Random Vibration and Stress Analysis of Fluidization Reactor System

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***Abstract*—This dissertation work focuses on performing vibration analysis to find dynamic stress and defection of the fluidization reactor. Reactor consists of many vertical and horizontal stacks, ladder, platforms etc. It is constitutes complex dynamic system. While design reactor of petrochemical refineries. It is very important to consider vibration characteristics into account. Fluidization systems running at high temperature and pressure close to the natural frequency of the system results in excessive deformation and large stress which leads to catastrophic failure of the system. With a view to this, an effort has been made in carrying out a feasibility study of dynamic behavior like dynamic stresses and displacement of the structure to determine with well-established theoretical method and performing the FEA (Finite Element Analysis. FEA performing when the reactor is operating condition and non-operating condition and conclusion is drawn based on the validation both theoretical and FEA results of dynamic analysis of the reactor.**

***Keywords*— Reactor, ASME, Analytical Modal Analysis, FEA, Random Vibration analysis.**

I. INTRODUCTION

Fluidized bed reactors are a relatively new tool in the chemical engineering field. The first fluidized bed gas generator was developed by Fritz Winkler in Germany in the 1920s.One of the first United States fluidized bed reactors used in the petroleum industry was the Catalytic Cracking Unit, created in Baton Rouge, LA in 1942 by the Standard Oil Company of New Jersey. This FBR and the many to follow were developed for the oil and petrochemical industries. Here catalysts were used to reduce petroleum to simpler compounds through a process known as cracking. The invention of this technology made it possible to significantly increase the production of various fuels in the United States.

Today fluidized bed reactors are still used to produce gasoline and other fuels, along with many other chemicals. Many industrially produced polymers are made using FBR technology, such as rubber, vinyl, chloride, polyethylene, styrenes, and polypropylene. Various utilities also use FBR's for coal gasification, nuclear power plants, and water and waste treatment settings. Used in these applications, fluidized bed reactors allow for a cleaner, more efficient process than previous standard reactor technologies.

A fluidized bed reactor (FBR) is a type of reactor device that can be used to carry out a variety of multiphase chemical reactions. In this type of reactor, a fluid (gas or liquid) is passed through a solid granular material (usually a catalyst possibly shaped as tiny spheres) at high enough velocities to suspend the solid and cause it to behave as though it were a fluid. This process, known as fluidization, imparts many important advantages to the FBR. As a result, the fluidized bed reactor is now used in many industrial applications.

Structural Integrity of important component like reactor is necessary for operational safety, reliability and economic plant operation. These structures are prone to excessive vibration resulting in flutter and fatigue failure. Performance of many structures such as Reactor, pressure vessel, vertical tower is severely affected by undesired vibration. It is required that structures must safely work during its service life. It is very much important to characterize the dynamic behavior of the space structures to ensure its survivability against excessive vibrations. In the study of dynamic behavior of structure, usually modal parameters like Natural Frequency Mode shapes and damping to be extracted.

The mechanical design of pressure vessels is done in accordance with the guideline provided in the ASME Pressure Vessel Code, Section VIII Div. 1, and Div. 2. Pressure vessels are made in all shapes and sizes, from a few cm in diameter to 5698 diameter and 40426 mm height including skirt support. The pressure may be more than 29.1 bar. Reactor vessel have more applications ranging from chemical industries, oil and gas plant, ammonia plant, heat exchanger, petroleum refineries & fertilizer industry etc. They are subjected to mechanical as well as thermal operating condition, therefore cylinder shows some limitations. In order to reduce weight / volume, thickness or to increase life of vessel, its durability and burst pressure researcher used multi-layer vessel.

In this dissertation work focus on vibration and dynamic analysis of skirt supported vertical reactor vessel for specific load cases. The dynamic displacements and material stresses must not exceed the specified maxima. The main problem while designing a reactor is loading conditions to control the vibration of vessel under operating condition and selection of proper members to ensure design requirement. For which an additional requirement of designing safe, while they are designing the reactor for all the cases the displacement and stresses should be less than allowable limit of the reactor as per specification S-G000-5351-001.

Vibration and stress analysis of the overall fluidization system on the structural support shall be performed. Reactor to be supported in order to control vibrations, supporting structure/ foundation details shall be defined after stress analysis;

1. In the first stage of the work, understanding for all the codes used by the industry to design of pressure vessel. After that getting the allowable limit of stresses of the specification of the project.
2. Make solid model for the project geometry in SIMENSE NX 8.5 and check all bodies and edges to completely swappable and splitting all bodies symmetrical of model.
3. Checking all the process nozzles are passing in PV ELITE software to considering all load and forces applied at certain location.
4. Performing modal analysis, when reactor is not working condition as a fixed-free condition in order to finding the frequency values obtained in the preliminary analysis of FEA model.
5. When reactor is operating condition, performed the static structural analysis for future analysis of modal analysis to obtain the excited natural frequency. Those all frequency extract for the random vibration fr determine the dynamic response of the structure.
6. Check the theoretical approach of modal and random vibration analysis results are validating with analytical analysis result of the FEA model.

All literature related to free transverse and random vibration of simple structures i.e. Beams are reviewed. Then various techniques of modal analysis i.e. Analytical, operational and experimental are reviewed.

