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H. Zhang, Y. Zhai, P. Titus

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Dynamic analysis and inertia load of ITER equatorial port plug EPP9 DSM2

Han Zhang[1], Yuhu Zhai[1], Julio Guirao[2], Silvia Iglesias[3], Peter Titus[1]

[1]Prineton Plasma Physics Lab,Princeton, New Jersey, hzhang@pppl.gov
[2]Numerical Analysis Technologies S.L. (NATEC), Gijon, Spain
[3]CHD, ITER Organization, Route de Vinon-sur-Verdon, CS 90 046, 13067 St. Paul Lez Durance Cedex, France

ABSTRACT

The work presented in this paper mainly focuses on the response spectrum analysis of ITER diagnostic equatorial port plug structure assembly (PPs) to extract dynamic behavior of PPs and the in-port diagnostic systems due to transient vacuum vessel (VV) movements during Non-symmetric plasma vertical displacement events (VDEs) and during the seismic loading. A generic equatorial port plug Structural (GEPP) analysis model was provided by ITER Organization (IO),   Based on the GEPP model, the US ITER equatorial port #9 Diagnostic Shielding Module (DSM) with in-port systems such as the Electron Cyclon Emission (ECE) was integrated in and the latest design of closure plate was used to replace the simple plate in the generic model too to ensure structural integrity. Two types of response spectrum analysis were performed The floor response spectra (FRS) analysis based on random vibration (PSD) is to provide the input spectra for the response spectrum analysis of next level components that will be mounted to the DSM or the closure plate The dynamic behavior of PPs and the in-port diagnostic systems due to vacuum vessel (VV) movements during plasma vertical displacement events (VDEs) and during the seismic loading is simulated with response spectrum analysis based on the deterministic method (Multi-Point Response Spectrum (MPRS)).

Keywords: EPP9; ECE; Inertia load; Response spectrum analysis.

I. MODELING OF EPP

The EPP model is based on the generic models from ITER IO[1]. The US ITER equatorial port #9 Diagnostic Shielding Module (DSM2) with in-port systems such as the Electron Cyclon Emission (ECE) was integrated in and toroidal interferometer/polarimeter (TIP) will also be included later to DSM3 when the CAD design model is provided. Latest design of the closure plate was used to replace the simple plate in the generic model too. With more accurate mass, mass distribution and stiffness of the model, the natural frequencies will be more precisely calculated, and so do the vibration behavior of PPs, the inertial loads on the whole assembly and on board components (DSM, Diagnostic first wall and PPs (fig. 1)).

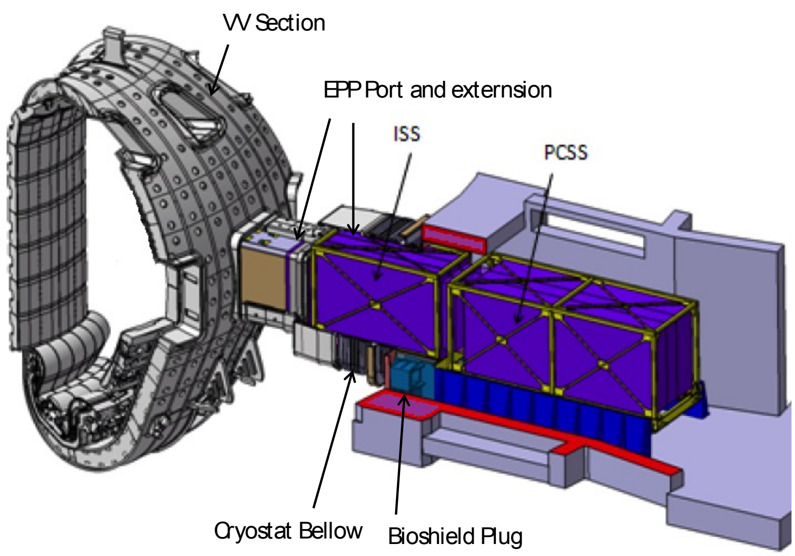

Figure 1: E9 port plug.

Two types of response spectrum analysis were done. The floor response spectra (FRS) analysis based on random vibration (PSD) is to provide the input spectra for the response spectrum analysis of next level components that will be mounted to any part of the port. The dynamic behavior of PPs and the in-port diagnostic systems due to vacuum vessel (VV) movements during plasma vertical displacement events (VDEs) and during the seismic loading is simulated with response spectrum analysis based on deterministic method (Multi-Point Response Spectrum (MPRS)).

