIVES OF THE WORK

The main objective of the work is to reduce the stresses developed in the contact lid of an Inflammable container due to an internal pressure and to improve the strength of the container. The following analysis is carried out to study the stresses in the container:

- Linear Static Structural Analysis of contact lid of an Inflammable container.
- Satellite analysis of bolts in the lid.
- Bearing bypass analysis.
- Bilinear (nonlinear) analysis.

The Finite Element Method (FEM) approach is used to solve the above problems.

III. METHODOLOGY

Material Selection

The material selected for the construction of Inflammable container is Grade B Seamless Carbon Steel. It is also called as ASME SA-106B. It is a carbon-manganese steel intended for several high temperature service conditions and it is suitable for bending, flanging and similar forming operations. The material properties of the SA-106B carbon steel is given in the below table.

TABLE 1: Material properties of SA-106B

Material	SA106 B
Density at room temperature, ρ	7850 kg/m3
Modulus of elasticity, E	2.06×105 Mpa
Tensile strength, Ts	415 Mpa
Yield strength	240 Mpa
Poisson's Ratio, μ	0.29
Factor of Safety, FOS	3
Tangent modulus	2×105 Mpa

Mathematical Modeling

Design specifications: From the pressure vessel design manual according to ASME standards, for the inside diameter of 1500 mm and internal pressure of 12Mpa, the allowable stress of SA-106B is 138 Mpa, Corrosion allowance for new vessel is 1mm, Joint efficiency for welded joints is 1 and Wall thickness co-efficient is 0.4. Thickness of the container: From pressure vessel design manual the thickness of the container is calculated from the below formula.

$$t = \frac{P\,R}{S\,E - 0.6\,P}$$

$$t = \frac{12 \times 750}{138 \times 1 - 0.6 \times 12}$$

$$t = 68.8 \text{ mm}$$

Geometric Modeling

The modeling of an inflammable container is done using ANSYS Workbench 14.5 software as per the design specifications discussed in the above. There are two cases of design including base model and the design improvisation i.e., container with doubler.

Case 1: Base model: Figure 1 shows the existing model of the inflammable container's contact lid which we called it as a base model for our reference. It is having a mass of 374.89 kg and a volume of 4.7756x107 mm3.

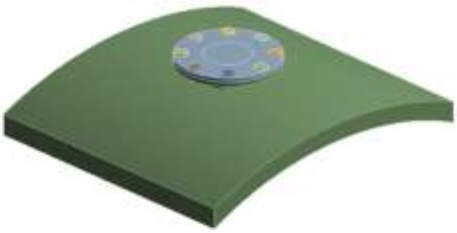

Fig.1. 3D model of Container lid

Case 2: Container with Doubler: Figure 2 shows the modified model of the contact lid where a sheet made up of same material as that of the base model is welded to the shell of a container at the neck region of the contact lid to improve the stiffness.

Fig.2. 3D model of Container lid with Doubler

Meshing

The geometric model of the container is meshed in ANSYS Workbench 14.5 by using advance meshing options to generate fine mesh for better and relatively accurate results. The TET elements are used for meshing and 73293 nodes and 36924 elements are created to generate better quality mesh.

Fig.3. Meshed model of Container lid

Boundary Conditions

The boundary conditions considered here are fixed support and internal pressure is applied as shown in figure 4 and 5 respectively.

