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Design and Finite Analysis of Canister Testing Chamber

L. Srinivas Naik[1], K. Srinivasa Chalapati[2], B. Ravi Kumar[3]
1. Associate professor. Department of Mechanical Engineering, Anurag Group of Institutions
2. Associate professor. Department of Mechanical Engineering Anurag Group of Institutions,
3. Associate professor. Department of Mechanical Engineering M.V.S.R. Engineering College.

Abstract

Canister testing Chamber is one of the most critical components in Defence Organization. Unavailability of data and literature regarding Missile Canister, are considered to be one of the main contributors for the failure of manufacturing Canister Chambers in a local industry.

Canister is used for carrying, storing and launching of missile. During storage and launching, the canister is subjected to an internal pressure of 45 kg/cm^2 and external pressure of 9 kg/ cm^2. So it is very important to test the canister for these pressures. The internal and external pressure testing chamber is used to test the canister. The canister is placed inside the testing chamber. Thus, the primary objective of this thesis is to develop a canister testing chamber and predicting the performance of canister by ANSYS a finite element analysis package.

The internal and external pressure testing of the canister is done by closing the canister both ends by dummy dished ends. The chamber will be used for the testing of the integrated canister assembly for the external pressure of 9 kg/ cm^2 and internal pressure of 45 kg/ cm^2. The test chamber will be dedicated especially to perform internal and external pressure testing of the canister. To estimate the structural stress, three – dimensional model of a canister chamber was made by finite element method using UniGraphics.

1. Introduction

Canister is cylindrical container for holding, carrying, storing and launching of missile, usually specified object or substance. The Canister Testing Chamber is used for testing the canister. This chamber will be used for the testing of the integrated chamber assembly for the internal pressure of 45 bar and external pressure of 9 bar. The testing chamber will be dedicated especially to perform the internal and external pressure testing.

The test shell setup is made from IS: 2062 plates welded to get 11 meters length and diameter of the shell is 1.5 meters. One end of the test setup will have dished end welded integrally to the cylinder. The other end shall be a hinged door with proper sealing. On the side of the dished end a screw rod is provided to press the dummy dish end for leak proof joint which shall withstand the internal pressure during testing. The screw is actuated by a hand wheel provided through nut. The nut is fixed in a welded housing on the dished end. The screw front portion will have good surface finish with proper sealing arrangement to withstand 45 bar pressure without any leak. This screw is used to press the dummy dish end against the canister. Between both the mating faces rubber/gasket will be provided to avoid any leak of water during pressure testing.

The chamber shell will have four supports externally for fixing the same on foundation. Inside the chamber a track is welded. A trolley is provided on which the canister is mounted to move the same into the chamber. The chamber will have inlet, outlet and air removal ports with suitable ball valves. 2 no's of pressure indicators, one analog and one digital will be provided. A storage tank and pumping system is also provided for pressurization of the chamber.

For the Finite Element analysis, the canister testing chamber assembly is classified into 3 subsystems.

- Chamber shell design
- Canister dished ends design
- Support legs design

Pressure vessels are probably one of the most widespread equipment within the different industrial sectors. In fact, there is no industrial plant without pressure vessels, steam boilers, tanks, autoclaves, collectors, heat exchangers, pipes, etc. More specifically, pressure vessels represent fundamental components in sectors of paramount industrial importance, such as the nuclear, oil, petrochemical, and chemical sectors. Canister testing chamber is also a horizontal pressure vessel. In the present study, structural analysis of a canister testing chamber used for canister testing will be performed. The most important factors that are concentrated are stress distribution and deflections.

2. Objective & Methodology

- The methodology adopted in the project has listed below:
- Design calculations of canister testing chamber are decided based up on canister dimensions and loads.
- From the calculations, a 3-D model of chamber is developed using Unigraphics
- After developing the model, Finite Element Analysis is carried out for the internal pressure, deflection and stresses on the Chamber. And also, factor of safety is calculated and this should be above 3.

