DESIGN AND ANALYSIS OF CANISTER TESTING CHAMBER

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ABSTRACT

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 14.5Tonnes. During launching of the missile, the canister is subjected to internal pressure of 1.176Mpa.The canister is carried horizontally inside the testing chamber and supported by trunion and latch at 3 points.The project comprises of design and analysis of the Canister testing chamber. The testing chamber has to be designed to withstand for an internal pressure of 1.176MPa. The project also includes the study of testing chamber for random vibrations which develop during transportation. Unigraphics software is used for modeling the Canister testing chamber, and ANSYS software is used for finite element analysis.

The project elucides in detail the methodology adopted for the analysis of Canister Testing Chamber.

1. INTRODUTION

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 14.5tonnes. During launching of the missile, the canister is subjected to internal pressure of 1.176Mpa.The canister is carried horizontally inside the testing chamber and supported by trunion and latch at 3 points.

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

2. COMPONENTS USED IN CANISTER TESTING CHAMBER:

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

3. PROBLEM DEFINITION AND METHODOLOGY

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 modeling 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.

4.DESIGN CONSTRAINTS AND MODELLING

4.1 3D MODEL OF A CANISTER TESTING CHAMBER

The steps involved while developing the 3D model of a canister testing chamber:

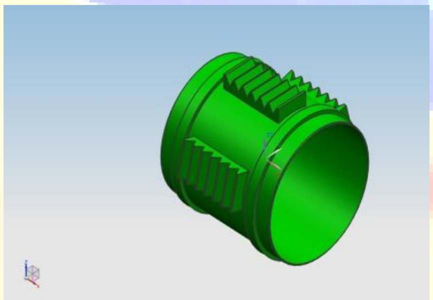


Figure 3D model of the chamber shell

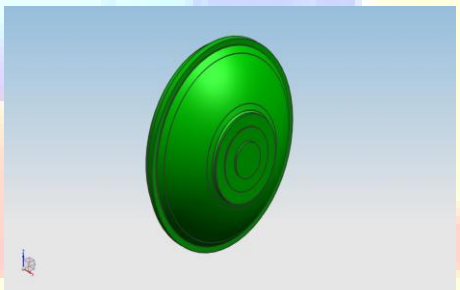


Figure 3D model of the shell head plate 1

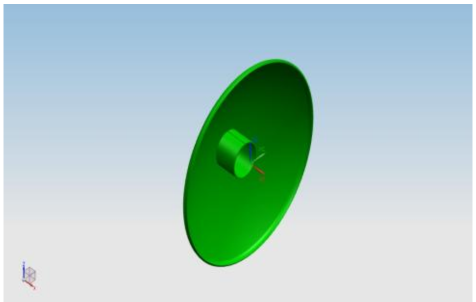


Figure 3D model of the shell head plate 2

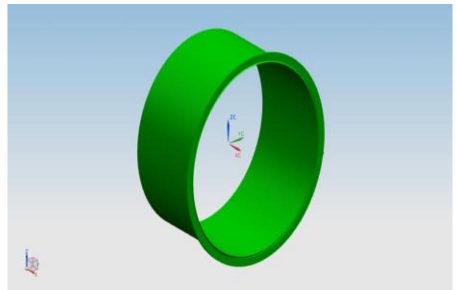


Figure 3D model of the spacer

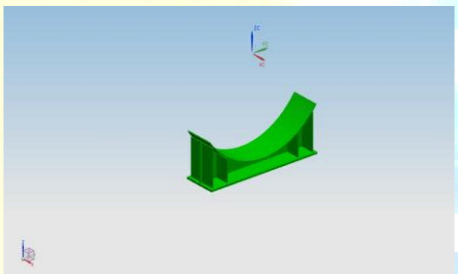


Figure 3D model of the bottom supports

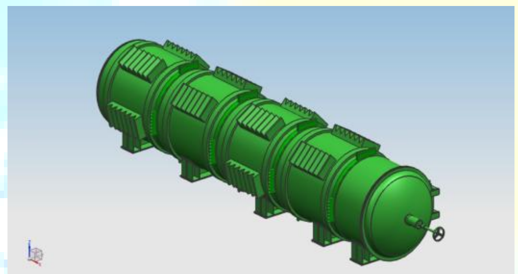


Figure 3D model of a canister testing chamber assembly

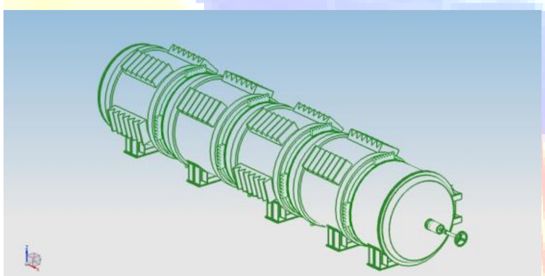


Figure Wire Frame 3D model of a canister testing chamber assembly

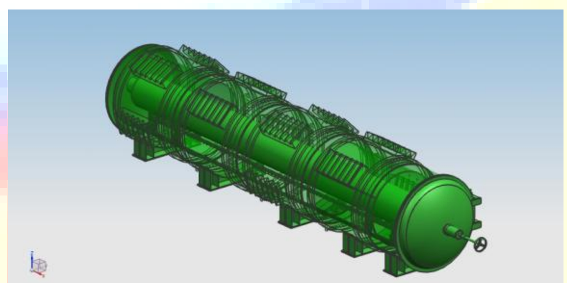
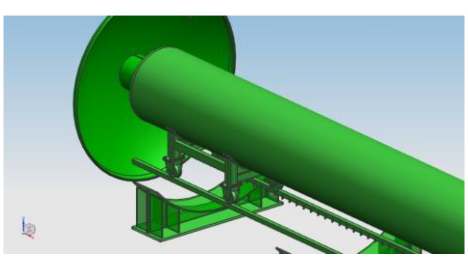


Figure:Wire Frame 3D model of a canister testing chamber assembly



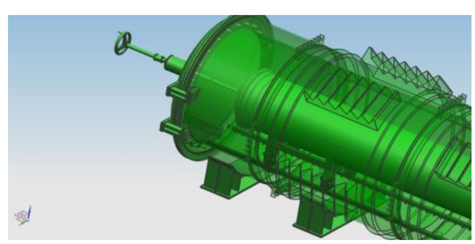


Figure:Wire Frame 3D model of a canister testing chamber Figure:Wire Frame 3D model of a canister testing chamber

Chapter 5

5.1 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 (Ex) =2.1e5N/ mm^2

Poisson's Ratio = 0.3

Density = 7880Tons/mm3

Yeild Strength = 250Mpa

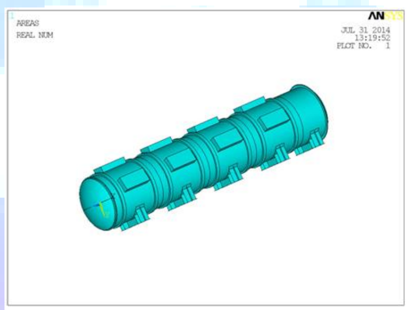


Fig. shows the 3D model of the canister testing chamber used for analysis

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.

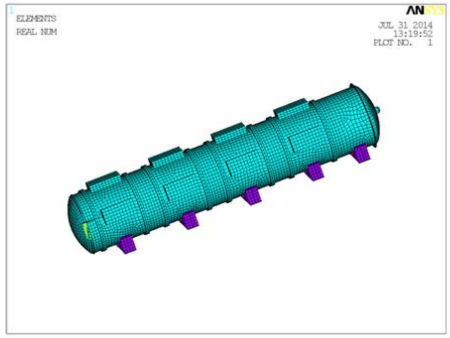


Fig. shows the FE model of the canister testing chamber used for analysis

Static Pressure analysis:

Static analysis is carried out on the canister testing chamber to check the structure behavior 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 is are connect using mesh connectivity.
3. Internal pressure of 1.176 Mpa is applied.

