DESIGN AND ANALYSIS OF MODERN MISSILE CANISTER TESTING CHAMBER

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ABSTRACT

Missiles are self-propelled, precision guided and also well-constructed machines. Because of their size and weight handling or transporting them is very difficult and risky. Most of the missiles are damaged due to carelessness and poor handling practices. To reduce the damage of missiles they are shipped, stored and handled with special equipment called canisters. These canisters are also used to launch, transport and store the missiles. During the launch and transport of the missiles, these canisters are subjected to external pressures and vibrations respectively. So, it is very important that these canisters are tested for the above said loads. These canisters are tested using canister testing chambers. The canister is placed inside the canister testing chamber and it is pressurized with water or air. The internal and external pressure testing of the canister is done by closing the canister both ends by dummy dished ends. Because of this reason, Canister testing Chamber is one of the most critical components in Defense Organization. The canister testing chamber design proposed is an externally ring stiffened structural shell with dogged lids that open for canister launch during testing. The canister testing chamber is approximately 1.8 meters outside diameter and 12 meters long and weighs approximately 14.5 tonnes. In the present work the design of Canister testing chamber is done and its model is prepared by using Unigraphics software. The testing is performed on the chamber by using ANSYS package for the natural free vibrations during transportation and also testing is done with specified pressure to withstand.

KEYWORDS

Approved Canisters, Launch, Transport, Store, Unigraphics and ANSYS.

INTRODUCTION

The canister testing chamber design proposed is an externally ring stiffened structural shell with dogged lids that open for canister launch during testing.[1] The canister testing chamber is approximately 1.8 meters outside diameter and 12 meters long and weighs approximately 14.5 tonnes. During launching of the missile, the canister is subjected to internal pressure of 1176 MPa. The canister is carried horizontally inside the testing chamber and supported by trunnion and latch at 3 points.

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. One of the sides dished end is provided with screw rod 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 1176 MPa 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 two 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. Two 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.

As per the Purpose of Design, the Canister Testing Chamber Assembly is classified into 3 Subsystems

- Canister Testing Chamber design.
- Dogged lids design.
- Support legs design.

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.

1.1 Components Used in Canister Testing Chamber

1. Canister Testing Chamber shells.
2. Canister dished ends.
4. Bolts.
5. Pressure gauges.

1.1.1 Chamber Shells/Pressure Vessels

A pressure vessel is a closed container designed to hold gases or liquids at a pressure substantially different from the ambient pressure. A pressure vessel is defined as a vessel in which the pressure is obtained from an indirect source or by the application of heat from an indirect source or a direct source. The vessel proper terminates at (a) the first
cumferential joint for welded end connections; (b) the face of the first flange in bolted flange connections; or (c) the first threaded joint in threaded connections." Pressure vessels include but are not limited to compressed gas storage tanks (i.e. air, oxygen, nitrogen tanks, etc.), anhydrous ammonia tanks, \textsuperscript{6}hydropneumatic tanks, autoclaves, hot water storage tanks, chemical reactors and refrigerant vessels, designed for a pressure greater than 15 psi and a volume greater than 5 cubic feet in volume or one and one-half cubic feet in volume with a pressure greater than 600 psi.

Pressure vessels can theoretically be almost any shape, but shapes made of sections of spheres, cylinders and cones are usually employed. A common design is a cylinder with end caps called heads. Head shapes are frequently either hemispherical or dished (Torispherical). More complicated shapes have historically been much harder to analyze for safe operation and are usually far more difficult to construct.

Theoretically, a spherical pressure vessel has approximately twice the strength of a cylindrical pressure vessel\textsuperscript{1}\textsuperscript{1}\textsuperscript{1}\textsuperscript{1} However, a spherical shape is difficult to manufacture and therefore more expensive, so most pressure vessels are cylindrical with 2:1 semi-elliptical heads or end caps on each end. Smaller pressure vessels are assembled from a pipe and two covers. A disadvantage of these vessels is that greater breadths are more expensive, so that for example the most economic shape of a 1,000 liters (35 cu. ft.), 250 bars (3,600 psi) pressure vessel might be a breadth of 914.4 millimetres (36 in) and a width of 1,701.8 millimetres (67 in) including the 2:1 semi-elliptical domed end caps.