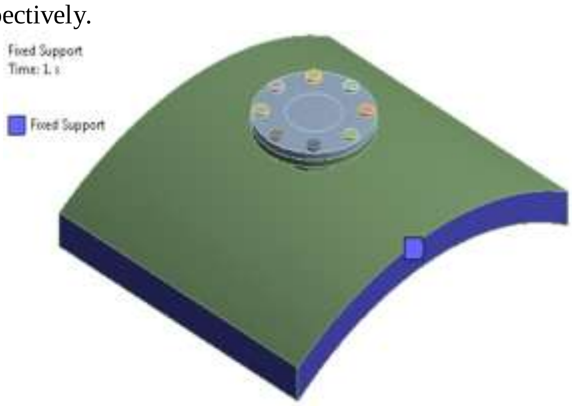

Fig.4. Fixed support of the container

Fig.5. Internal Pressure

IV. ANALYSIS OF THE MODEL

Linear Static Analysis: Linear static analysis is the most basic type of analysis. The term “linear” means that the compound responses, for example stress or displacement which is linearly related to the applied force. The term “static” means that the forces do not vary with time or that the time variation is minimal and can therefore safely ignored. When loads are applied to a body, the body deforms and the effect of load is transmitted all over the body. The external loads generate internal forces and reactions to restore the body into a state of equilibrium. Satellite Analysis of Bolts: Satellite analysis of bolts is carried out to study the sustainability of the contact lid when the half number of bolts in a lid are failed under specific condition then the remaining bolts are able to withstand the load or not under the same condition. Bearing Bypass Analysis: The term bearing bypass is generally used in the analysis of multi rowed bolted joints to define the amount of load taken by a bolt and how much of the total load bypasses that bolted row and is passed out to the next row of bolts. The bearing load is reactive at a specific bolt under consideration while the bolt hole bypasses the part of the load i.e., bypass load is reactive at somewhere else. Bilinear Analysis: Bilinear analysis consists of incremental application of loads. In calculations, loads are not considered at a time but are gradually increased and solutions to successive equilibrium states are performed.

V. RESULTS AND DISCUSSION

Analysis of the contact lid of an inflammable container has been done using ANSYS as post processor. The equivalent stress, total deformation, maximum and minimum principal stress in a lid and equivalent stress in bolts are discussed.

Case 1: Base Model

The results of linear static analysis obtained for the base model under the given boundary conditions are given below.

Equivalent Stress:

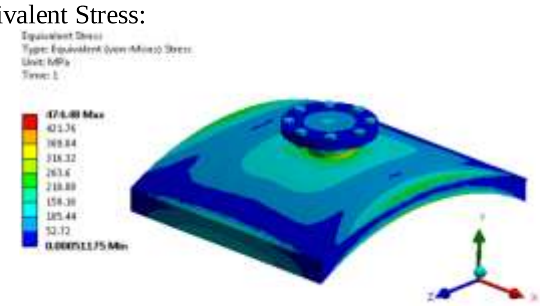

Fig.6. Equivalent stress in base model

The above figure shows Equivalent stress of 474.48 Mpa for the given boundary conditions.

Total Deformation:

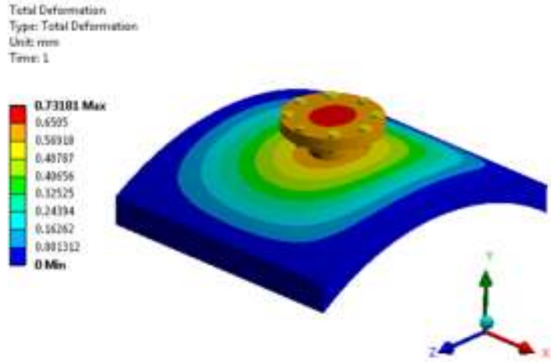

Fig.7. Total deformation in base model

The above figure shows Total deformation of 0.73 mm for the given boundary conditions.

Maximum Principal Stress:

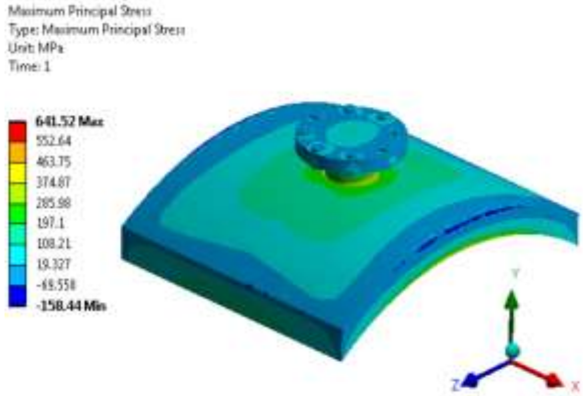

Fig.8. Maximum principal stress in base model

The above figure shows Maximum principal stress of 641.52 Mpa for the given boundary conditions.