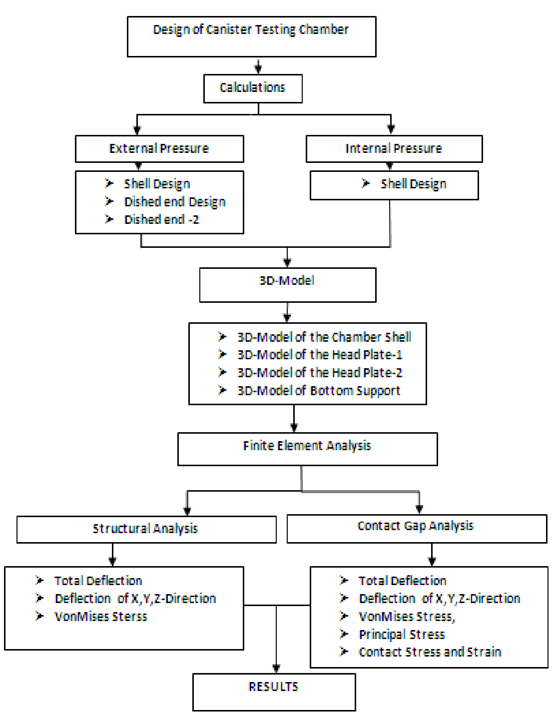

Fig.1. Flow Chart showing Methodology

3. Design Constraints and Modelling

The design formulas used in the "design by rule" method are based on the principal stress theory for calculating the average hoop stress. The principal stress theory of failure states that failure occurs when one of the three principal stresses reaches the yield strength of the material. Assuming that the radial stress is negligible, the other two principal stresses can be determined by simple formulas based on engineering mechanics. The Code recognizes that the shell thickness may be such that the radial stress may not be negligible, and adjustments have been made in the appropriate formulas. Various formulae used to calculate the wall thickness for numerous canister testing chamber geometries are shown below.

3.1 Shell Design Calculations for external pressure

Formulas for calculation of cylindrical shell Thickness

$$t_1 = \frac{PR_i}{(SE - 0.6P)}$$

Where

t_1 = Minimum required thickness (cm), P = Operating pressure (kg/cm^2), R_i = Shell Inside radius cm)

S = Allowable stress (kg/cm^2), E = Weld joint efficiency factor

Design Consideration:

Operating pressure (P) = 9 kg/cm^2, Shell Inside radius (R_i) = 75 cm

Allowable stress (S) = 1200 kg/cm^2, Weld joint efficiency factor (E) = 0.6

3.2 Dished End-1 Design Calculations

Formulae for calculation of Dished End Thickness

$$t_1 = \frac{PR_i}{(SE - 0.6P)}$$

Where

t_1 = Minimum required thickness (cm), P = Operating pressure (kg/cm^2), R_i = Shell Inside radius (cm), S = Allowable stress (kg/cm^2), E = Weld joint efficiency factor

Design Consideration:

Operating pressure (P) = 9 kg/cm^2, Shell Inside radius (R_i) = 75 cm Allowable stress (S) = 1200 kg/cm^2, Weld joint efficiency factor (E) = 0.6

3.3 Dished End-2 Design Calculations

Formulae for calculation of Dished End Thickness

$$t_1 = \frac{PR_i W}{(2SE - 0.2P)}$$

Where

t_1 = Minimum required thickness (cm), P = Operating pressure (kg/cm^2), R_i = Shell Inside radius (cm), S = Allowable stress (kg/cm^2), E = Weld joint efficiency factor, W = Dished End Factor

Design Consideration:

Operating pressure (P) = 9 kg/cm^2, Shell Inside radius (R_i) = 75 cm, Allowable stress (S) = 1200 kg/cm^2, Weld joint efficiency factor (E) = 1

Dished end factor (W) = $0.25 * (3 + \sqrt{\frac{Ri}{0.1Ri}}$)

3.4 Shell Design Calculations for internal pressure

Formulae for calculation of cylindrical shell Thickness

$$t_1 = \frac{PR_i}{(SE - 0.6P)}$$

Where

t_1 = Minimum required thickness (cm), P = Operating pressure (kg/cm^2), R_i = Shell Inside radius (cm), S = Allowable stress (kg/cm^2), E = Weld joint efficiency factor.