If we draw a comparison between iron and steel, we find steel in many ways even better than iron. Steel may not be as strong as iron is, but it is far more resistant and does not corrode and gets rusted like iron does. And that is the reason it is used in the making of drills and tools and power saws. The hardness and rigidity of high speed steel depends on the metal used in the making of the alloy and its percentage of composition in it. Basically, this steel is used in the making of tools that cut other metals.

Carbon Steels, which can include High Carbon Steel and High Alloy Steel, are the softest and usually the cheapest of the seven types we offer. Many woodworking tools are made from this material. Many craftsmen like Carbon Steel, because the tools are soft enough to sharpen with a file. Virtually any woodworking tool can be found in a carbon steel version. Some woodworking tools are only available in Carbon Steel or Carbide Tipped, because it is too difficult to make them from anything else or they would be too expensive. If you are cutting softwood or just a few holes in hardwoods or plastics, Carbon Steel is your answer. If you have a lot of holes to cut in a hard material, you may want to choose a better grade of steel. The tools we manufacture from Carbon Steel are heat treated to 62% hardness and cannot be sharpened with a file. A stone type of grinding wheel is required to resharpen them.

\subsection*{1.2 MATERIALS OF CANISTER TESTING CHAMBER

\subsection*{1.2.1 Types of Steel and Uses}

Steel is basically an alloy of iron and carbon with a small percentage of other metals such as nickel, chromium, aluminium, cobalt, molybdenum, tungsten, etc. Steel is a hard ductile and malleable solid and is probably the most solid material after plastic and iron.
High Speed Steel, sometimes abbreviated to HSS, comes in various different grades generally used in the metalworking industry to make drills, end mills, turning tools and other tools designed specifically to cut metal. In woods and plastics, all grades of HSS far outlast the cheaper Carbon Steel or Stainless Steel. The various grades of HSS we use are identified by M1, M2, M7 and M50, M1 being the most expensive grade. Very few woodworking tools are made from HSS. It is too expensive to use for large tools, very tough to machine and can be subject to breakage with rough treatment in handheld equipment. M1 is the hardest and also the most brittle of the bunch. You cannot have your cake and eat it too! We use M1, M2 and M7 for applications when better tool life is required and breakage is not a problem. M50 is used when breakage could be an issue. Tools made of High Speed Steel will always have HS or HSS stamped or etched on them. Do not be fooled by imitations. We recommend HSS for most applications because the tools are reasonably priced, last a long time in woods and plastics and have more sizes and lengths available than any other type of material. However, if you are cutting thousands of holes in hard materials, you need some type of Carbide Tooling. Sharpening HSS tools requires a grinding wheel made of stone or one that is Borazon plated.

Cobalt Steel is very similar to High Speed Steel. Its identifier is M40CO or M42. Most drills made of Cobalt have a brownish gold tint and are marked with their identifier. Cobalt is a step up from HSS and offers better tool life than HSS. Since Cobalt is harder and therefore more brittle than HSS, Cobalt drills usually have a more rugged construction with less room for chips to escape in the flute area. Although they work great cutting materials like stainless steel and cast iron, they do not work well in wood or plastics because they do not clear chips well. In an application in which a good grade of HSS Drill cut 2000 holes before becoming dull, a Cobalt Drill might cut 2200 holes before dulling. Sharpening Cobalt Steel tools requires a grinding wheel made of stone or one that is Borazon plated.

Cobalt Tipped is the material of choice for tools used in high production applications. The Carbide is super hard, resharpenable and replaceable. Carbide can cut faster at higher spindle speeds, because it is impervious to the heat produced by those speeds. Since Carbide is extremely hard, it is also extremely brittle. This is especially true in the case of woodworking tools. The slightest contact with another metal object could cause the Carbide to chip. Although some grades of Carbide are designed to work well in metals and cement, the type found on woodworking tools in not. The Carbide Tips are usually brazed to the cutting edges of tools made of softer materials like Carbon Steel. Sharpening Carbide Tipped tools requires Diamond plated grinding wheels.

Among these material IS: 2062 steel has been selected for canister manufacturing.