Minimum Principal Stress:

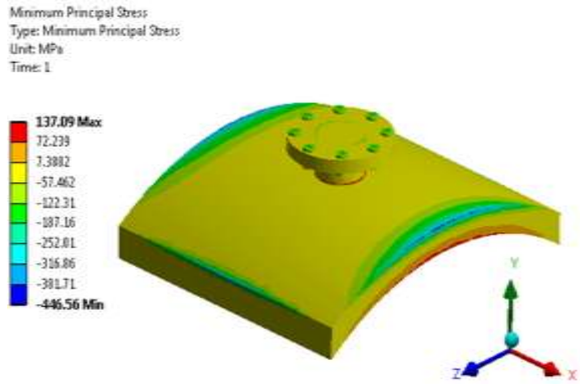

Fig.9. Minimum principal stress in base model

The above figure shows Minimum principal stress of 137.09 Mpa for the given boundary conditions.

Equivalent Stress in bolts:

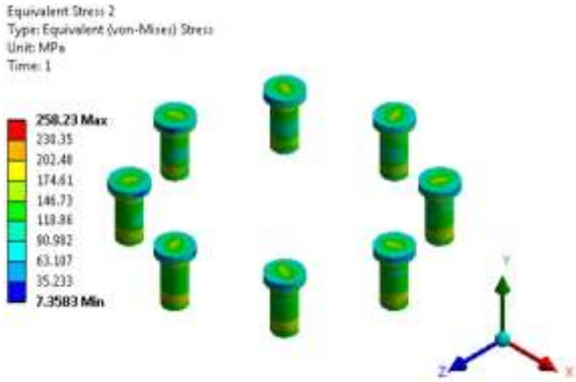

Fig.10. Equivalent stress in bolts of base model

The above figure shows equivalent stress of 258.23 Mpa in bolts for the given boundary conditions.

Case 2: Container with Doubler

The results of linear static analysis obtained for the container with doubler under the given boundary conditions are given below.

Equivalent Stress:

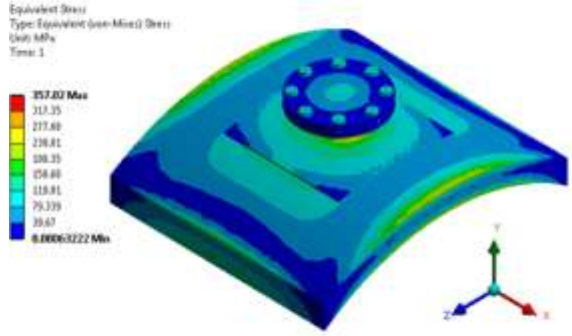

Fig.11. Equivalent stress in container with doubler

The above figure shows Equivalent stress of 357.02 Mpa for the given boundary conditions.

Total Deformation:

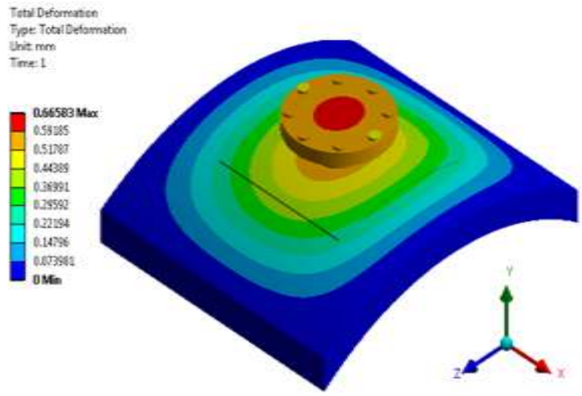

Fig.12 Total deformation in container with doubler

The above figure shows Total deformation of 0.66 mm for the given boundary conditions.

Maximum Principal Stress:

Fig.13. Maximum principal stress in container with doubler

The above figure shows Maximum principal stress of 485.62 Mpa for the given boundary conditions.

Minimum Principal Stress:

Fig.14. Minimum principal stress in container with doubler

The above figure shows Minimum principal stress of 131.36 Mpa for the given boundary conditions.

