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Application of Substructure Techniques to Systematically Integrated Reactor Components

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1. Introduction

To obtain more accurate dynamic characteristic results for complex systematically integrated reactor components, more detailed FE model will be adequate, but in this case, as the required resources for 3D and FE model preparation and CPU run-time become inevitably huge, the substructure technique utilizing matrix reductions is recommended .

In this study, to develop and apply substructure technique for systematically integrated reactor components, two dynamic characteristic analyses with Block Lanczos and reduced methods are performed. Also one dynamic analysis utilizing the substructure technique is done and the results of them are compared .

2. Methods and Results

2.1 3D and FE models

Total 5 assemblies including RPV assembly, UGS barrel, CSB assembly, SGC assembly, Flow Mixing Header assembly are modeled in 3D and SOLID45 and FLUID80 elements of FE program ANSYS[1] are chosen for FE analyses. SA508 Class 4 is used for material of all the components.

2.2 Dynamic Analysis for Detailed Model (Block Lanczos Method)

In this FE analysis model, fixed conditions are applied for RPV cylindrical surface and utilizing Block Lanczos method, the lowest 50 modes are calculated with the first natural frequency 29.5 Hz.

2.3 Dynamic Analysis for Detailed Model (Reduced Method)

In general, Guyan's reduction is applied when one selects reduced method for dynamic analysis, one advantage for substructure model is that reduced mass and stiffness matrices are stored into the special elements and they are used properly for other analyses later. In this analysis, dynamic analysis results subject to reduced method are compared with ones subject to Block Lanczos method to see the Guyan's reduction levels.

For Guyan's reduction, it is important to determine and select master DOF subject to mass and stiffness concentration and as the auto selection function provided by software usually chooses mass-dominant element preferentially, it is probable that thin plate structures are bypassed. On the other hand, manual selection may give more accurate results as the analysts can select master DOFs considering each component dynamic characteristics. Usually, the number of master DOFs is double the number of natural frequencies sought. In this analysis, to obtain 50 natural frequencies, 500 master DOFs are used and the calculated frequencies are compared with ones of the detailed model subject to Block Lanczos method.

Table I: Natural Frequencies Comparison

Block Lanczos (A)		Reduced Method (auto select, B)		Reduced Method (manual select, C)	
Mode	Frequency (Hz)	Frequency (Hz)	Diff[1] .(%)	Frequency (Hz)	Diff[2] (%)
1	29.522	30.223	-2.38	28.937	1.98
2	29.522	30.460	-3.18	28.939	1.97
3	71.940	83.076	-15.48	74.229	-3.18
4	75.673	83.789	-10.73	77.245	-2.08
5	75.673	87.863	-16.11	77.250	-2.08
6	83.959	103.550	-23.33	88.126	-4.96
7	83.959	105.110	-25.18	88.155	-5.00
8	92.104	106.560	-15.70	95.533	-3.72
9	92.104	109.960	-19.39	95.546	-3.74
10	92.430	118.680	-28.40	96.048	-3.91
11	95.640	124.500	-30.18	102.490	-7.16
12	141.730	156.760	-10.61	155.480	-9.70
13	142.420	159.840	-12.23	156.100	-9.61
14	142.810	168.120	-17.72	161.110	-12.81
15	146.030	169.840	-16.31	164.820	-12.87
16	146.150	172.630	-18.12	167.440	-14.57
17	151.290	173.150	-14.45	172.170	-13.80
18	160.950	178.530	-10.92	177.130	-10.05
19	160.950	190.970	-18.65	180.250	-11.99
20	162.920	192.320	-18.05	185.150	-13.64

1 : Diff = 100x(A-B)/A
2 : Diff = 100x(A-C)/A

Comparing the natural frequency results of analysis cases subject to Block Lanczos and reduced methods(auto and manual selections), for the first mode through tenth one, it is found that the maximum difference is 5% for manual selection, and 20% for auto selection.(Table I) When utilizing reduced method, it is seen that the proper master DOFs selection is important and can give accurate results.

2.4 Dynamic Analysis for Substructure Model (Block Lanczos Method)

Total 500 master DOFs which are selected manually in previous reduced method analysis are also used here and constrained nodes which will be subject to loads in seismic analyses.

For analysis models using super elements, the natural frequencies are calculated using Block Lanczos method, not reduced method, and mode shapes are obtained by expansion process in the model where super elements are generated.

Fig. 1 and Fig. 2 show the first 2 mode shapes and corresponding natural frequencies. It is seen that the exact same results are obtained when compared with the reduced method case.

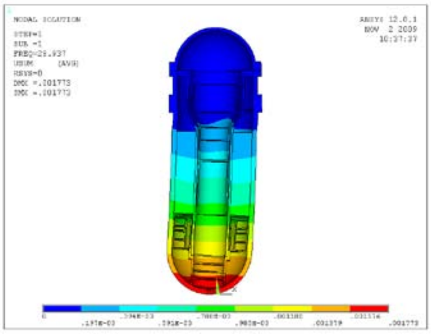

Fig. 1 The 1st mode shape (28.937 Hz)

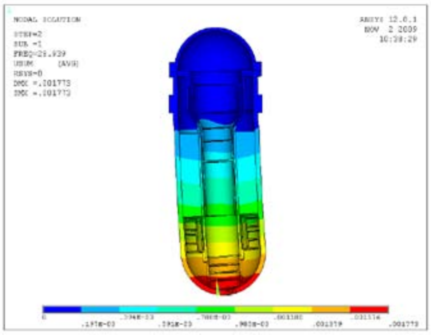

Fig. 2 The 2nd mode shape (29.939 Hz)

Table II: Natural Frequencies for Detailed and Substructure Models

Mode	Block Lanczos Method (detailed model, A) Natural Frequency(Hz)	Block Lanczos Method (substructure model, B) Natural Frequency(Hz)	Diff.[1] (%)
1	29.522	28.937	1.98
2	29.522	29.939	1.97
3	71.940	74.229	-3.18
4	75.673	77.245	-2.08
5	75.673	77.250	-2.08
6	83.959	88.126	-4.96
7	83.959	88.155	-5.00
8	92.104	95.533	-3.72
9	92.104	95.546	-3.74
10	92.430	96.048	-3.91
11	95.640	102.49	-7.16
12	141.730	155.48	-9.70
13	142.420	156.10	-9.61
14	142.810	161.11	-12.81
15	146.030	164.82	-12.87
16	146.150	167.44	-14.57
17	151.290	172.17	-13.80
18	160.950	177.14	-10.05
19	160.950	180.25	-11.99
20	162.920	185.15	-13.64

1 : Diff=100x(A-B)/A

3. Conclusions

Table II shows the first 20 natural frequencies calculated for the detailed model using Block Lanczos method and the substructure model using Block Lanczos method. It is seen that the substructure model results within 5% difference compared with the detailed model results considering the important lowest 10 modes.

Also it is found that the natural frequencies calculated from the substructure model analysis subject to Block Lanczos method are the same as ones from the detailed model analysis subject to reduced method with manual master DOFs selection.

REFERENCES

[1] ANSYS, Inc., ANSYS User's Manuals, Ver. 7.0, 2003