IS: Properties 2062 grade Plates may supply steel plate, coils, sheet and strip of various material and sizes, details are listed in Table 1.1:

<table>
<thead>
<tr>
<th>Grade</th>
<th>C% Max.</th>
<th>Mn% Max.</th>
<th>S% Max.</th>
<th>P% Max.</th>
<th>Si% Max.</th>
<th>C.E.% Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.23</td>
<td>1.50</td>
<td>0.050</td>
<td>0.050</td>
<td>0.40</td>
<td>0.42</td>
</tr>
<tr>
<td>B</td>
<td>0.22</td>
<td>1.50</td>
<td>0.045</td>
<td>0.045</td>
<td>0.40</td>
<td>0.41</td>
</tr>
<tr>
<td>C</td>
<td>0.20</td>
<td>1.50</td>
<td>0.040</td>
<td>0.040</td>
<td>0.40</td>
<td>0.39</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grade</th>
<th>UTS (MPa) Min.</th>
<th>Y.S. (MPa) Min.</th>
<th>EL% Min. 5.65 Sqrt (So)</th>
<th>Bend Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>410</td>
<td>250</td>
<td>240</td>
<td>23</td>
</tr>
<tr>
<td>B</td>
<td>410</td>
<td>250</td>
<td>240</td>
<td>23</td>
</tr>
<tr>
<td>C</td>
<td>410</td>
<td>250</td>
<td>240</td>
<td>23</td>
</tr>
</tbody>
</table>

Table 1.2.2: Chemical Composition and Mechanical Properties of Steel (Indian Standard)

- **Canister Dished Ends**
  Dishes are generally used to close the ends of canister chamber.

  Generally, they are two types:
  1. Fixed type dishes,
  2. Clamped type dishes.

- **Fixed Type Dishes**
  In this type, dishes welded to canister chamber for providing to prevent leakage of pressure.

- **Clamped Type**
  In this type, dishes are used to open or close the canister chamber through clamps and it acts as a Door to loading and unloading of missile. Clamped type dishes are fastened by using bolts, bolts also play a major role in designing of canister chamber. For this application M12, M22&M36 bolts are analysed. Properties of these bolts are shown below.

- **Definition of Bolt**
  Bolts are defined as headed fasteners having external threads that meet an exacting uniform bolt thread specification (such as M, MJ, UN, UNR and UNJ), such that they can accept a non tapered nut.

- **Preferred Diameters**
  Preferred nominal diameters for bolts and threaded rod are as listed below. The fourth series listed below should be limited to unusual requirements when none of the preceding series can be used. Reference individual standards prior to specification. Sizes 5 to 45 are commonly used in construction.

  1. **First choice:** M2 2.5 3 4 5 6 8 10 12 16 20 24 30 36 42
  2. **Second choice:** M3.5 4 14 18 22 27 33 39 45
  3. **Third choice:** M15 17 25 40
  4. **Avoid:** M7 9 11 26 28 32 35 38
II. DESIGN CALCULATIONS OF CANISTER TESTING CHAMBER

2.1 Design Formulas

The design formulas used in the method are based on the principal stress theory. 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. As shown below various formulas used to calculate the wall thickness for numerous canister testing chamber geometries.

2.1.1 Shell Design Calculations for external pressure

Formulas for calculation of cylindrical shell thickness

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

Where
\[ t_1 = \text{Minimum required thickness (mm)} \]
\[ P = \text{Operating pressure (MPa)} \]
\[ R_i = \text{Shell Inside radius (mm)} \]
\[ S = \text{Allowable stress (MPa)} \]
\[ E = \text{Weld joint efficiency factor} \]

- **Inputs**
  - Operating pressure \( P \) = 1.176798 MPa
  - Shell Inside radius \( R_i \) = 950 mm
  - Allowable stress \( S \) = 250 MPa
  - Weld joint efficiency factor \( E \) = 0.6

\[ t_1 = \frac{1.176798 \times 950}{(0.96 - 0.6 \times 250)} = 16 \text{mm} \]

Minimum required thickness \( t_1 \) = 7.0935mm

As per BIS Standard nominal thickness considered

\[ t_1 = 16 \text{mm} \]

Milling tolerance (\( m \)) = 0.06xt = 0.96mm

Modification in weld portion (\( w \)) = 1.5 + if (\( t < 12 \)) 0.6 else 0.8

(Checking Only One side welding with no backup plate)

\[ w = 2.3 \text{mm} \]