Ansys modal and response spectrum analysis will automatically convert a nonlinear model to a linear one, but how to make conversion is not clear and this is not described in any published document. In the generic models, there are lots of contact pairs (e.g. the bolted joints and positioning mechanism etc.) and also pretensions are added to the bolts. We ran the same model under ANSYS 16.2 and 15.0 and then 17.0. With ANSYS 16.2, it doesn't converge. With 15.0 and 17.0, it does, but the results have some variance. Finally, we changed all the contact pairs to "all bonded" setting, and remove the pretensions. The variance between different ANSYS versions still exists which might be due to the internal contact stiffness setting according to the reply of ANSYS.

FRS of several points of the ECE and closure plates is provided in this report. Results of inertial loads, stress and deformation will also be discussed.

II. Boundary conditions

Excitations for PP, i.e. FRS calculated by IO, were added to the component attachment point of PP (Fig. 2). Current input spectra are from the symmetric VDE results of IO, but to estimate the rotating VDE effects, all the spectra are maximized at 5-8 Hz, which is very conservative (Fig. 3). FRS derivation is based on direct spectra-to-spectra method (random vibration analysis in ANSYS). The input is power spectrum density (PSD), which is calculated from the equation given by IO and ANSYS documentation[2]:

$$\boldsymbol{FRS(\omega_i)} = \left(S_{pi}\omega_i\left(\frac{\pi}{4\xi}-1\right) + \int_0^{\omega_i} S_p d\omega \right)^{\frac{1}{2}}$$

Where[2]:

S_{pi} = power spectral density for the ith mode (obtained from the input PSD spectrum at frequency ω_i and effective damping ratio ξ)

ξ = damping ratio (input as RATIO, DMPRAT command, defaults to .01)

However, the equation seems still problematic because the calculated PSD based on this equation will sometimes produce negative values.

Deformation, stress and reaction force etc. are calculated using the deterministic response spectrum method (Multipoint Response Spectrum analysis in ANSYS).

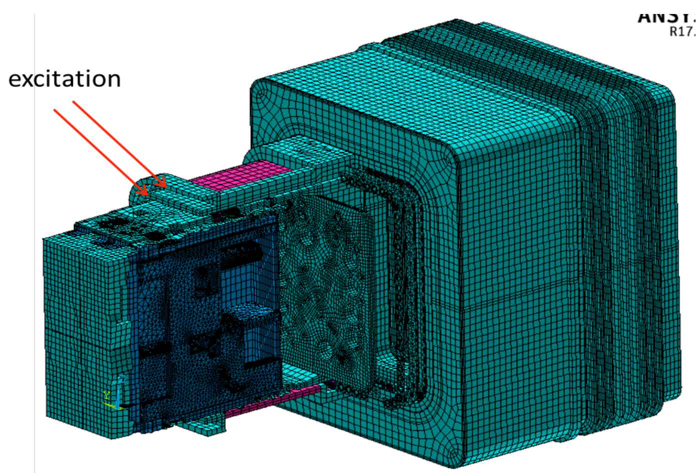

Figure 2: GEPP model with the latest design of DSM integrated.