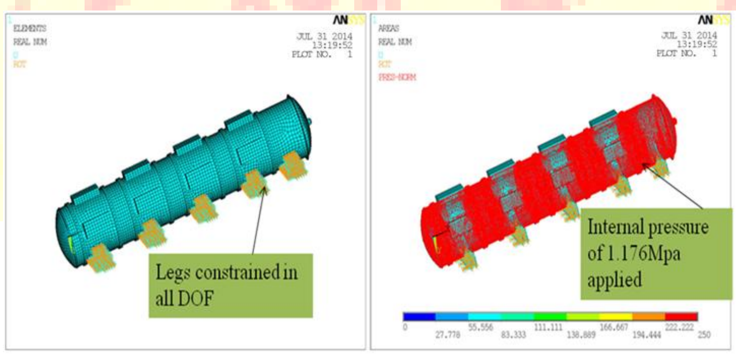


Fig. shows the Boundary conditions and loading applied on canister testing chamber

Results of the Static pressure analysis:

Total Deflection (Usum): Maximum Deflection of 2.5mm is observed on the canister testing chamber.

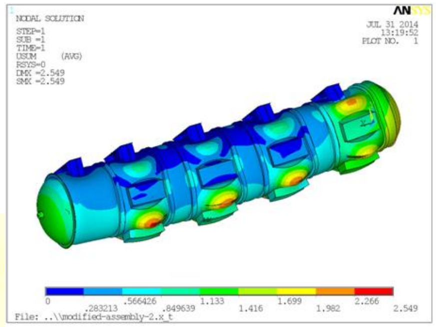


Fig. Total deflection observed on the modified testing chamber with legs

From the above analysis it can be observed that the maximum deflection is 2.5mm and the maximum VonMises stress is 160Mpa.The yield strength of the material is 250Mpa.From the above analysis it can be concluded that the modified canister testing chamber is safe for the internal pressure of 1.176 Mpa.

Modal Analysis on the Modified Model

Modal analysis was carried out on the modified 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 is 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.

MODE	FREQUENCY	PARTICIPATION FACTOR			EFFECTIVE MASS		
		X-Dir	Y-Dir	Z-Dir	X-Dir	Y-Dir	Z-Dir
1	17.8606	3.45E-04	4.18E-03	0.32955	1.19E-07	1.75E-05	1.8606
2	42.2239	-0.16714	0.2523	-8.05E-03	2.79E-02	6.36564	6.48E-05
3	53.9966	-0.72492	-4.41E-02	-5.61E-03	0.525509	1.95E-03	3.14E-05
4	57.1675	1.11E-02	-1.99E-02	-1.49E-02	1.24E-04	3.97E-04	2.23E-04
5	76.1107	-6.99E-03	-5.32E-03	0.46948	4.88E-05	2.83E-05	0.220415
6	80.0037	-0.34698	0.11109	2.52E-03	0.120397	0.127893	6.33E-06
7	86.5923	4.78E-02	5.83E-02	1.19E-02	2.29E-03	3.40E-03	1.42E-04
8	94.9678	-8.87E-02	-5.32E-02	-0.15723	7.86E-03	2.84E-03	2.47E-02
9	100.604	0.20752	0.17032	-1.83E-02	0.43649	2.90E-02	3.36E-04
10	109.301	-9.04E-02	-3.37E-03	-0.217	8.17E-03	1.13E-05	4.71E-02
11	121.362	0.25427	0.55581	1.89E-02	6.47E-02	0.308923	3.56E-04

12	122.574	0.18667	0.21288	-2.89E-02	3.48E-02	4.53E-02	8.36E-04
13	126.745	0.14014	0.133033	-5.71E-03	1.96E-02	0.16871	3.26E-05
14	131.632	0.11056	0.11103	1.48E-03	1.11712	1.23E-02	2.18E-06
15	133.84	-0.1771	-1.40E-02	-3.32E-03	0.31051	1.96E-04	1.10E-05
16	140.051	-0.11106	-1.74E-02	0.13495	1.23E-02	3.03E-04	1.82E-02
17	145.375	-0.59621	-0.16892	-1.86E-02	0.35547	2.85E-02	3.45E-04
18	148.219	1.7956	4.96E-02	8.32E-04	3.22406	2.46E-03	6.93E-07