Bending Tolerance (\( b \)) = 0.002t

(Considered at 0.2% of the Nominal Thickness)

\[ b = 0.032 \text{mm} \]

Final Thickness of canister Testing chamber

\[ t_1 = t_1 + m + w + b + CA \]

\[ t_1 = 11.382 \text{mm} \]

As per BIS Final Standard Thickness

\[ t_2 = 16 \text{mm} \]

2.1.2 Dished End-1 Design Calculations

Formulas for calculation of Dished End Thickness

\[ t_2 = \frac{PR_i}{(SE - 0.6P)} \]

Where
\[ t_2 = \text{Minimum required thickness (mm)} \]
\[ P = \text{Operating pressure (MPa)} \]
\[ R_i = \text{Shell Inside radius (mm)} \]
\[ S = \text{Allowable stress (MPa)} \]
\[ E = \text{Weld joint efficiency factor} \]

- **Inputs**
  - Operating pressure \( P \) = 1.176798 MPa
  - Shell Inside radius \( R_i \) = 950 mm
  - Allowable stress \( S \) = 250 MPa
  - Weld joint efficiency factor \( E \) = 0.6

\[ t_2 = \frac{1.176798 \times 950}{(0.96 - 0.6 \times 250)} = 16 \text{mm} \]

Minimum required thickness \( t_2 \) = 7.4452 mm

2.1.3 Dished End-2 Design Calculations

Formulas for calculation of Dished End Thickness

\[ t_3 = \frac{PR_i/W}{(SE - 0.2P)} \]

Where
\[ t_3 = \text{Minimum required thickness (mm)} \]
\[ P = \text{Operating pressure (MPa)} \]
\[ R_i = \text{Shell Inside radius (mm)} \]
\[ S = \text{Allowable stress (MPa)} \]
\[ E = \text{Weld joint efficiency factor} \]

- **Inputs**
  - Operating pressure \( P \) = 1.176798 MPa
  - Shell Inside radius \( R_i \) = 950 mm
  - Allowable stress \( S \) = 250 MPa
  - Weld joint efficiency factor \( E \) = 1

\[ t_3 = \frac{1.176798 \times 950}{(0.833 - 0.2 \times 250)} = 2.3 \text{mm} \]

Dished end factor \( W \) = 0.25 x (3 + \sqrt{\frac{R_i}{0.1R_i}})

\[ W = 0.833 \]

Minimum required thickness \( t_3 \) = 1.852 mm

2.1.4. Shell Design Calculations for internal pressure

Cylindrical shell Thickness

\[ t_4 = \frac{PR_i}{(SE - 0.6P)} \]
Where
\( t_4 = \) Minimum required thickness (mm)
\( P = \) Operating pressure (MPa)
\( R_i = \) Shell Inside radius (mm)
\( S = \) Allowable stress (MPa)
\( E = \) Weld joint efficiency factor

**Inputs:**
- Operating pressure (P) = 45 MPa
- Shell Inside radius (Ri) = 335 mm
- Allowable stress (S) = 250 MPa
- Weld joint efficiency factor (E) = 1

Min. required thickness (mm) = \( 45 \times 335 \times \frac{1}{250X1-0.6X45} = 1.28 \text{ cm} \)

Milling tolerance (m) = 0.06x1 = 1.2 mm
Modification in weld portion (w) = 1.5 + if (t<12)0.6 else 0.8
(Considering Only One side welding with no backup plate)

<table>
<thead>
<tr>
<th>Input</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Standard nominal thickness</td>
<td>12.8 mm</td>
</tr>
<tr>
<td>Bending Tolerance</td>
<td>0.002t</td>
</tr>
<tr>
<td>Final Thickness(t4)</td>
<td>20 mm</td>
</tr>
</tbody>
</table>

Margin = 2.6
Final Standard Thickness with Margin = 20 mm

III. MODELLING OF CANISTER TESTING CHAMBER

3.1 Model of A Canister Testing Chamber

Canister Testing Chamber has been designed and optimized for vibration control and internal pressures. Canister Testing Chamber is a structural frame used to test the canister used to store and launch the missiles. The function of the Canister Testing Chamber is to house the canister and test it for the internal pressure; 3D modelling software (UNIGRAPHICS NX) was used for designing and analysis software (ANSYS) was used for structural analysis.

