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Stress Analysis of Top Hat Type Structure for Random Loading

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Abstract

To resolve several arguments raised for the current analysis of a structure like top hat, which is composed of flange, cylinder and plate, the dynamic response analysis is performed for the full and half models. The dynamic characteristics are investigated for full and half models and the results are compared between them. The responses such as bolt reactions and stresses due to random loading are also obtained using the analysis capabilities between commercial programs which have the routine for the random vibration analysis. Several general purpose structural analysis programs are used to get the response due to the random loadings. Also the application of the random loading and the effect of correlations are studied and the general directions for the generation of design load due to random loading are suggested.

Introduction

The top hat assembly which is also called guide structure support system is one of very important structure of the reactor vessel internals. It is located on the upper part of the reactor vessel internals and is attached to the upper flange of upper guide structure by bolts. It provides the guidance for the control element assembly (CEA) extension shafts into the closure head nozzles when the closure head is being lowered onto the reactor vessel. It also provides lateral support for the CEAs when the CEAs are lowered to the upper guide structure laydown area floor.

The current analysis used half symmetric model to represent the structure like top hat for the response evaluation. For this point several arguments were raised about this model which may not show all modes. Especially if the asymmetric loadings are imposed on the structure the response between full model and half model will be different. To resolve above problem for the future nuclear power plant design, the full and half models are developed and the dynamic characteristics are compared between them. The responses such as bolt reactions and stresses are also compared.

Another issue is the difference of analysis capabilities between commercial programs which have the routine for the random vibration analysis. Several general purpose structural analysis programs like STARDYNE [1], ANSYS [2] and NISA II [3] are used to get the response due to the random loadings. The responses between them are compared and the general directions for the future nuclear power plant design are suggested.

Modal Analysis

The finite element models of the top hat structure are made using the ANSYS code and a frequency analysis of the top hat structure is performed to get the eigenvalues and eigenvectors for the full and half models. Several different codes are used and the results are compared with each other.

A modal analysis of the top hat structure is carried out to calculate the natural frequencies and modeshapes. For ANSYS run, the reduced method is used for the mode extraction where the HBI algorithm (Householder - Bisection - Inverse iteration) is applied for the calculation of the eigenvalues and eigenvectors. The master degrees of freedom were selected enough not to have missing modes. For STARDYNE run, Lanczos extraction method is used. This method is an iterative process which extracts the requested number of modes from the full size mathematical model and associated degrees of freedom.

The frequencies obtained are shown in Table 1 for full and half models. There is a good agreement between full and half model even though several flange modes are not appeared in the half symmetric model for the high frequency range. But it is not important because the mode participation factors for those modes are very low and is negligible from the response point of view. Modeshape contour plots are compared and also good agreement is reached between full and half models.

Table 1. Comparison of frequencies between full and half models.

Mode no.		*Full model*			*Half model*	
(θ, r)	*ANSYS*	*STARDYNE*	*Mode*	*ANSYS*	*STARDYNE*	*Mode*
(0,0)	*12.6*	*12.7*	*(1)*	*12.6*	*12.7*	*(1)*
(0,1)	*26.2*	*26.4*	*(2,3)*	*26.2*	*26.4*	*(2)*
(0,2)	*43.2-43.5*	*43.6-43.8*	*(4,5)*	*43.5*	*43.6*	*(3)*
(1,0)	*47.9*	*48.3*	*(6)*	*47.9*	*48.3*	*(4)*
(1,1)	*55.1*	*56.8*	*(7,8)*	*55.1*	*56.8*	*(5)*
(0,3)	*64.2*	*64.4*	*(9,10)*	*64.3*	*64.4*	*(6)*
(2,0)	*74.0*	*75.6*	*(11)*	*74.1*	*75.6*	*(7)*
(1,1)	*75.9-76.0*	*75.6-76.2*	*(12,13)*	*75.8*	*76.2*	*(8)*

Random Analysis

Using the modal analysis information, response analysis of the top hat structure for random excitations is performed to get the bolt reactions and stresses for the full and half models. Several types of forcing functions and different codes are used and the results are compared with each other.