The American Society of Mechanical Engineers [ASME] Section VIII, Division 1 & 2 [1], According to The standard gives the procedure to carry out the combined stress analysis of pressure vessel. The pressure vessels are designed as per ASME section viii division 1 & 2.Most of all type of pressure vessel design based on the ASME section VIII division I. Moss, D. R., Pressure Vessel Design Manual [2], This book is the manual for the pressure vessel design. It covers all the aspect of the design procedure of the pressure vessel Freese, C. E. [3], this paper has primarily concerned with the vibration of vertical tall tower, vessel and column. It described the accurate method to estimate the fundamental frequency and period of vibration of the tall and uniform vessel. Eugen Megyesy & Paul /buthod [7], Pressure vessel design handbook, this is book of design and construction of pressure vessel and guideline of stress analysis of different component of vessel.it gives also to formula of natural frequency of vessel under wind loading of vertical tall stack tower for different dynamic loading condition. Jaap Wijker [17], Author presents the book on the Random Vibrations in Spacecraft Structures Design Theory and Applications. This book covers the most of all fundamentals of the random vibration of the structure. Anil K Chopra [11], Author present book on Dynamics of Structures (Theory and Application to Earthquake Engineering) which gives information regarding fundamental of vibration and also information regarding earthquake engineering and response of the structure during earthquake and describe the fundamental of vibration of static structural problem.

While designing the Pressure Vessels, Reactor, Vertical tower, wind and seismic conditions shall be checked by the designer as they can have the major roll in failing the vessel. These structures are prone to excessive vibration resulting in utter and fatigue failure. Performance of many vertical vessel structures is severely affected by undesired vibration. It is very much important to characterize the dynamic behavior of the structures to ensure its survivability against excessive vibrations. So, the main motivation behind this project is to provide some guidelines to the designer, to use the codes without wasting much time by compiling these codes at one place, which are applicable to vessels only.

II. MODAL ANALYSIS

Modal analysis has become the most important technology in improving and optimizing dynamic characteristics of engineering structures in the past few years. It is not only used for in aeronautical and mechanical engineering, but modal analysis has also research another applications for civil and building structures, space structures, and transportation.

A. Finite Element Model:

The solid model of the reactor is used for life assessment. The geometric modeling of the reactor is carried out in NX ver. 8.5 software. All the necessary partitions & splits are made in NX software. Partition and splits are made based on the meshing requirement, load application and restraints entire document should be in Times New Roman or Times font. Type 3 fonts must not be used. Other font types may be used if needed for special purposes.

The analysis software used is Ansys Version 16.2. The model generated in the NX is transferred to Ansys Design Modeller, as a Para solid, for Analysis and further process. Material Properties are defined in Ansys Engineering Data. The Meshing, application of the load and boundary conditions are done in Ansys Mechanical. Ansys APDL is used for solving the model and the results are view in Ansys Mechanical.

B. Modeling Data:

By considering the below-mentioned dimensions a 3D model of reactor is made for assessment:

TABLE I
Modeling Data

Shell Inner Diameter	= 2819.5 mm
Shell thickness	= 60 mm
Hemispherical Head Crown thickness	= 48 mm
Crown thickness (Bottom)	= 56 mm
Skirt thickness	= 30 mm
Insulation thickness	= 40 mm
Corrosion allowance	= 3 mm

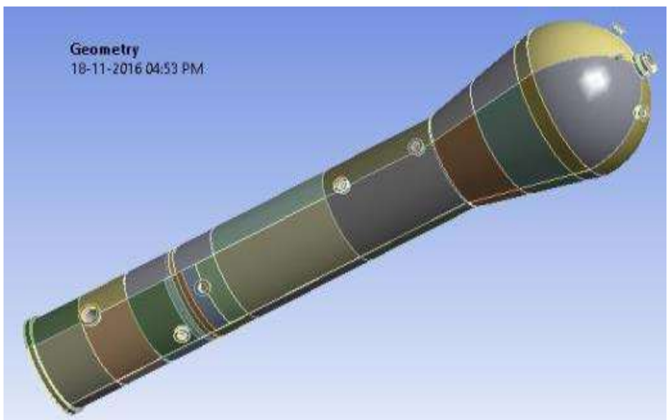


Fig. 1 Solid model of reactor

Reactor as shown in fig 1 is used in chemical process plant. Reactor containing catalyst, conducting highly exothermic process like hydrocarbon, naphthalene, oxidation of ethylene and hydrogenation reaction.

C. Meshing Properties:

Solid185 Quad elements are used for meshing the structure. SOLID185 is a first order 3-D 8-node solid element that exhibits linear displacement behavior. The element is defined by 8 nodes having three degrees of freedom per node: translations in the nodal x, y, and z directions.