The Methodology followed in my Project is as follows:
- Perform the Design calculations of the Canister Testing Chamber.
- Perform internal pressure analysis and documents the deflections and stresses.
- Perform Modal analysis to find natural frequencies on the original model of the Canister Testing Chamber.
- Optimize the original model (Iterative method) to shift the natural frequencies above the operating frequency of Canister Testing Chamber by changing design stiffness.
- Perform internal pressure analysis on the optimized model and documents the deflections and stresses.
- Perform Power Spectral Density analysis (PSD) on the optimized model to find the effect of all the frequencies present below the operating frequency range of Canister Testing Chamber in X, Y and Z direction.
The finite element method has become a powerful tool for the numerical solution of a wide range of engineering problems. It has developed simultaneously with the increasing use of high-speed electronic digital computers and with the growing emphasis on numerical methods for engineering analysis.

4.1 Material Properties of the Canister Testing Chamber:

The material used for the construction of canister testing chamber is IS 2062 grade steel. The mechanical properties are mentioned below:

- Young's Modulus (E) = 200 GPa
- Poisson's Ratio = 0.3
- Density = 7880 Tons/m³
- Yield Strength = 250 MPa

4.2 Element Type Used: Shell 63 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) analyses.

4.3 Shell 63 Input Data: The geometry, node locations and the coordinate system for this element are shown in Figure “SHELL63 Geometry.”

For certain non-homogeneous or sandwich shell applications, the following real constants are provided: RMI is the ratio of the bending moment of inertia to be used to that calculated from the input thicknesses. RMI defaults to 1.0. CT0P and CB0T are the distances from the middle surface to the extreme fibers to be used for stress evaluations. Both CT0P and CB0T are positive, assuming that the middle surface is between the fibers used for stress evaluation. If not input, stresses are based on the input thicknesses. ADMSUA is the added mass per unit area.

IV. STATIC AND DYNAMIC ANALYSIS OF CANISTER TESTING CHAMBER

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.
a. **Meshing Details:** The canister testing chamber is meshed using shell 63 element type. It is a quad 4 node element. Thickness is given as the real constant. The thickness of the chamber is given as 20mm. Total number of elements created is 10223 and the number of nodes created are 11527. The mesh model of the canister testing chamber is shown below.

![Mesh Model of Canister Testing Chamber](image1)

**Fig. 4.3:** Shows the Boundary Conditions and Loading Applied on Canister Testing Chamber

**4.4 Static Pressure Analysis:** Static analysis is carried out on the canister testing chamber to check the structure behaviour due to an internal pressure of 1.176 MPa. The boundary conditions used for the internal pressure analysis is shown below.

**Boundary Conditions used for Static Analysis**
1. Legs are constrained in all degrees of freedom
2. Dog lids are connected using mesh connectivity.
3. Internal pressure of 1.176 MPa is applied.

**RESULTS OF THE STATIC PRESSURE ANALYSIS**
- **Total Deflection (Usum):** Maximum Deflection of 4.28mm is observed on the canister testing chamber.

![Total Deflection Observed on the Testing Chamber](image2)

**Fig. 4.4:** Total Deflection Observed on the Testing Chamber

- **Von Mises:** Maximum Von Mises stress of 194 Mpa observed on the Testing Chamber

![Von Mises Stress on the Testing Chamber](image3)

**Fig. 4.5:** Total Deflection Observed on the Testing Chamber in Isometric View

- **Von Mises Stress on the Testing Chamber**

![1st Principal Stress on the Testing Chamber](image4)

**Fig. 4.6:** 1st Principal Stress on the Testing Chamber

From the above analysis, it can be observed that the maximum deflection is 4.5mm and the maximum Von Mises stress is 195MPa. The yield strength of the material is 250 MPa. From the above analysis it can be concluded that the canister testing chamber is safe for the internal pressure of 1.176MPa.

**4.5 Dynamic Analysis (Modal Analysis)**

Modal analysis is used to determine the natural frequencies and mode shapes of a structure. They are also required if we want to do a spectrum analysis or a mode superposition harmonic or transient analysis. You can choose from several mode-extraction methods: Block Lanczos, subspace, PCG Lanczos, reduced, unsymmetric, damped and QR damped. The
damped and QR damped methods allow you to include damping in the structure.