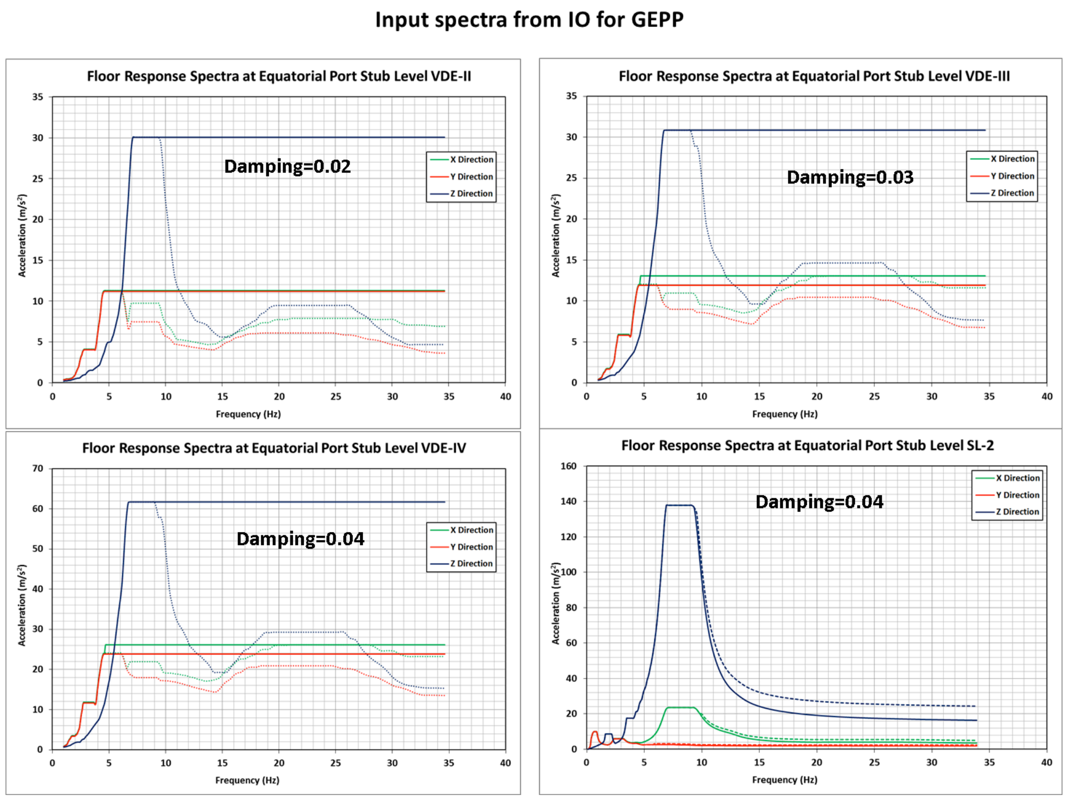

Figure 3: Input spectra from IO for GEPP.

III. RESULTS

Fig. 4 shows the major modal shapes which are related to the DSM2 of our interest. Comparing to IO's result of natural frequencies, the major frequencies are about 3~5 Hz lower, which may due to the added mass to DSMs. Fig. 5 is the output FRS at one point of the ECE of DSM2 with Envelop (broadened spectra) and Fig. 6 is at the center of closure plate. These FRS are the input of future response spectrum analysis of the component that will be mounted to this DSM. Generally speaking, future components that will be mounted to this DSM should be designed to avoid the resonance frequencies of it. If not possible, more damping should be designed and analysis should be done to evaluate the dynamic behavior.

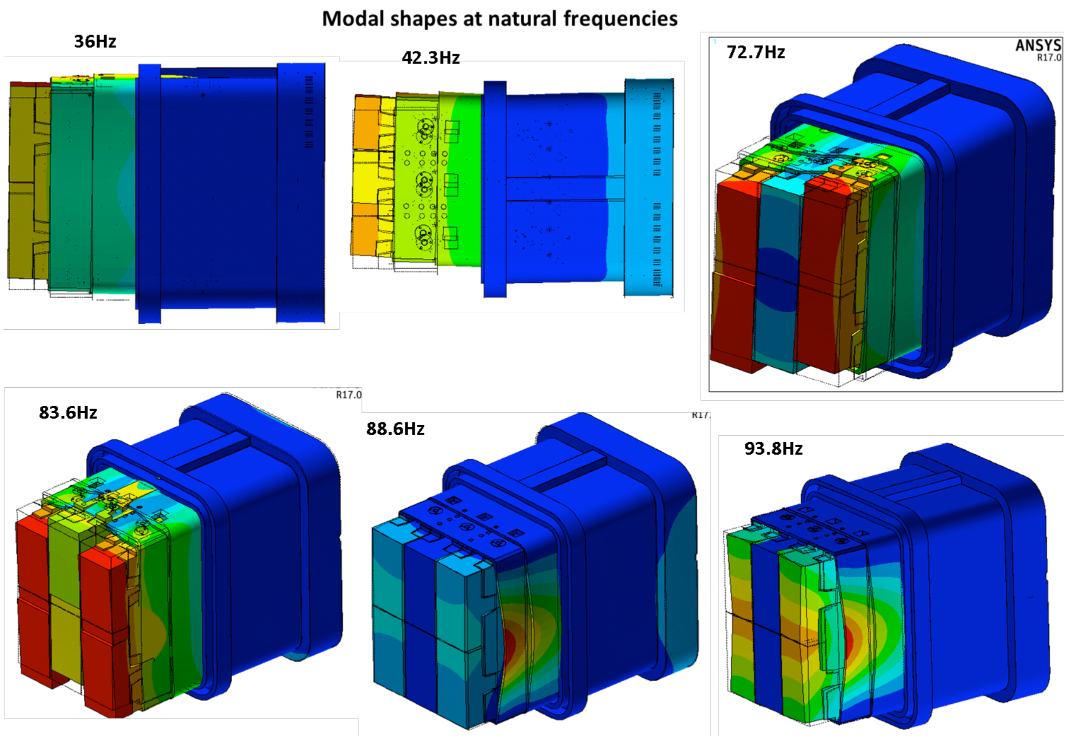

Figure 4: Major modal shapes at natural frequencies.