As per ANSYS design manual for good mesh quality there some criteria for the fine mesh elements for meshing. The detail of meshing for analysis with 3 elements across section is as given below:

- Total number of elements in the part: 254192
- Total number of nodes in the part: 327576
- Aspect ratio: 0.9997
- Skewness (< 0.95): 0.2685
- Orthogonal quality (>0.1): 0.8345

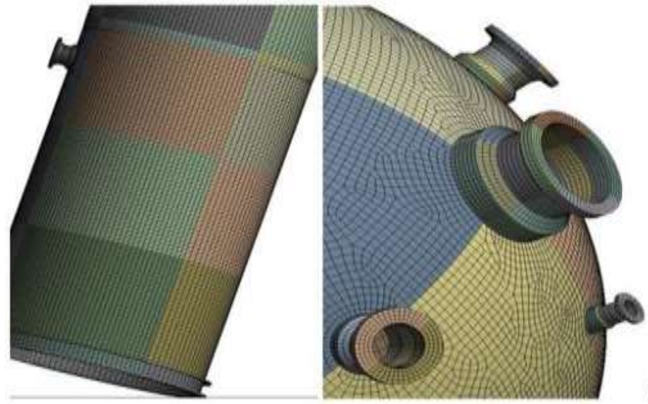


Fig. 2 Meshing detail of FEA model

For evaluating the natural frequency and the mode shapes due to mechanical loads, the Nodes on bottom surface of support Skirt are fixed in all direction.

D. FEA Results:

Modal Analysis is performed using workbench ANSYS 16.2 software package. After that, we got the natural frequency and each natural frequency have own mode shapes.

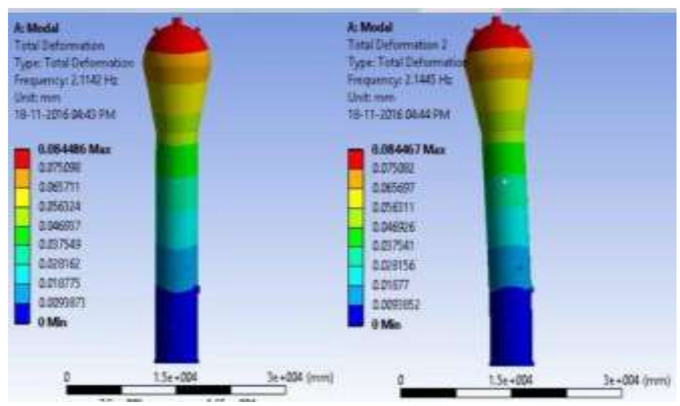


Figure 3: Mode shapes 1 & 2 of Natural frequency

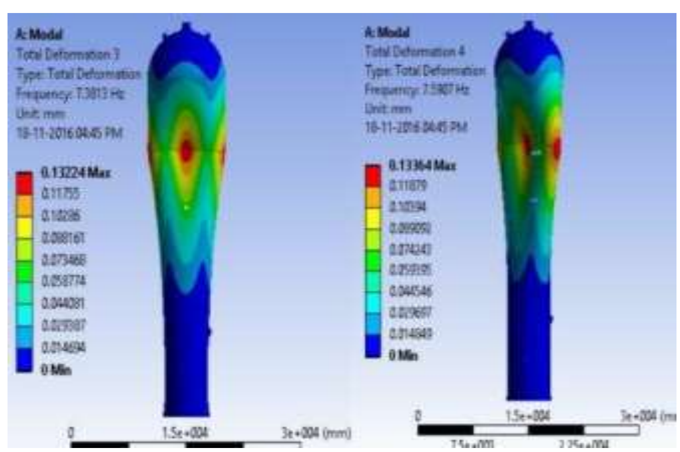


Figure 4: Mode shapes 3 & 4 of Natural frequency

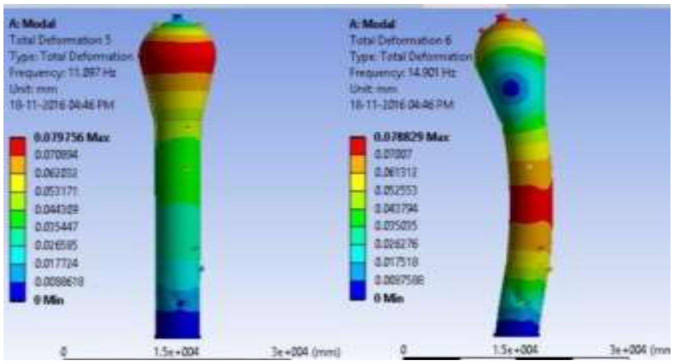


Figure.5: Mode shapes 5 & 6 of natural frequency

TABLE II
Natural Frequency

MODE	NATURAL FREQUENCY (Hz)
1	2.1142
2	2.1445
3	7.3813
4	7.5907
5	11.097
6	14.901

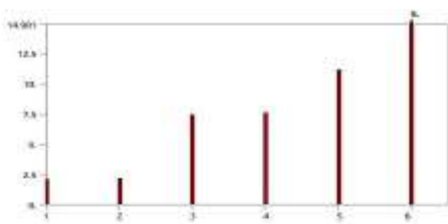


Figure.6: Graph of mode shape vs. frequency

E. Theoretical Approach:

E. Megyesy, natural frequency formula [5]:

As, a result of wind, another dynamic loading, vertical vessel develop vibration. The period of the vibration should be limited, since large natural periods can lead to fatigue failure. The allowable period has been computed from the maximum permissible deflection.