Modal analysis was carried out to determine the natural frequencies and mode shapes of a structure in the frequency range of 0-150Hz. Block Lanczos mode-extraction methods is used to extract the frequencies and mode shapes. The total mass of the testing chamber considered for analysis is 14 tonnes.

From the above results it can be observed that there exists 1 critical frequency in X, Y and Z directions. The critical frequencies are 135Hz in X-Direction, 36Hz in Y-Direction and 15Hz in Z-Direction. These frequencies are critical because the mass participation is very high in these frequencies. The mass participations of critical frequencies are given below.

4.6. Static Pressure Analysis on the Model
Static analysis is carried out on the modified canister testing chamber to check the structure behaviour due to an internal pressure of 1.176MPa. The boundary conditions used for the internal pressure analysis is shown below.

Boundary Conditions used for Static Analysis
1. Legs are constrained in all degrees of freedom.
2. Dog lids are connect using mesh connectivity.
3. Internal pressure of 1.176MPa is applied.

4.7 Results of the Static pressure analysis
- Total Deflection (Usum): Maximum Deflection of 2.5mm is observed on the canister testing chamber.
From the above analysis it can be observed that the maximum deflection is 2.5mm and the maximum Von Mises stress is 160 MPa. The yield strength of the material is 250 MPa. From the above analysis it can be concluded that the canister testing chamber is safe for the internal pressure of 1.176 MPa.

4.8 Modal Analysis of Canister Testing Chamber

Modal analysis was carried out on the model to determine the natural frequencies and mode shapes of a structure in the frequency range of 0 - 150 Hz. Block Lanczos mode extraction methods are used to extract the frequencies and mode shapes. Eigen values and their mass participations in all the three directions in the range 0 - 150 Hz are listed in the Table 4.1.

<table>
<thead>
<tr>
<th>MODE</th>
<th>FREQUENCY (Hz)</th>
<th>PARTICIPATION FACTOR</th>
<th>EFFECTIVE MASS (kg)</th>
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<td></td>
<td>X-Dir</td>
<td>Y-Dir</td>
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</tbody>
</table>

Table 4.8: Modal Analysis Values

4.9 Mode Shapes of the Canister Testing Chamber

![Fig. 4.14: 1st and 2nd Mode Shapes @17.8 and 42.2Hz Respectively](image-url)
Fig. 4.15: 3rd and 4th Mode shapes @53 and 57Hz Respectively

Fig. 4.16: 5th and 6th Mode shapes @76 and 80Hz Respectively

Fig. 4.17: 7th and 8th Mode shapes @86 and 94Hz Respectively

Fig. 4.18: 9th and 10th Mode shapes @100 and 109Hz Respectively
Fig 4.19: 11th and 12th Mode shapes @ 121 and 122 Hz Respectively

Fig 4.20: 13th and 14th Mode shapes @ 126 and 131 Hz Respectively

Fig 4.21: 15th and 16th Mode shapes @ 133 and 140 Hz Respectively

Fig 4.22: 17th and 18th Mode shapes @ 145 and 149 Hz Respectively
From the above analysis results, it is observed that the critical modes present in the original model are shifted out of the frequency zone of 0-150Hz due to the changes implement. Random vibration analysis is performed on the modified canister testing chamber to check the structure behaviour due to random loading.

4.9 Power Spectrum Density (PSD) Analysis

A Random Vibration Analysis is a form of Spectrum Analysis

- The spectrum is a graph of spectral value versus frequency that captures the intensity and frequency content of time-history loads.
- Random vibration analysis is probabilistic in nature, because both input and output quantities represent only the probability that they take on certain values. Random Vibration Analysis uses Power spectral density to quantify the loading.
- A PSD spectrum is a statistical measure of the response of a structure to random dynamic loading conditions. It is a graph of the PSD value versus frequency, where the PSD may be a displacement PSD, velocity PSD, acceleration PSD or force PSD. Mathematically, the area under a PSD versus-frequency curve is equal to the variance.

- **PSD Analysis along X-direction**
  PSD analysis is carried out on modified model of canister testing chamber with base excitation in X direction from 0-150Hz to observe the structure behavior due to random vibrations.