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:

Random	**g2/Hz**
8	**0.003**
10	0.02
135	0.02
150	0.001

Table.8 shows the spectral values Vs frequency for PSD analysis

Boundary Conditions

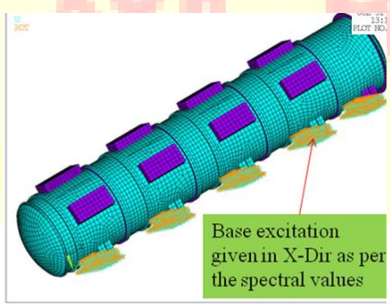


Fig. Boundary conditions used for PSD in X-dir for modified testing chamber

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

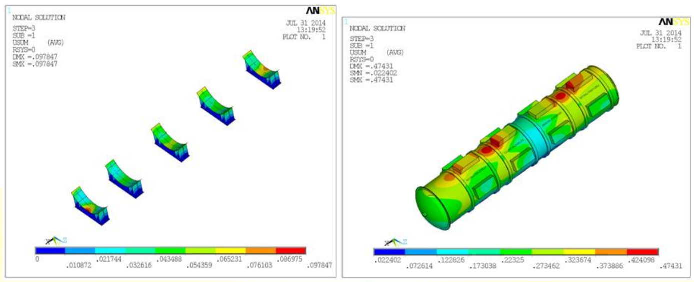


Fig. Total deflection of legs and chamber shell of modified testing chamber for PSD in X-dir

Results- VonMises 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

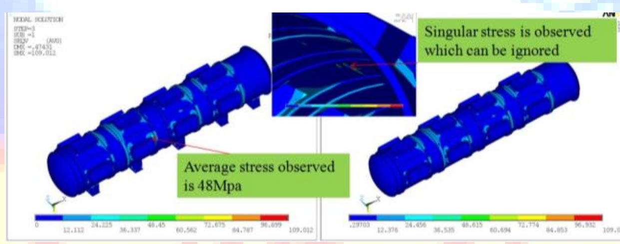


Fig. VonMises Stress of modified testing chamber for PSD in X-

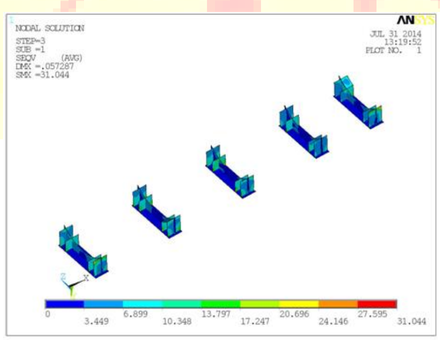


Fig. VonMises Stress of legs of modified testing chamber for PSD in X-Dir

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:

Random	**g2/Hz**
8	**0.003**
10	0.02
135	0.02
150	0.001

Table.8 shows the spectral values Vs frequency for PSD analysis

Boundary Conditions

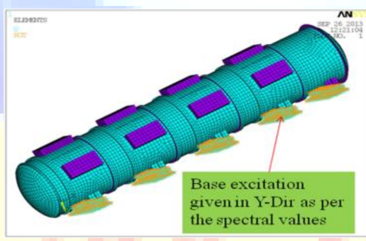


Fig. Boundary conditions used for PSD in Y-dir for modified testing chamber

Results- Total Deflection:

The maximum 1 sigma deflection observed is 1.58 mm

The maximum 3 sigma deflection observed is 4.74 mm

This implies that only 0.3% of the time the Canister Testing Chamber deflection reaches 4.74mm