Formula's for period of vibration:

Period of vibration: T (sec)

$$T = 0.0000265 * \left(\frac{H}{D}\right)^2 * \sqrt{\frac{wD}{t}}$$

Natural frequency: f_n (Hz)

$$f_n = \frac{1}{T}$$

D = Outside diameter, ft.
H = Length of vessel including skirt, ft.
g = 32.2 ft. per sec square, acceleration.
t = Thickness of skirt at the base, in
V = Total shear, lb.
W = Weight of tower, lb.
w = Weight of tower per foot of height, lb.
f_n = Natural frequency , Hz.

The period of vibration:

$$T = 0.0000265 * \left(\frac{H}{D}\right)^2 * \sqrt{\frac{wD}{t}}$$

$$= 0.0000265 * \left(\frac{132.63124}{18.894358}\right)^2 * \sqrt{\frac{8327.711 * 18.894358}{1.181103}}$$

T = 0.476604635 sec

Natural frequency: $f_n = \frac{1}{T}$

$$= \frac{1}{0.476604635}$$

= 2.098175 Hz.

Similarly we get all natural frequency for all mode shape.

TABLE III
Validation Results

MODE	Natural frequency (Hz)	
	ANALYTICAL RESULT	THEORETICAL RESULT
1	2.1142	2.0981
2	2.1445	2.1284
3	7.3813	7.3650
4	7.5907	7.5844
5	11.097	11.062
6	14.901	14.356

III. Static Analysis

The stress analysis of the shell and nozzle is required under design condition & differential pressure. This analyses and evaluates the mechanical stresses due to the discontinuities and that due Internal Pressure and another loading condition.

A. Loading Condition:

The design data required for the analysis is as given below.

Design code:	: ASME Sec. VIII Div. II Ed.2015
Design Pressure	: 2.91 MPa
Design Temperature	: 170 °C
Operating Pressure	: 2.28 / 2.35 MPa
Operating Temperature	: 40 / 125 °C
Corrosion Allowance	: 3 mm
Vertical Loading	: 10200 KN (-Y Direction)
Shear Loading	:520 KN (+X Direction)

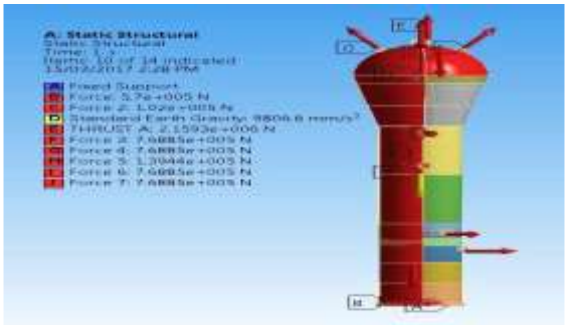


Figure.7: Loading and boundary condition

B. Mechanical results:

Mechanical results are obtained as per the load cases define the von misses stress plot & displacement plot for load cases. Maximum displacement observed is as listed in the table below.

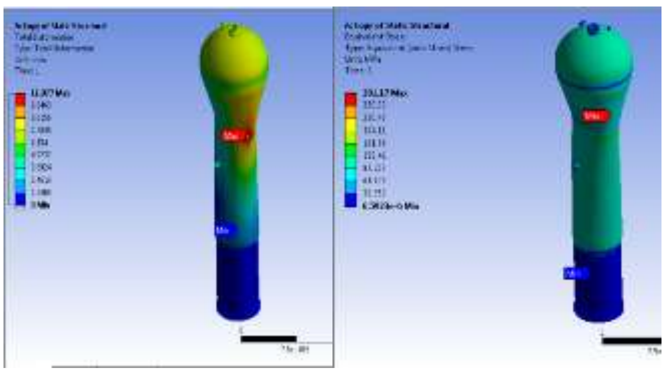
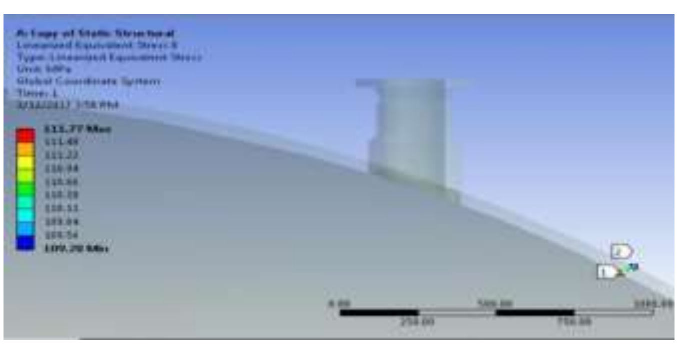
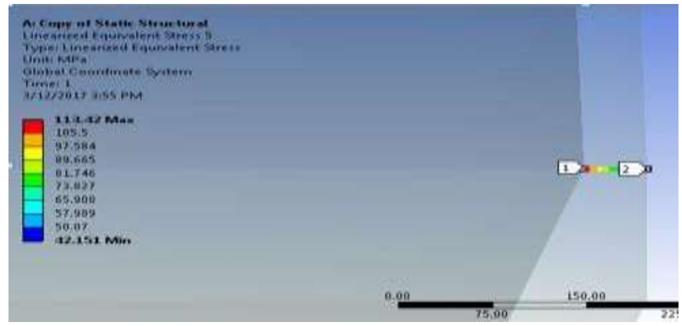


Figure 8: Static Structural Analysis Results

Load Case	Total Deformation	Equivalent (Von misses) stress
LC 1	11.077 mm	291.17 MPa

Here the equivalent stress is above the allowable stresses so we linearized stresses where maximum stress is observed. The stress evaluation for each of the SCL and at the end nodal points of SCL's is done as per Code ASME Section VIII, Div2, Ed. 2015, and Part 5. The Linearized Stress results calculate membrane, bending, peak, and total stress along a straight line path in the Mechanical application.