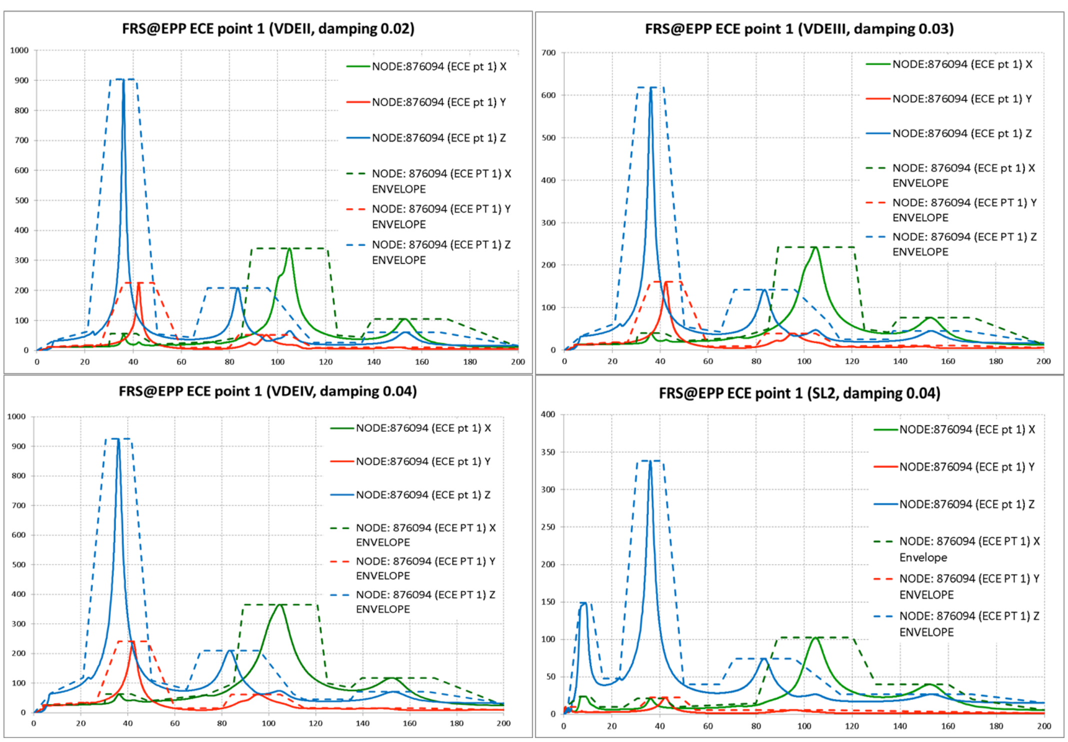

Figure 5: Output FRS at the DSM ECE (one of the six pointed selected).