Design Consideration:

Operating pressure (P) = 45 kg/cm^2, Shell Inside radius (R_i) = 33.5 cm

Allowable stress (S) = 1200 kg/cm^2, Weld joint efficiency factor (E) = 1

3.5 Support Legs Design

Base Plate Design Calculations:

Formula for calculation of Base Plate Length (L_b)

$$\mathbf{L_b} = \frac{\underline{(2 \text{ X } (Ri + T) \text{ X } \sin 60^0 + 50)}}{50}$$

Where

Ri = Inner Radius of Shell (mm),

T = Thickness of Shell (mm),

Design Consideration:

Shell Inside radius (R_i) = 750 mm, Thickness of Shell (T) = 16mm

Formula for calculation of Base Plate Width (W_b)

Base Plate Width (W_b)

$$= \frac{\{[\underline{(Ri+T)}]/50\} \text{X } 50}{2}$$

Center Rib Design Calculations:

Formula for calculation of Center Rib

Center Height from Base (Hc =

$$\frac{\underline{(Ri + T + Wb + 50)} \text{ X } 50}{50}$$

Height of Center Rib (H) =

(Hc – 50) – (Ri + T) Sin 60^0 – 100

Length of Center Rib (L) = **(L_b – 100)**

Side Rib - 1 Design Calculations:

Length of Side Rib (Ls1) – 1 = **(H+ 100)**

Width of Side Rib (Ws1) – 1 = **(W_b – 50)**

Side Rib - 2 Design Calculations:

Length of Side Rib(Ls2) – 2 = **(H+ 100)/2**

Width of Side Rib(Ws1) – 2 = **(W_b – 50)**

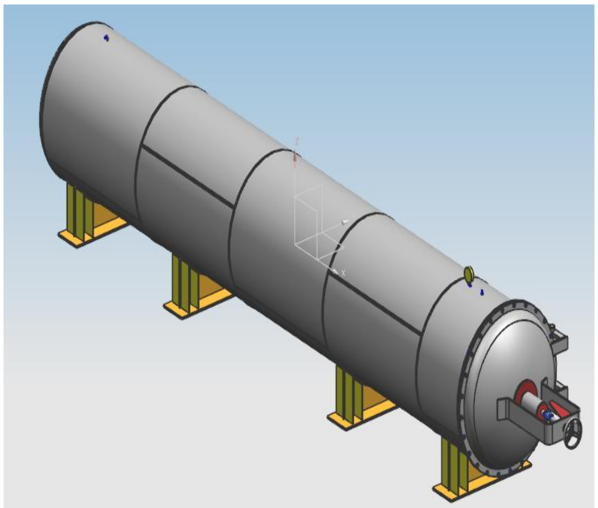

Fig.2. 3D model of a canister testing chamber assembly

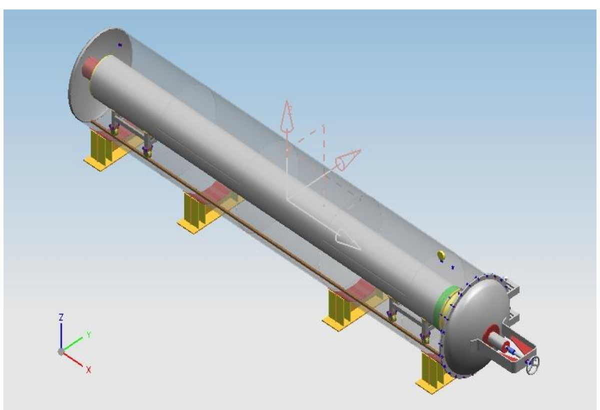

Fig.3. 3D model of a canister and canister testing chamber assembly

4. Finite Element Analysis:

The finite element is a mathematical method for solving ordinary and partial differential equations. Because it is a numerical method, it has the ability to solve complex problems that can be represented in differential equation form. As these types of equations occur naturally in virtually all fields of the physical sciences, the applications of the finite element method are limitless as regards the solution of practical design problems.