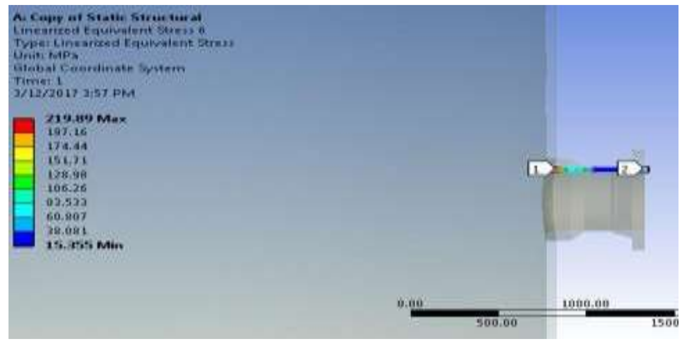


Figure 9: SCL FEA Analysis Results

Allowable stress Limits are considered as per Part5, ASME Section VIII, Div 2. It is tabulated in table for all materials.

TABLE IV
Allowable Stresses

Stress category	Stress Limit	SA 516 GR 70 @170°C (N/mm^2)	SA 105 @ 170°C (N/mm^2
General Primary Stress	Pm= Sm	152.4	132.4
Local Primary Stress	PL=1.5Sm	228.6	213.6
Primary + Secondary Stress	PL+Pb+Q=3Sm	457	427.2

The Stress intensities at SCL's and nodal end point of SCL's are categorized as primary and primary plus Secondary stresses as per Code and the stress intensities are checked with allowable limits. A computer program is made and membrane and bending component is found along each defined path.

TABLE V
Primary Membrane Equivalent stress

SCL	Location with material	Stress Category	Equivalent stress MPa	Allowable Stress MPa
SCL 1	Shell (SA 516 Gr 70)	PL=1.5Sm	110.5	228.6
SCL 2	Shell (SA 516 Gr 70)	PL=Sm	75.461	152.4
SCL 3	Nozzle 24_ (SA 105)	PL=1.5Sm	36.609	213.6

Table show that Summary of primary membrane equivalent stress for Mechanical Loading@ 170 °C (LC1).

TABLE VI
Primary + Secondary Equivalent Stress

SCL	Location with material	Stress Category	Equivalent stress MPa	Allowable Stress MPa
SCL 1	Shell (SA 516 Gr 70)	PL+Pb+Q= 3Sm	111.8	457.6
SCL 2	Shell (SA 516 Gr 70)	PL=1.5Sm	113.41	228.6
SCL 3	Nozzle 24_ (SA 105)	PL+Pb+Q= 3Sm	99.405	427.2

Table show that Summary of primary + secondary equivalent stress for Mechanical loading@ 170 °C (LC1)

Here all case of Equivalent stresses is below the allowable stresses so design is safe for stress analysis.

This mode shapes are imposed in random vibration dynamic for determining the dynamic response of the structure. Refer below mode shapes for FEA plots.