**Boundary Conditions:**
Functional vibration levels – PSD:

<table>
<thead>
<tr>
<th>Random</th>
<th>g2/Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>0.003</td>
</tr>
<tr>
<td>10</td>
<td>0.02</td>
</tr>
<tr>
<td>135</td>
<td>0.02</td>
</tr>
<tr>
<td>150</td>
<td>0.001</td>
</tr>
</tbody>
</table>

*Table 4.9.1 Shows the Spectral Values Vs Frequency for PSD Analysis*

- **Results-Von Mises Stress:**
  The maximum 1 sigma Stress observed is 48 MPa.
  The maximum 3 sigma Stress observed is 144 MPa.
  This implies that only 0.3% of the time the Canister Testing Chamber stress reaches 144 MPa.

- **Results-Total Deflection:**
  The maximum 1 sigma deflection observed is 0.47 mm.
  The maximum 3 sigma deflection observed is 1.41 mm.

This implies that only 0.3% of the time the Canister Testing Chamber deflection reaches 1.41mm.
Fig. 4.27: Von Mises Stress of Legs of Testing Chamber for PSD in X-Dir

Fig. 4.28: PSD-X Response on Legs of chamber in Linear and Logarithmic Scale

Fig. 4.29: PSD-X Response on Shell of Chamber in Linear and Logarithmic Scale

Fig. 4.30: PSD-X Response on Dogged lids of Chamber in Linear and Logarithmic Scale

From the above Graphs it is seen that
- Maximum PSD response on the legs is 1.1g²/Hz at a frequency of 126Hz
- Maximum PSD response on the shell is 16g²/Hz at a frequency of 100.6Hz
- Maximum PSD response on the dogged lids is 8.5g²/Hz at a frequency of 100.6Hz

The Yield strength of the material Steel (IS: 2062 grade) is 250 N/mm². From the above analysis the maximum 3 sigma stress observed is 144 N/mm². From the above results and it can be concluded the Modified Canister Testing Chamber assembly is safe for the random vibrations in X-direction.

- **PSD Analysis along Y-direction**
  PSD analysis is carried out on modified model of canister testing chamber with base excitation in Y direction from 0-150Hz to observe the structure behavior due to random vibrations.

**Boundary Conditions**
Functional vibration levels – PSD:

<table>
<thead>
<tr>
<th>Random</th>
<th>g²/Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>0.003</td>
</tr>
<tr>
<td>10</td>
<td>0.02</td>
</tr>
<tr>
<td>135</td>
<td>0.02</td>
</tr>
<tr>
<td>150</td>
<td>0.001</td>
</tr>
</tbody>
</table>

*Table 4.9.2: Shows the Spectral Values Vs frequency for PSD Analysis*
Boundary Conditions

![Boundary Conditions](image)

**Fig. 4.31: Boundary Conditions used for PSD in Y-dir Testing Chamber**

Results - Total Deflection:
The maximum 1 sigma deflection observed is 1.58mm.
The maximum 3 sigma deflection observed is 4.74mm. This implies that only 0.3% of the time the Canister Testing Chamber deflection reaches 4.74mm.

![Total Deflection of Testing Chamber for PSD in Y-dir](image)

**Fig. 4.32: Total Deflection of Testing Chamber for PSD in Y-dir**

Results - Von Mises Stress:
The maximum 1 sigma Stress observed is 29.4MPa. The maximum 3 sigma Stress observed is 88.2MPa. This implies that only 0.3% of the time the Canister Testing Chamber stress reaches 88.2MPa.

![Von Mises Stress of Testing Chamber for PSD in Y-dir](image)

**Fig. 4.34: Von Mises Stress of Testing Chamber for PSD in Y-dir**

![Von Mises Stress of Legs of Testing Chamber for PSD in Y-dir](image)

**Fig. 4.35: Von Mises Stress of Legs of Testing Chamber for PSD in Y-dir**
From the above graphs it is seen that

- Maximum PSD response on the legs is 0.33g²/Hz at a frequency of 42Hz.
- Maximum PSD response on the shell is 19g²/Hz at a frequency of 42Hz.
- Maximum PSD response on the dogged lids is 7.5g²/Hz at a frequency of 80Hz.

The Yield strength of the material Steel (IS:2062 grade) is 250 N/mm². From the above analysis the maximum 3 sigma stress observed is 88.2 N/mm². From the above results and it can be concluded the Modified Canister Testing Chamber assembly is safe for the random vibrations in Y-direction.