Element Type Used:

Shell63 has both bending and membrane capabilities. Both in-plane and normal loads are permitted. The element has six degrees of freedom at each node: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z-axes. Stress stiffening and large deflection capabilities are included. A consistent tangent stiffness matrix option is available for use in large deflection (finite rotation) analysis.

Boundary Conditions

- Base plates are constrained in all degrees of freedom
- Head closure is bolted to chamber using Constraint equations – Simulating bolts
- Internal pressure of 9 bar is applied
- Gravity – 9810 mm/sec^2 is applied to simulate self weight

Meshing Details

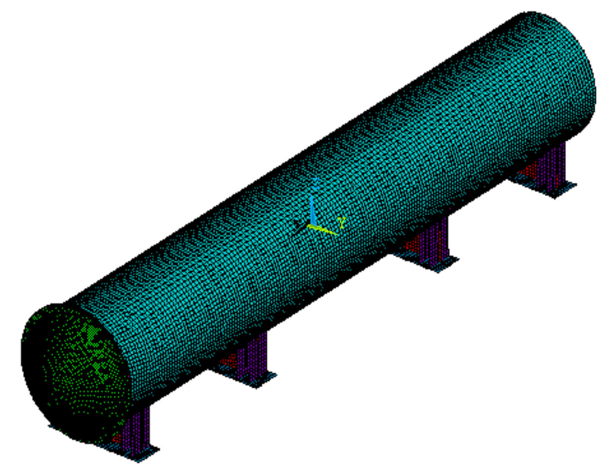