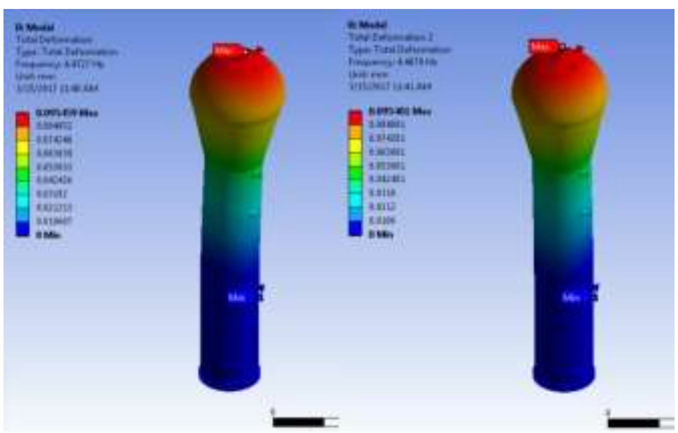


Figure 10: Mode shape 1 & 2 of Excited Frequency

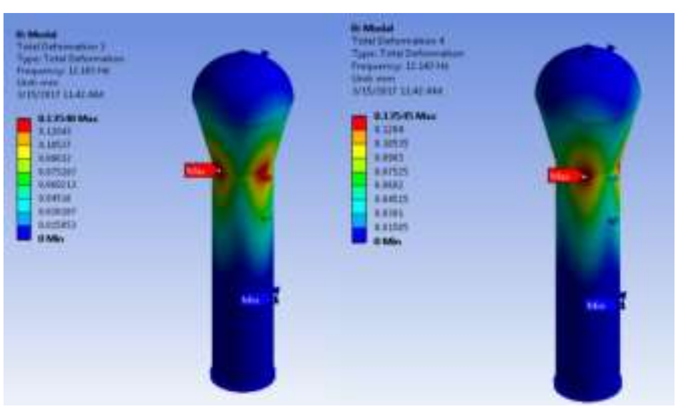


Figure 11: Mode shape 3 & 4 of Excited Frequency

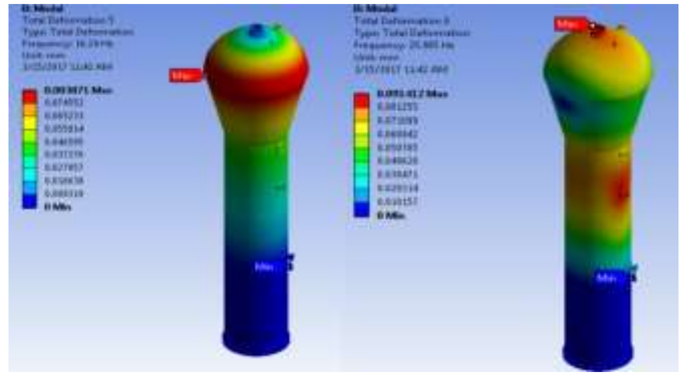


Figure 12: Mode shape 5 & 6 of Excited Frequency

IV. Random Vibration Analysis

Random vibration analysis is used to define the structure response under random loading. ANSYS uses the power spectral density (PSD) spectrum as random vibration analysis of the load input. Power spectral density is a kind of probability statistics method, and is the root mean square value of random variables, including a measure of the random vibration energy and frequency information. Power spectrum that can be displacement, velocity, acceleration or force power spectral density and other forms.

Random vibration is extracting all mode shapes for determining the dynamic response of the structure. Without modal analysis we cannot determine the any type of dynamic response of the structure. In random vibration analysis the random excitation force give in the form of power spectral density. Then solver solving the above load case and determines the dynamic stresses and deformation and response of the structure.

Random vibration is getting all load case and boundary condition taking from the previous analysis and excites the all mode shape getting base excitation forces for evaluation maximum deformation and stresses.

A. Random Excitation Force:

In random vibration analysis, the input excitation force applied in +X direction in form of PSD G acceleration. Power Spectral Density (PSD) is the frequency response of a random or periodic signal. It tells us where the average power is distributed as a function of frequency. The input forces like as PSD G ACCELERATION :(as per frequency range)

TABLE VII
PSD G Acceleration

Frequency	G^2/ Hz
5	0.0387
10	0.0417
15	0.0463
20	0.0463
25	0.0387

The Hz value in [G2/Hz] refers to a bandwidth rather than to the frequency in Hz along the X-axis. The RMS value of a signal is equal to the standard deviation, assuming a zero mean. The standard deviation is usually represented by sigma.

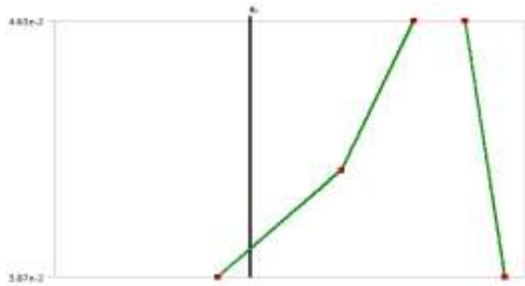


Figure 13: PSD Curve

PSD response analysis: Taking the PSD G acceleration as input base excitation spectrum as the input condition, then basing on the results of the modal analysis we can analyses the random vibration response and getting the maximum stress under the action of the random load spectrum. For maximum dynamic stresses and deflection, it may be used the scale factor 3 sigma and probability 99.73%for determine Random vibration response of the structure. Getting the direction deformation in X direction and equivalents stress in X & Y direction.

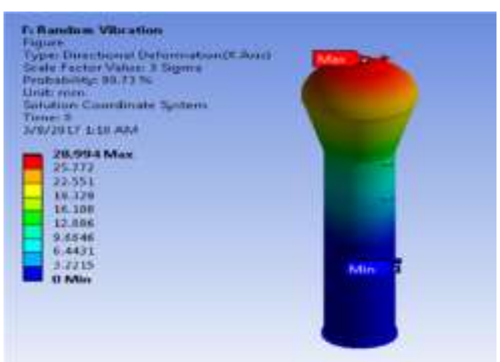


Figure 14: Directional deformation in x direction

Figure 15: Equivalent stresses in X direction

Here Equivalent stresses are below the allowable stress value so design safe in random loading condition. And Directional deformation is also below the allowable limit according to E. Megasy approach. So design safe.

B. Dynamic Response of reactor:

To compute the RMS values from these breakpoints we need to compute the area under the curve defined by the breakpoints. From dynamic stress evaluation we get the maximum deformation and stresses as per dynamic loading condition. We can show that the maximum deformation occurred at the top nozzle place on top head of the reactor.so, we find the displacement response PSD of those nodes at different frequency as per dynamic loading condition Mechanical results are obtained as per the load cases define the von misses stress plot

Displacement response:

All boundary and loading conditions are taken from the random vibration analysis. From FEA analysis of the random vibration we show that the maximum deformation occurred at top of the vessel so we select that node for determine the displacement and acceleration response of the reactor.