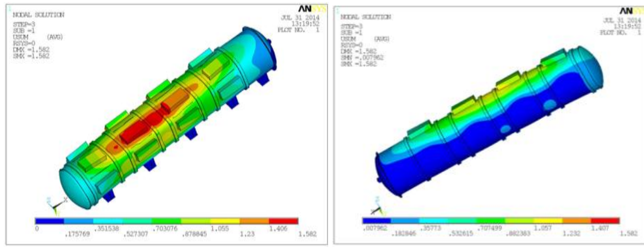


Fig. Total deflection of modified testing chamber for PSD in Y-dir

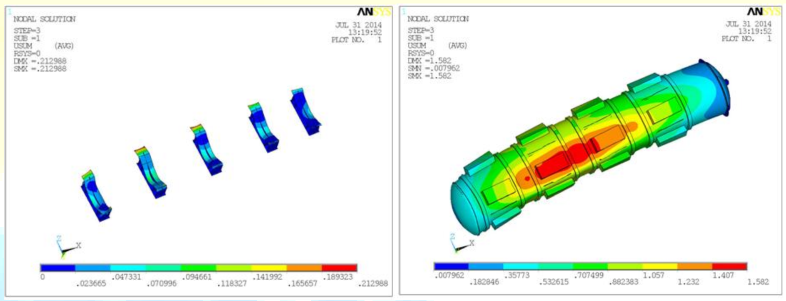


Fig. Total deflection of legs and chamber shell of modified testing chamber for PSD in Y-dir

Results- VonMises Stress:

The maximum 1 sigma Stress observed is 29.4 Mpa

The maximum 3 sigma Stress observed is 88.2 Mpa

This implies that only 0.3% of the time the Canister Testing Chamber stress reaches 88.2 Mpa

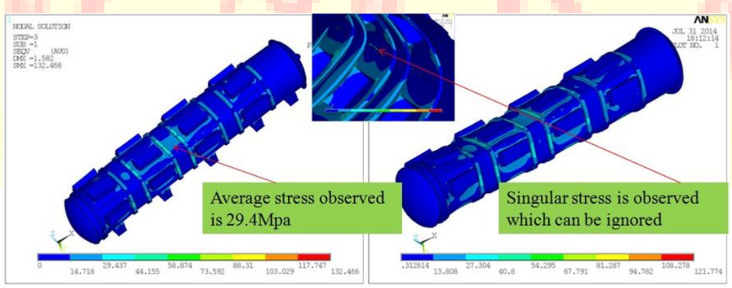


Fig. VonMises Stress of modified testing chamber for PSD in Y-Dir

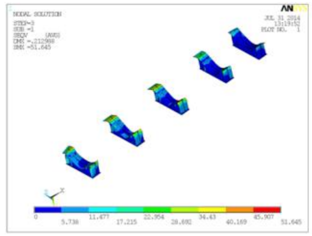


Fig. VonMises Stress of legs of modified testing chamber for PSD in Y-Dir

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.

Boundary Conditions:

Functional vibration levels – PSD:

Random	**g2/Hz**
8	**0.003**
10	0.02
135	0.02
150	0.001

Table.8 shows the spectral values Vs frequency for PSD analysis

Boundary Conditions

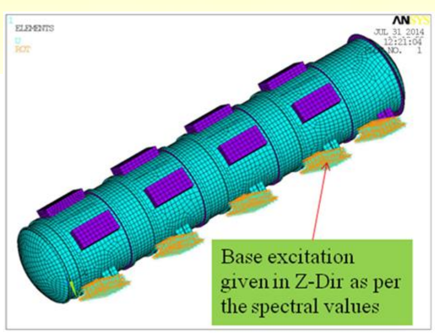


Fig. Boundary conditions used for PSD in Z-dir for modified testing chamber

Results- Total Deflection:

The maximum 1 sigma deflection observed is 5.07 mm

The maximum 3 sigma deflection observed is 15.21 mm

This implies that only 0.3% of the time the Canister Testing Chamber deflection reaches 15.2mm