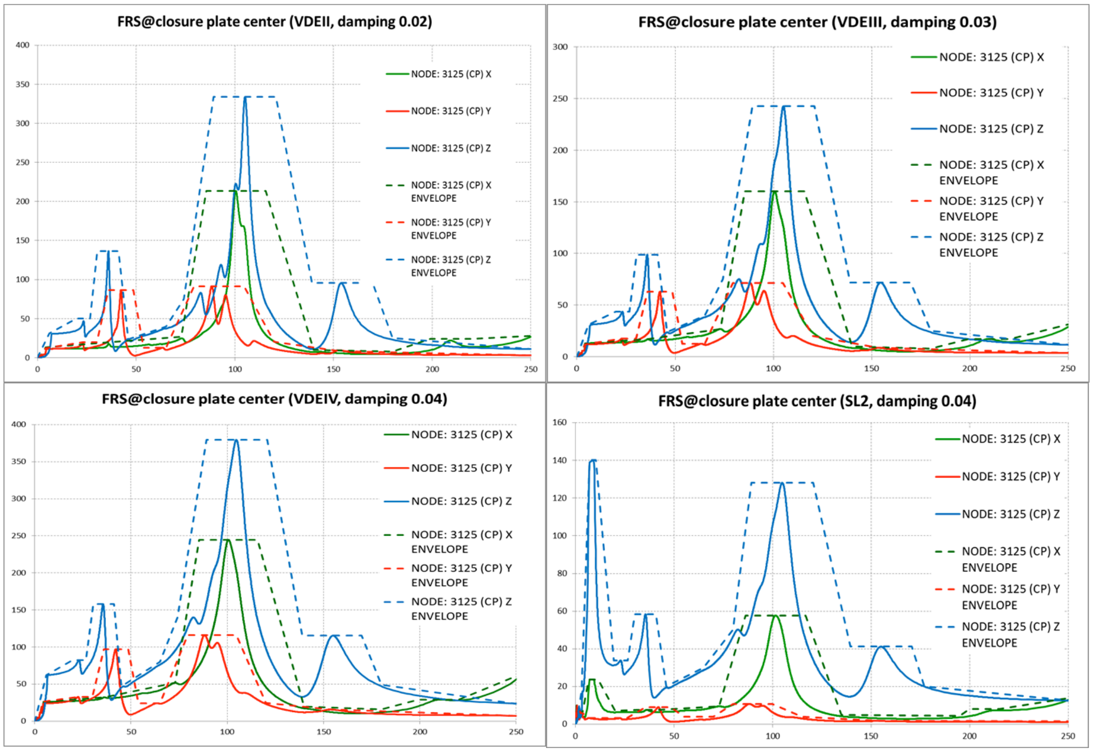

Figure 6: Output FRS at the center of closure plate.

Deformation, stress and forces are calculated based on deterministic method (MPRS+SRSS). Fig. 7 shows the deflection of EPP and Fig. 8 is a close view of DSMs upon VDEII. Peaks are all at the port extension where is more flexible. For DSMs of our interest, the max displacement is less than 1mm, in Z direction. Stress of most areas is lower than 50MPa. But around the pins that are used to fix DSMs, the stresses are higher than 300MPa. This should be due to the linearization of the model. Non-linear model should be used to evaluate the stress of these areas. Reaction forces are summed in the global coordinate. If required, summation of forces and moments can be done to other coordinate systems.

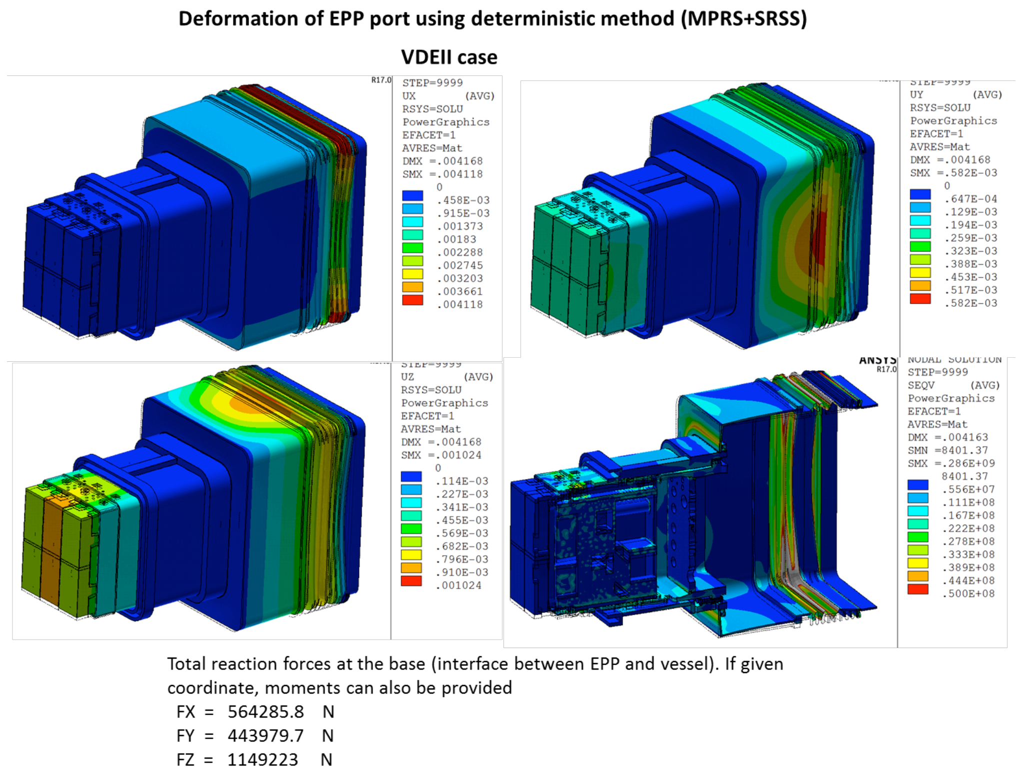

Figure 7: Deformation, equivalent stress and reaction forces of EPP.