In displacement response, give results of the displacement of that node for different excited frequency and plot graph of the all displacement as per frequency. Its show in fig.

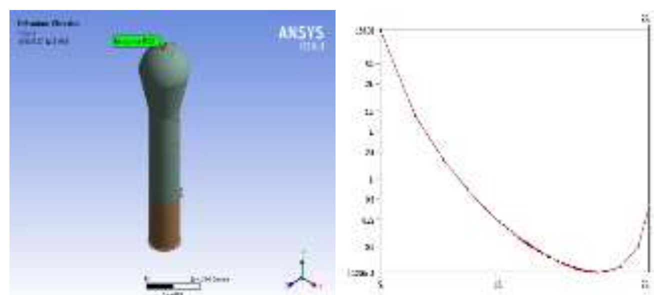


Figure 16: Response curve of the displacement response

Object Name	*Response PSD*
State	Solved
Definition	
Type	Response PSD
Location Method	Geometry Selection
Geometry	1 Vertex
Orientation	Solution Coordinate System
Reference	Absolute (including base motion)
Suppressed	No
Options	
Result Type	Displacement
Result Selection	X Axis
Selected Frequency Range	Full
Results	
Node ID	12885
RMS Value	9.926 mm
RMS Percentage	100. %
Expected Frequency	5.8704 Hz

Figure 17: FEA results of displacement response

Acceleration response:

Acceleration response to compute the RMS values from these breakpoints we need to compute the area under the curve defined by the breakpoints. Similarly all psd acceleration excited for different frequency to plotting the graph of acceleration response curve.

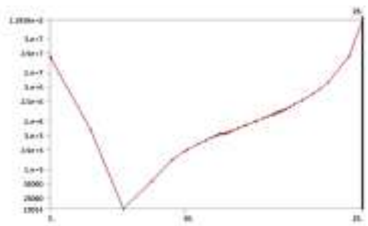


Figure 18: Response curve of acceleration response

Object Name	Response PSD
State	Solved
Definition	
Type	Response PSD
Location Method	Geometry Selection
Geometry	1 Vertex
Orientation	Solution Coordinate System
Reference	Absolute (including base motion)
Suppressed	No
Options	
Result Type	Acceleration
Result Selection	X Axis
Selected Frequency Range	Full
Acceleration in G	No
Results	
Node ID	85611
RMS Value	9982.57 mm/s²
RMS Percentage	100. %
Expected Frequency	21.881 Hz

Figure 17: FEA results of acceleration response

V. VALIDATION OF FEA RESULTS

A. Theoretical approach of Total Deformation:

Eugene Megasy Theory [5],
The deflection due to wind load may be calculated by using the formula for uniformly loaded cantilever beam.

Maximum deflection: $\Delta m = \frac{P_W * D * H * (12H)^3}{8 * E * I}$

Wind pressure $P_W = \frac{V}{D*H}$

$= \frac{570000}{18.89436 \times 132.6312} = 51.1345\ psf.$

Maximum deflection: $\Delta m = \frac{P_W * D * H * (12H)^3}{8 * E * I}$

$= \frac{51.134 \times 18.89436 \times 132.6312 \times (12 \times 132.6312)^3}{8 \times 2.81E+07 \times 5238936}$

Δm = 0.438531 inch = 11.13871 mm

As per Megasy approach,

The maximum allowable limit of deformation of Tower should be designed to deflect no more than 6 inches per 100 feet of height.

So, our FEA model height (including skirt height) is 132.67 ft. for determine the maximum deformation.

Maximum allowable deflection: 4.523812 in = 114.9051 mm

Theoretical deformation value of the vessel is less than the maximum allowable deflection so design is safe in working condition.

B. Validation of deformation of the vessel:

Comparing the theoretical and analytical value of the total deformation for validate the results.

TABLE VIII
Validation Results of deformation

Load case	Theoretical approach	Analytical approach
LC1	11.138 mm	11.077 mm

C. Theoretical approach for Acceleration response of the reactor:

A random spectrum is defined as a set of frequency and amplitude breakpoints, like these:

To compute the RMS values from these breakpoints we need to compute the area under the curve defined by the breakpoints. At first glance this appears simple because the area can be split up into a group of squares and triangles, which are easy to compute. But note that the triangles are the result of straight lines on *log-log* graph paper, and not on *linear* graph paper. We can still take advantage of the triangles; however we need to use a special formula for computing the area of triangles on *log-log* graph paper.

The definition of a straight line on *log-log* graphs between two breakpoints (*f1*, *a1*) and (*f2*, *a2*) is a power relationship, where the slope is the exponent, and the offset is the multiplicative factor.

Area =offset * f^{slope}

The slope and offset that define this straight line, are computed as follows.

Slope = $\frac{\log(a_2) - \log(a_1)}{\log(f_2) - \log(f_1)}$

Offset = $\frac{a_1}{f_1^{\,slope}}$

Given this slope and offset we can integrate from f_1 to f_2 to compute the area under the line.

Area $=\frac{offset}{slope+1}*({f_2}^{slope+1} - {f_1}^{slope+1})$ (if slope ≠ -1)

When slope=1 we have a special case where this formula doesn't hold. For this case we note that (a = offset / f) which integrates to a natural log function.