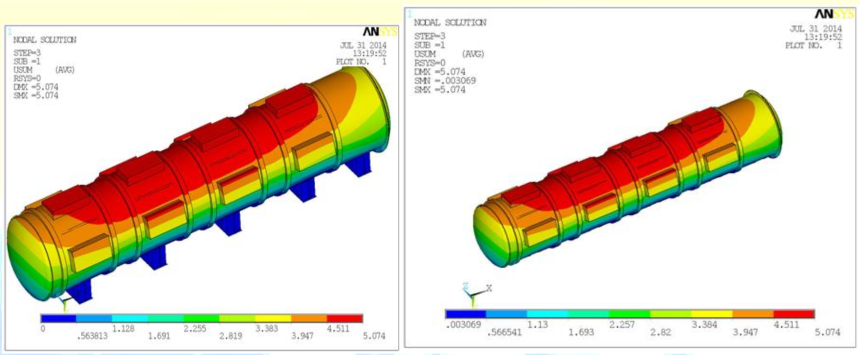


Fig. Total deflection of modified testing chamber for PSD in Z-dir

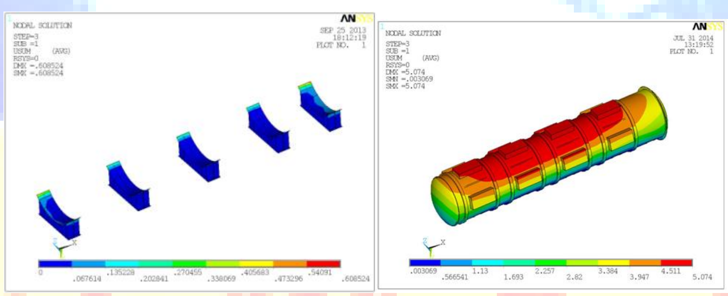


Fig. Total deflection of legs and chamber shell of modified testing chamber for PSD in Z-dir

Results- VonMises Stress:

The maximum 1 sigma Stress observed is 53.3 Mpa

The maximum 3 sigma Stress observed is 159.9 Mpa

This implies that only 0.3% of the time the Canister Testing Chamber stress reaches 159.9 Mpa

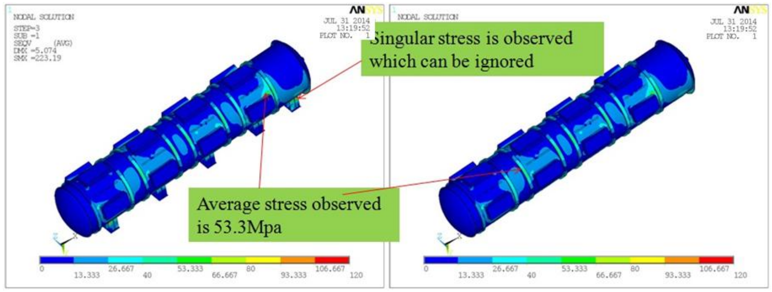


Fig. VonMises Stress of modified testing chamber for PSD in Z-Dir

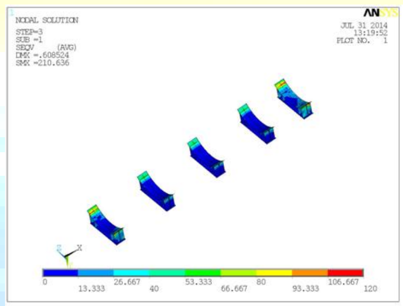


Fig. VonMises Stress of legs of modified testing chamber for PSD in Z-Dir

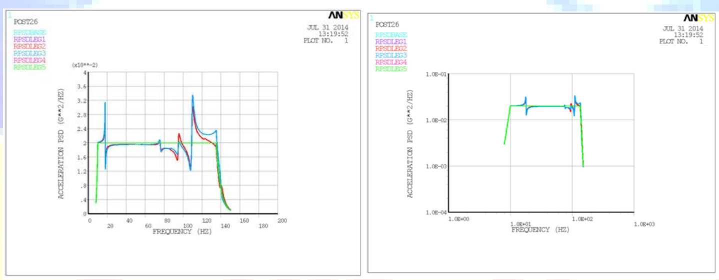


Fig. shows PSD-Z Response on Legs of testing chamber in Linear and Logarithmic Scale