- PSD analysis along Z-direction

PSD analysis is carried out on modified model of canister testing chamber with base excitation in Z direction from 0-150Hz to observe the structure behavior due to random vibrations.

<table>
<thead>
<tr>
<th>Random</th>
<th>g²/Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>0.003</td>
</tr>
<tr>
<td>10</td>
<td>0.02</td>
</tr>
<tr>
<td>135</td>
<td>0.02</td>
</tr>
<tr>
<td>150</td>
<td>0.001</td>
</tr>
</tbody>
</table>

*Table 4.9.3: Shows the spectral values Vs frequency for PSD analysis (Z)*
• Results- Total Deflection
The maximum 1 sigma deflection observed is 5.07mm.
The maximum 3 sigma deflection observed is 15.21mm.
This implies that only 0.3% of the time the Canister Testing Chamber deflection reaches 15.2mm.

Fig. 4.40: Total Deflection of Testing Chamber for PSD in Z-dir

Fig. 4.41: Total Deflection of Legs and Chamber Shell of Testing Chamber for PSD in Z-directions

• Results-Von Mises Stress
The maximum 1 sigma Stress observed is 53.3MPa.
The maximum 3 sigma Stress observed is 159.9MPa.
This implies that only 0.3% of the time the Canister Testing Chamber stress reaches 159.9MPa.

Fig. 4.42: Von Mises Stress of Testing Chamber for PSD in Z-Dir
From the above graphs it is seen that,
- Maximum PSD response on the legs is 0.0032 g²/Hz at a frequency of 109Hz.
- Maximum PSD response on the shell is 75 g²/Hz at a frequency of 17.8Hz.
- Maximum PSD response on the dogged lids is 21 g²/Hz at a frequency of 17.8Hz.

The Yield strength of the material Steel (IS: 2062 grade) is 250 N/mm². From the above analysis the maximum 3 sigma stress observed is 159.9 N/mm². From the above results and it can be concluded the Missile Modified Canister Testing Chamber assembly is safe for the random vibrations in Z-direction.
V. RESULTS AND DISCUSSIONS

Canister Testing Chamber was studied for 3 different cases for the original model:
- Pressure Analysis
- Modal Analysis
- Power Spectrum Density analysis

The following observations were made from the modal analysis of the original model:

[16] From the modal analysis on the original model it is observed that there exist 3 critical natural frequencies in the operation frequency range of 0-150Hz. It is necessary to shift these natural frequencies above the operating range of 0-150Hz to protect the Canister Testing Chamber assembly structure from vibrations.

From the above analysis, it is concluded that the Canister Testing Chamber requires some changes. These changes are implemented in the model and Pressure Analysis, Modal Analysis, Power Spectrum Density analysis were carried out to check the frequencies and temperature.

The following observations are made on the Canister Testing Chamber. It is observed that the critical natural frequencies in the operation frequency range of 0-150Hz were shifted to above 150Hz due to the changes implemented.

VI CONCLUSIONS AND FUTURE SCOPE OF WORK

In this work Canister Testing Chamber has been designed and optimized for vibration control and internal pressures. For validating the theoretical values Power Spectrum Density analysis has been carried out using ANSYS software.

From the above analysis, it is concluded that the critical natural frequencies in the operation frequency range of 0-150Hz were shifted to above 150Hz due to the changes implemented as shown in the report. Therefore, it is concluded that the Canister Testing Chamber is safe under the given operating conditions.

- FUTURE SCOPE OF WORK

During transportation Canister Testing Chamber is subjected to shock loads. Shock analysis has to be carried out to check the structure behaviour in X, Y and Z directions. Canister Testing Chamber has to be shock resistant and resilient to vibration as these are one of its factors of failure.

Transient analysis would be the main analysis where the shock loading can be simulated onto the Canister Testing Chamber. The transient simulation has to be divided into two separate load steps:
1. Initial condition - 1g load at 1e-5 sec
2. Shock pulse - 20g load at 18e-3 sec

A full transient dynamic analysis can be used as calculation for obtaining the more accurate values when compared to those obtained by the Reduced or Modal Superposition methods. However, this calculation method would be very expensive, meaning it would take a lot more time and computational resource.

REFERENCES