Fig.4. Meshed Finite Element Model of thecanister testing chamber

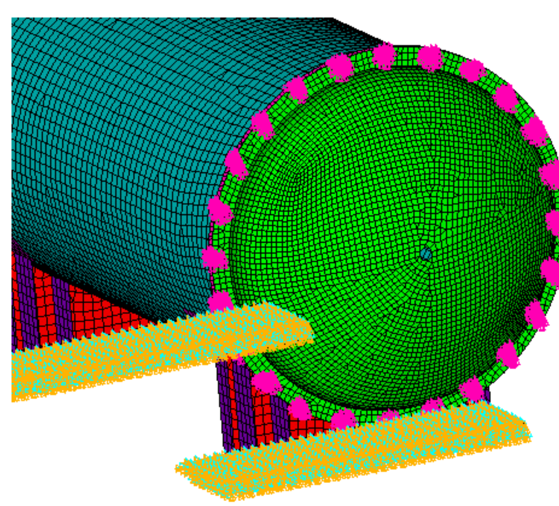

Fig.5. Base plates constrained in all degrees of freedom

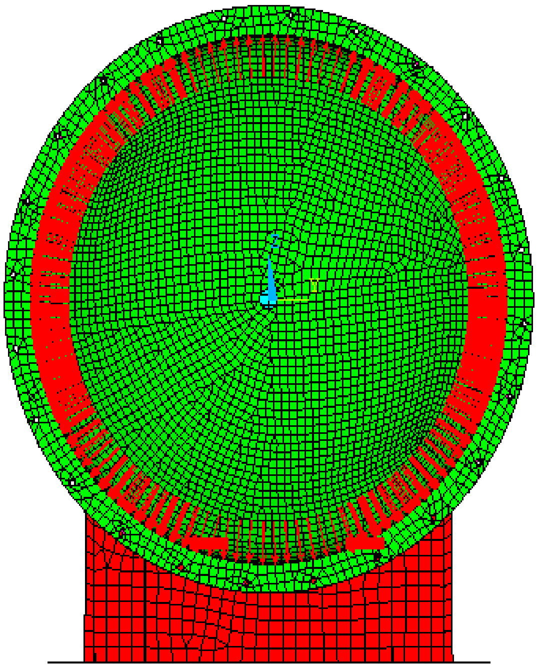

Fig.6. Application of Internal pressure

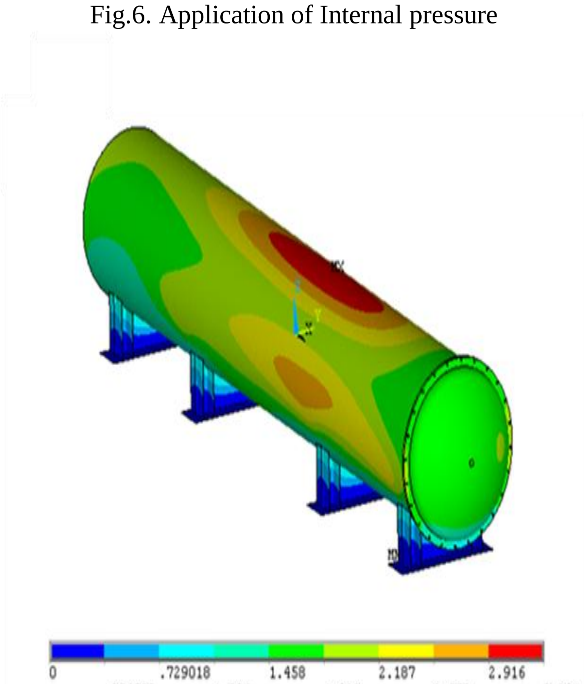

Fig.7 The total deflection of the canister testing chamber

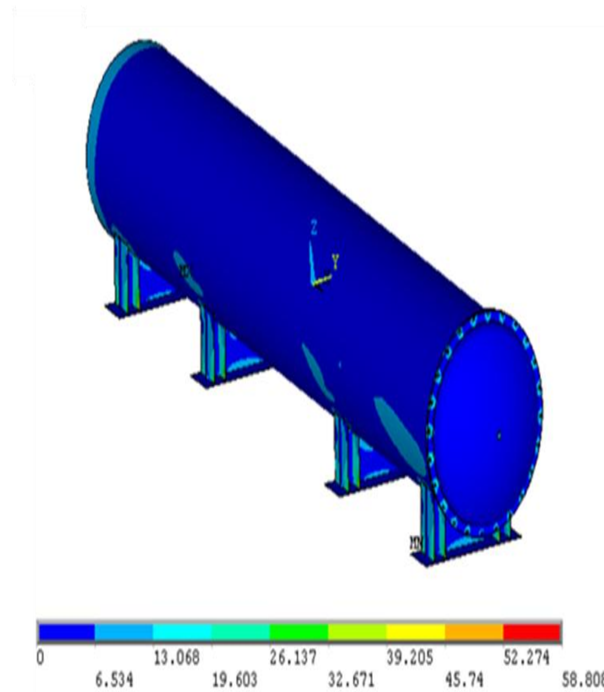

Fig.8. Von Mises Stress on the canister testing chamber

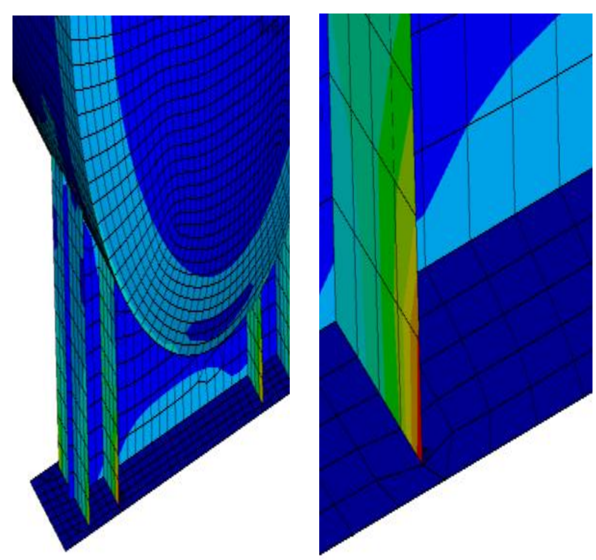

Fig.9. Von Mises Stress on the canister testing chamber support

5. Results:

- The maximum vonMises stress observed on the canister testing chamber is 58 Mpa.
- The maximum deflection observed on the canister testing chamber is 3.2 mm.