Area $=\frac{a_2}{slope+1} * \left(f_2 - f_1 * \left(\frac{f_1}{f_2}\right)^{slope}\right)$ (if slope = 1)

(Hint: some programs, including Microsoft Excel define the log () function as a base-10 logarithm, and define the ln () function as the natural (base-e) logarithm. Be sure to use the correct function in your calculation. As a test, for a natural logarithm, log (2.71828182845905) = 1.0.)

Area $= (\log(f_2) - \log(f_1)) * offset$ (if slope = -1)

So, for each pair of breakpoints we can use equations (4) or (5) to compute the area under the curve. The total area under the curve will then be the sum of the individual area calculations between each pair of breakpoints, and this sum is the *mean-square* acceleration. We take the square-root of the result to get the RMS acceleration level.
Using our example breakpoints, the sum is computed as follows:
From frequency 5 to 10 Hz:

Determine the slope and offset:

Slope $= \frac{\log(a_2)-\log(a_1)}{\log(f_2)-\log(f_1)}$ Slope $= \frac{\log(0.0417)-\log(0.0387)}{\log(10)-\log(5)}$

Slope = 0.107714

Offset $=\frac{a_1}{{f_1}^{slope}}$ Offset $=\frac{0.0387}{5^{0.107714}}$

Offset =0.03254

Here slope value is positive so determine area under curve by using equation

Area $=\frac{a_2}{slope+1} * \left(f_2 - f_1 * \left(\frac{f_1}{f_2}\right)^{slope}\right)$

Area $=\frac{10}{0.107714+1} * \left(10 - 5 * \left(\frac{5}{10}\right)^{0.107714}\right)$

Area (A_1) = 0.201766915

Similarly calculate area under the all frequency range from given table.

TABLE IX
Acceleration
Response

Frequency (Hz)	Amplitude (G2/Hz)	Slope	Offset	Acceleration area
5	0.0387	*	*	*
10	0.0417	0.1077	0.03254	0.2017
15	0.0463	0.2580	0.02301	0.2205
20	0.0463	0	0.0463	0.2315
25	0.0387	-0.8035	0.5140	0.2112
		Total		0.8650
		Root mean square value		0.93009
		Acceleration (Grms)=		*0.93018*

D. Theoretical approach for Displacement response of the reactor:

According to Random vibration by **Barry controls[10],**

Displacement could be analyzed in the same manner as acceleration, except that rather than using units of g2/Hz, the units would be in2/Hz. The RMS displacement would be the square root of the area under the curve of in2/Hz. However, since accelerometers are the most frequently used method of measuring random vibration, alternate methods are used to determine displacement. For a band limited white spectrum, the RMS displacement can be shown to be given by:

Xrms = Grms $* \frac{g}{4*\pi^2} * \sqrt{\frac{({f_2}^3-{f_1}^3)}{3*({f_1}^2*{f_2}^3)} * \frac{1}{f_2-f_1}}$

For most cases, f 2 is significantly higher than f l so above Equation 4 can be rewrite in different form:

Xrms $= \frac{\text{Grms}*586}{\sqrt{({f_1}^3*f_2)}}$

We can show that, In FEA analysis of random vibration the maximum deformation occurred at the nodes of the top nozzle of the vessel those placed on the top of the head so we can determine the displacement response of that node.

Grms = input acceleration = .930092 G
g = acceleration constant = 9810 mm/s^2
f1 = lower frequency, = 5 Hz
f2 = upper frequency = 25 Hz

Displacement response:

Xrms $= \frac{0.91*586}{\sqrt{(5^3*25)}}$= 9.539244 mm

Validation of the Dynamic Responses Results of the Structure:

Comparing the FEA response results and theoretically response results, from below table we can show that both results are nearly equal. The displacement of that node result has nearly to the allowable limit of the theoretical approach. So design of reactor has not more conflict with dynamic loading condition.

TABLE X
Validation Results of Response

Dynamic response	Theoretical approach	Analytical approach
Displacement response	9.53922 mm	9.9264 mm
Acceleration response	9120.73 mm/s^2	9982.57 mm/s^2

IV. CONCLUSIONS

This dissertation aimed for performing Random vibration and Stress analysis of vertical skirt supported fluidization reactor. The finite element methodology is used to predict the dynamic responses of the fluidization reactor.

When Reactor is non-operating condition, the parametric study of the natural frequency and mode shapes of the reactor results obtained analytically using E. Megasy method and validating results is found to be in close confirmation with FEA results.

The Static structural analysis to determine the Total Deformation and Equivalent stresses under operating condition. Discontinuity stress analysis at cone to shell and nozzle junction is carried out using ASME Sec VIII Div. 2 Part 5, stresses at junction is maximum compared to other parts in model and stresses are less than allowable stress 228.6 MPa, hence design is safe.

The Modal analysis and Random vibration analysis is performed to evaluate the Dynamic stresses and Deformation of the reactor under operating dynamic conditions using FEA (Finite Element Analysis). And also determine the Displacement Response and Acceleration Responses of the structure under random excitation force in operating condition using FEA. The results obtained from analytical process are successfully validated with Finite element analysis and good agreement found between FEA and analytical results are within allowable hence design is safe.

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