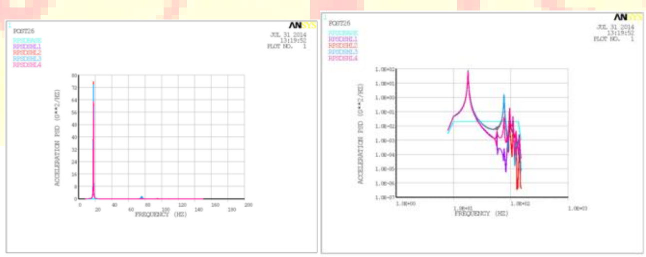


Fig. shows PSD-Z Response on shell of testing chamber in Linear and Logarithmic Scale

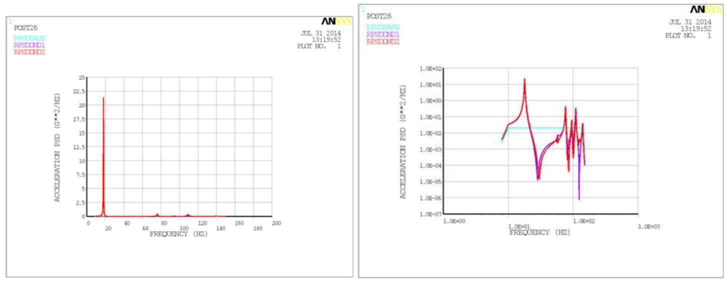


Fig. shows PSD-Z Response on Dogged lids of testing chamber in Linear and Logarithmic Scale

From the above graphs it is seen that

- Maximum PSD response on the legs is 0.0032 g2/Hz at a frequency of 109 Hz
- Maximum PSD response on the shell is 75 g2/Hz at a frequency of 17.8 Hz
- Maximum PSD response on the dogged lids is 21 g2/Hz at a frequency of 17.8 Hz

RESULTS AND DISCUSSIONS

Canister Testing Chamber was studied for 3 different cases for original and modified model:

- Pressure Analysis
- Modal Analysis
- Power Spectrum Density analysis

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

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.

The following observations are made on the Modified 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.

CONCLUSION & FUTURE SCOPE

In the present paper a Canister Testing Chamber has been designed and optimized for vibration control and internal pressures.

Canister Testing Chamber was studied for 3 different cases for baseline and modified model

- Pressure Analysis
- Modal Analysis
- Power Spectrum Density analysis

From the above analysis it is concluded that 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 concluded that the modified Canister Testing Chamber is safe under the given operating conditions.

FUTURE SCOPE

During transportation Canister Testing Chamber is subjected to shock loads as well.

So, Shock analysis has to be carried out to check the structure behavior for shock loads 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. The objective of this study is to understand the effects of dynamic loading on a Canister Testing Chamber more specifically Shock using finite element analysis program ANSYS.

Utilizing numerical simulation, analysis will be performed on the Canister Testing Chamber to check if the system withstands the loads and the stresses are within the design limit. The Canister Testing Chamber will be subjected to 20g accelerations at 18ms shock pulse

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References

1. Raiko, H., Salo, J.-P. 1992. The design analysis of ACP-canister for nuclear waste disposal. Report YIT-92-05, Nuclear Waste Commission of Finnish Power Companies, Helsinki.

2. Salo, J.-P., Raiko, H. 1990. The copper/steel canister design for nuclear waste disposal. TV 0/KP A Turvallisuus ja tekniikka, Work Report 90-10,Rev. 1., Teollisuuden Voima Oy, Helsinki.

3. Aalto, H., Rajainmaki, H & Laakso, L. 1996. Production methods and costs of oxygen free copper canisters for nuclear waste disposal. Report POSIV A-96-08, Posiva Oy, Helsinki.

4. State Environmental Protection Administration of China. HJ/T 390-2007 Technical requirement for environmental protection product. Control system of fuel evaporative pollutants from vehicle with