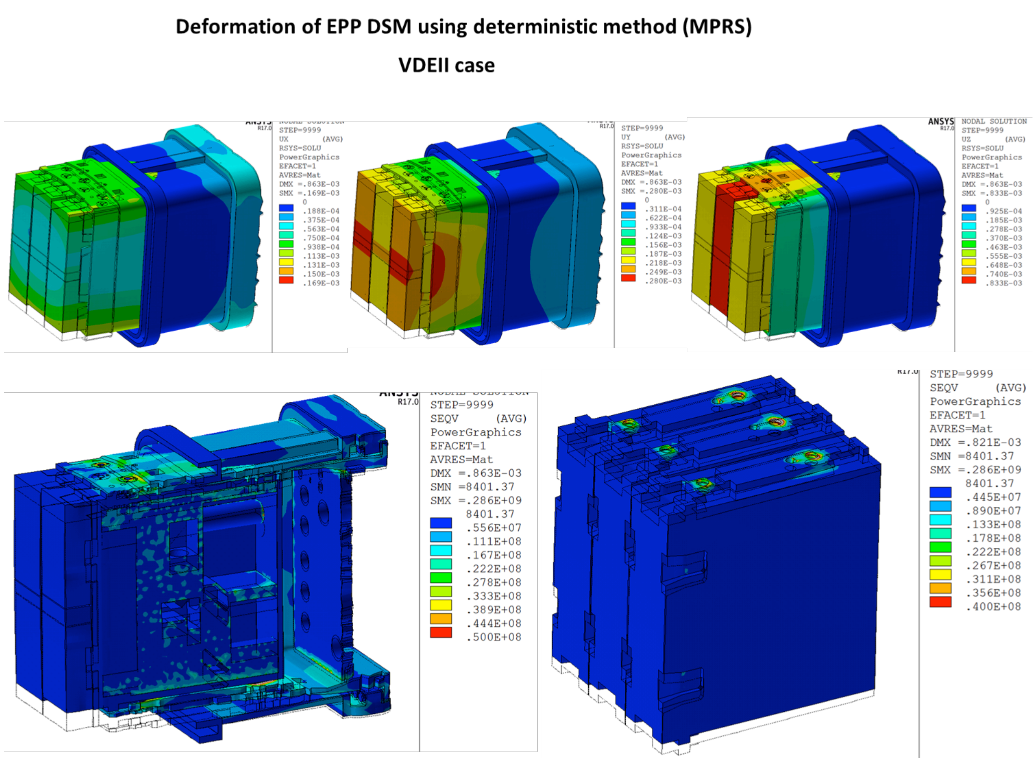

Figure 8: close view of DSMs.

IV. Conclusions and Discussions

Response spectrum analysis is used to determine inertial load. However, response spectrum analysis can only be done with linearized model. Non-linear factors, like contact pairs or non-linear material properties, will be automatically linearized. Results should be carefully checked where strong non- linearity may exist.

Current input spectra are all maximized at 5-8 Hz, which is very conservative.

Stresses are not very high at most places. For the connection areas, stresses are high which may be due to the model linearization. These stresses should be further evaluated.

Response spectrum analysis is the steady state result. For VDEs which are last only for a very short time, less than 1s, forces may be better determined by a transient analysis of the dynamic process.

Floor response spectra (FRS) are calculated with random vibration method. For the component that will be mounted to any points and is missing in this model, the FRS of that location is the input for the response spectrum analysis of the next level system components.

Although random vibration method can give the results of deformation, stress and force etc., these results for the port are simulated with deterministic method (MPRS+SRSS). Comparing the two, deterministic method (MPRS+SRSS) will produce more conservative and reliable results when input spectra can be clearly given.

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2. ANSYS documentation, https://www.sharcnet.ca/Software/Ansys/16.2.3/en-us/help/ans_thry/thy_anproc7.html.

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