- The yield strength of the material used for chassis manufacturing is 260 N/mm^2.

The following graphs shows the relation between strain and the Bolt sizes. Bolt size is represented on X-axis and Strain on Y-axis.

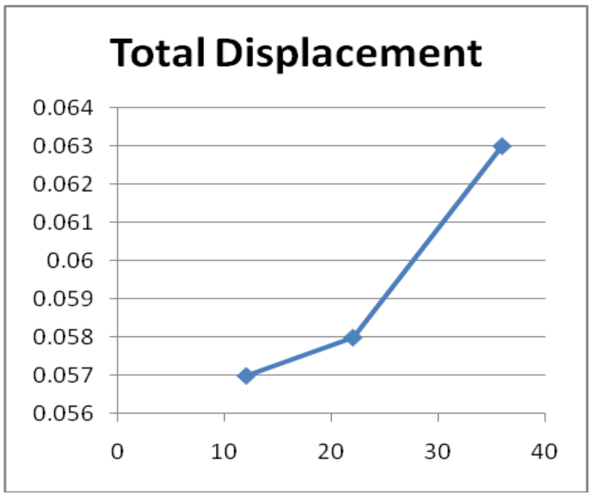

Fig.10 Total Displacement

From the above graph, as the diameter of bolt increases, the strain gradually increases from M12 bolt to M36 bolt size.

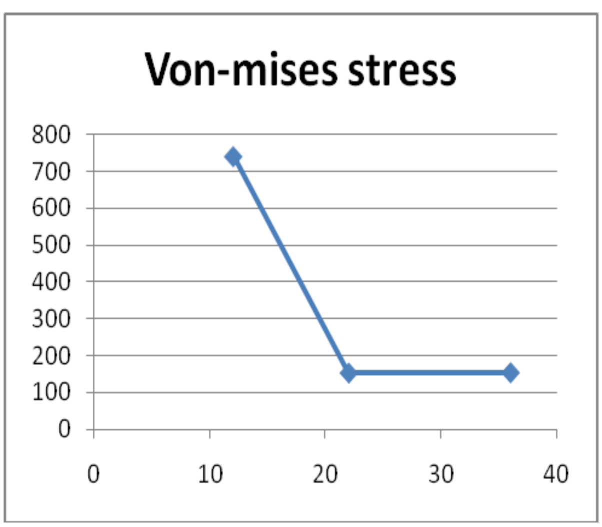

Fig.11 Fig Von – Mises Stress

The Fig.11 shows that the Von-mises stress for M12 Bolt is very high, for M22 bolt stress decreases and again slightly decreases for M36

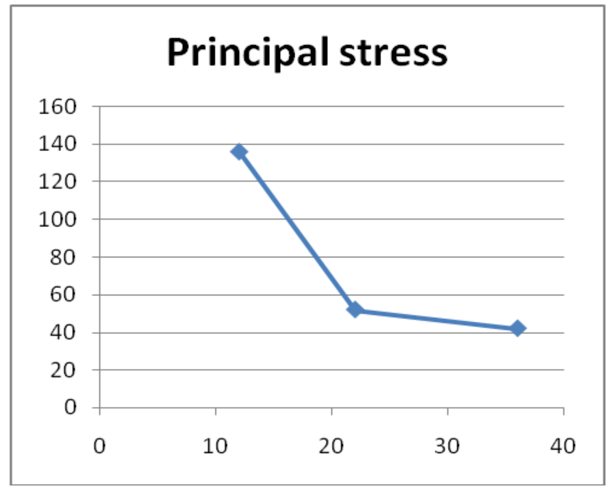

Fig.12 Principal Stress

The above graph shows that the Principal stress for M12 Bolt is very high, for M22 bolt stress decreases and again slightly decreases for M36

6. Conclusions:

- The maximum VonMises stress observed on the canister testing chamber is 58 Mpa.
- The maximum deflection observed on the canister testing chamber is 3.2 mm.
- From the results, it is concluded that the designed horizontal canister testing chamber is safe for the internal pressure of 45 kg/cm^2

7. References

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