Equivalent Stress in bolts:

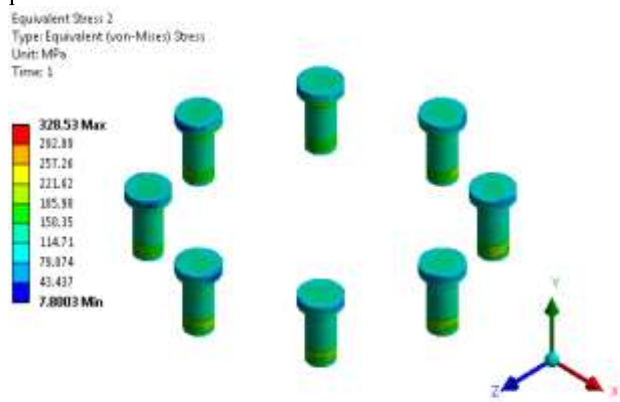

Fig.15. Equivalent stress in bolts of container with doubler

The above figure shows equivalent stress of 328.53 Mpa in bolts for the given boundary conditions.

It is seen from the results that the stresses in the lid are reduced for the container with doubler as compared to the base model. Thus the satellite analysis, bearing bypass and bilinear analysis are carried out for the container with doubler.

Satellite Analysis of Bolts

The results of satellite analysis obtained for the container with doubler under the given boundary conditions are given below.

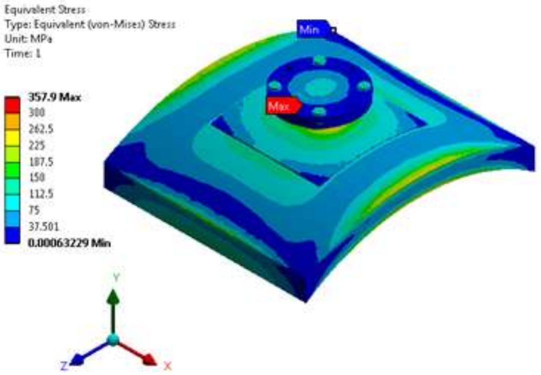

Fig.16. Equivalent stress in container with doubler

The above figure shows Equivalent stress of 357.9 Mpa for the given boundary conditions

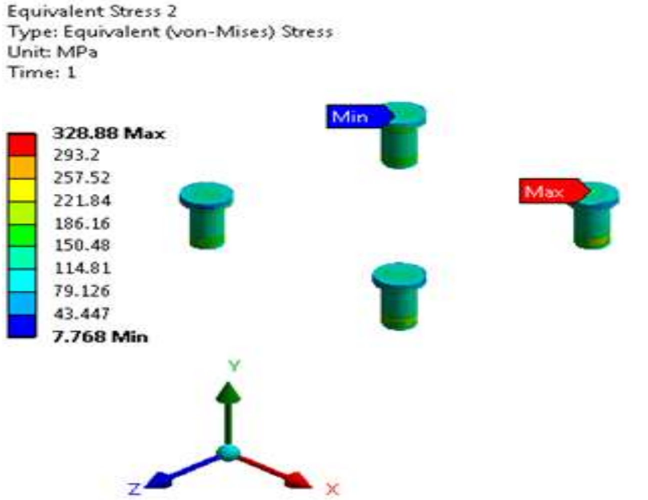

Fig.17. Equivalent stress in bolts of container with doubler

The above figure shows equivalent stress of 328.88 Mpa in bolts for the given boundary conditions.

Bearing Bypass Analysis

The results of bearing bypass analysis obtained for the container with doubler under the given boundary conditions are given below.

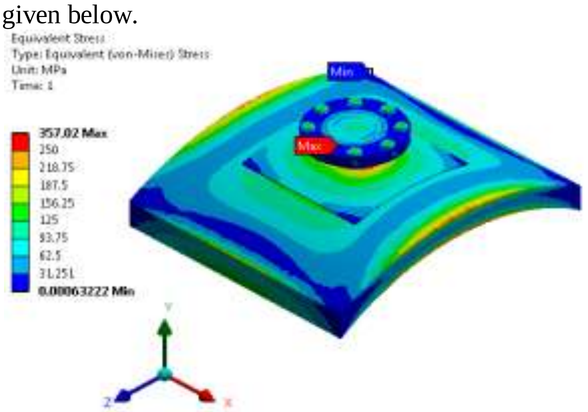

Fig.18. Equivalent stress in container with doubler

The above figure shows Equivalent stress of 357.02 Mpa for the given boundary conditions