Base Excitation

The base excitations are applied as a form of PSD at the bolt locations. They are applied to the model in a fully correlated fashion. The PSD is input up to 130 Hz which is enough to cover all important modes.

Bolt reactions and stress intensities are summarized in Tables 2 and 3. As shown in Table 2, there is a good agreement between full and half models for bolt reactions but each code generates a little different reactions. STARDYNE and NISA generate almost the same reactions which are different from those of ANSYS. This is not a problem for the designer's point of view because the design bolt reactions are calculated using the maximum of all bolts for shear, axial force and moment. Stress intensities of the plate are the same between codes but the cylinder stresses show a big difference and are not acceptable for different codes and should be investigated further even though they are not used by designer. Even though it needs more work to draw a general result, the same stresses for plate are assumed to be obtained from different codes. Therefore in the pressure excitation analysis only STARDYNE runs were made for several cases.

Pressure Excitation

The pressure PSDs are applied to the plate and cylinder in various correlated cases. Since the area in each node has three different directions upon which the PSD acts, these areas projected in the x, y and z directions are generated from the nodal weights which is available in modal analysis run. The following equations are used to calculate the projected areas ;

$$A_x = \frac{\omega_n}{\rho_{cyl} t_{cyl}} \frac{x}{\sqrt{x^2 + y^2}}, \quad A_y = \frac{\omega_n}{\rho_{cyl} t_{cyl}} \frac{y}{\sqrt{x^2 + y^2}}, \quad A_z = \frac{\omega_n}{\rho_{pl} t_{pl}}$$

where ω_n : nodal weight,
ρ_{cyl} : density of the cylinder,
ρ_{pl} : density of the plate,
t_{cyl} : thickness of the cylinder,
t_{pl} : thickness of the plate.

No projected area exists for a node on the plate ($z = 0$) except for A_x. For a node on the cylinder, no projected area exists for the z direction.

Table 2. Comparison of bolt reactions for base excitation.

Node no.	ANSYS Fx	ANSYS Fy	ANSYS Fz	ANSYS Mx	ANSYS My	STARDYNE Fx	STARDYNE Fy	STARDYNE Fz	STARDYNE Mx	STARDYNE My
Half model										
501	99.4	55.0	236.7	242.1	659.0	104.0	55.1	260.9	487.5	681.2
507	471.6	286.1	335.3	765.2	726.3	484.6	290.9	368.7	750.8	611.1
513	760.0	257.6	15.4	18.9	105.9	771.6	0.0	0.0	0.0	145.6
519	471.3	285.1	335.7	766.2	727.4	484.7	291.0	368.7	750.9	611.0
525	99.1	54.8	237.1	242.6	660.1	104.1	55.1	261.0	487.6	681.3
Total	1901.4	938.7	1160.3	2035.0	2878.7	1949.0	692.1	1259.3	2476.8	2730.2
Full model										
501	198.7	122.8	472.0	476.2	1320.1	210.0	0.0	522.0	0.0	1375.8
507	474.6	287.7	335.2	764.8	726.6	478.4	282.3	368.9	755.4	619.9
513	755.0	255.9	20.9	68.2	98.3	757.0	0.0	0.0	0.0	140.0
519	476.7	292.8	336.1	767.0	728.7	478.3	282.2	368.9	755.4	619.8
525	199.1	130.9	473.3	477.9	1324.2	210.0	0.0	522.1	0.0	1375.9
531	466.4	281.8	335.1	764.6	727.4	478.5	282.4	368.8	755.5	619.7
537	762.1	257.5	25.2	67.2	103.7	756.8	0.0	0.0	0.0	139.8
543	469.1	285.0	333.2	759.6	722.6	478.5	282.3	368.8	755.4	619.7
Total	3801.7	1914.4	2330.9	4145.6	5751.7	3847.5	1129.2	2519.5	3021.7	5510.6

Table 3. Comparison of stress intensities for base excitation (unit = psi).