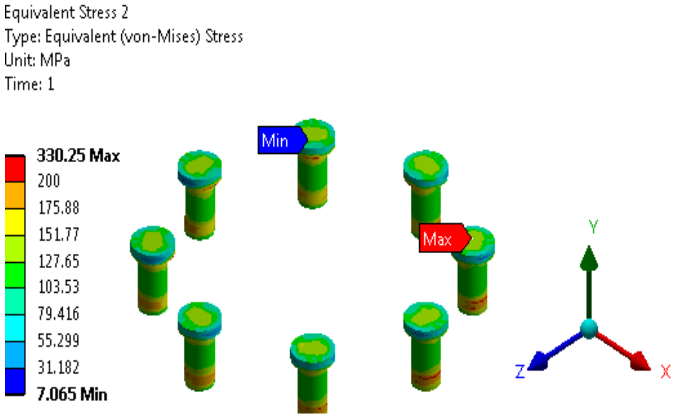

Fig.19. Equivalent stress in bolts of container with doubler

The above figure shows equivalent stress of 330.25 Mpa in bolts for the given boundary conditions.

Bilinear Analysis

The results of bilinear analysis obtained for the container with doubler under the given boundary conditions are given below.

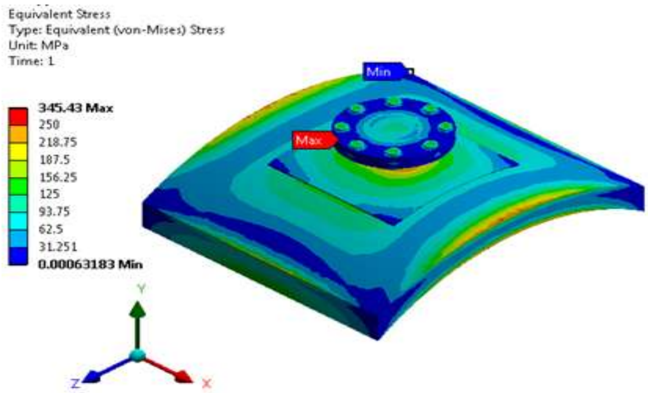

Fig.20. Equivalent stress in container with doubler

The above figure shows Equivalent stress of 345.43 Mpa for the given boundary conditions

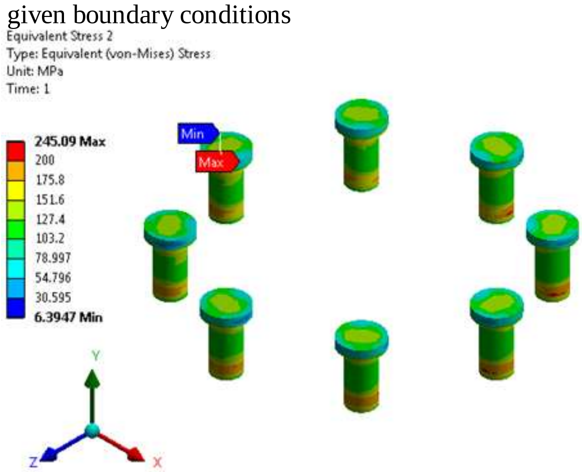

Fig.21. Equivalent stress in bolts of container with doubler

The above figure shows equivalent stress of 245.09 Mpa in bolts for the given boundary conditions.

VI. CONCLUSION

The results of linear static analysis for base model and the design improvisation model i.e., container with doubler are compared and tabulated below.

TABLE II: Comparison of stresses

Sl. No		Case 1	Case 2
1	Equivalent stress (Mpa)	474.48	357.02
2	Maximum principal stress (Mpa)	641.52	485.62
3	Minimum principal stress (Mpa)	137.09	131.36
4	Total deformation (mm)	0.7318	0.6658

From the results tabulated above, there is a reduction of 117.46 Mpa in equivalent stress, 155.9 Mpa in maximum principal stress, 5.73 Mpa in minimum principal stress and 0.066 mm in total deformation. It is concluded that the stresses obtained for the container with doubler are comparatively smaller than the base model i.e., container without doubler. Providing the doubler at the neck of the contact lid reduces the stresses in the container to some extent thus improving its stiffness and safety against failure.

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