Component	Location	ANSYS Half	ANSYS Full	STARDYNE Half	STARDYNE Full	NISA Full
Assembly	Top	134.0 (302.1)	134.5 (303.0)	36.9	37.0	50.2
	Bot.	135.0 (290.9)	135.6 (291.9)	58.9	59.3	43.0
Plate	Top	23.7 (36.6)	24.3 (35.9)	23.1	23.1	33.3
	Bot.	22.9 (35.9)	23.9 (36.3)	23.5	23.4	33.9
Cylinder	Top	31.6 (62.0)	31.6 (61.9)	25.7	26.2	43.2
	Bot.	51.2 (115.1)	51.3 (115.1)	58.9	59.3	51.5

( ) obtained from post-processing plot of the ANSYS POST1 run : esel,elem, . . ., plesol,s,int

Axial direction loading

The pressure PSDs are applied to the plate in the axial direction in fully correlated, partially correlated and fully uncorrelated fashions. The bolt reactions and stress intensities are summarized. As anticipated, fully correlated case generates the highest response, which is a general trend for random response analysis.

Horizontal direction loading

The pressure PSDs are applied to the cylinder in the horizontal direction in fully correlated, fully uncorrelated, partially correlated and segment correlated fashions. The bolt reactions and stress intensities are summarized. Partially correlated case generates the highest bolt reactions following segment correlated, fully correlated, fully uncorrelated case for full and half models. Figure 1, which shows bolt loads for full model, also indicates that the fully correlated and partially correlated cases give the highest reactions for axial and horizontal loadings, respectively. The differences between half and full models are not clearly clarified but it is assumed that half model gives too much conservative reactions. The stress intensities from Table 3 can be explained for plate and cylinder separately. For plate, fully correlated case gives highest stress intensities following partially correlated, segment correlated and fully uncorrelated cases. For cylinder, partially correlated case gives highest stress intensities following fully correlated, segment correlated and fully uncorrelated cases. It is noticeable that the highest stress intensities in plate and cylinder are obtained for fully correlated case and partially correlated case, respectively (Figure 2). It was anticipated that fully correlated loading generate the highest responses for all case but if it is applied in the horizontal direction it may compensate each other. This is a good explanation for cylinder to have a maximum stress in a partially correlated fashion. As in the case of the bolt reactions, the half model is assumed to generate too much conservative stresses.

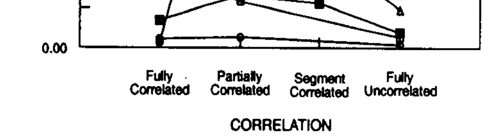

Fig. 1. Comparison of bolt reactions

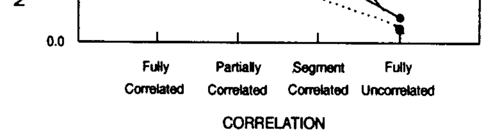

Fig. 2. Comparison of stress intensities

Concluding Remarks

The structure like top hat, which is composed of flange, cylinder and top plate is studied for the dynamic responses due to random loading. The modal characteristics between full and half models are investigated. Random responses such as reactions and stresses are obtained using several commercial computer codes. The following conclusions were reached :

1. Half model shows similar modal characteristics as full model except high frequency range which is negligible.
2. Maximum responses are obtained for the fully correlated case of axial pressure excitation random loading.
3. Fully correlated case generates the maximum responses in plate for horizontal pressure excitation random loading.
4. Partially correlated case generates the maximum responses in cylinder for horizontal pressure excitation random loading.
5. Half model gives almost the same responses as full model for the loadings of base excitation and fully correlated axial direction pressure excitation.
6. The different stresses between computer programs are obtained, sometimes which are significant, and this should be studied in the future.

Based on these conclusions, the followings are suggested for the generation of design load due to random loading :

1. For pressure excitation the fully correlated axial loading and partially correlated horizontal loading are applied to the cylinder, and the fully correlated axial loading and fully correlated horizontal loading are applied to the plate.
2. Half model of the cylinder and plate may be used for the loading of base excitation to save the computing time.
3. Care should be taken to get the stress values from the post-processing run of the ANSYS code.

References

1. GMC, *STARDYNE User Information Manual*, General Microelectronics Corporation, 1987.
2. SASI, *ANSYS User's Manual for Revision 5.0*, Swanson Analysis Systems, Inc., February 15, 1994.
3. EMRC, *NISA User's Manual*, Engineering Mechanics Research Corp., December 31, 1994