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Modal Characteristics of the Fuel Skeleton According to the Attachment Conditions of the Instrument Tube

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1. Introduction

The guide tube(GT)s including an instrument tube(IT) help to maintain a fuel assembly's structural integrity as main structural components under any operating conditions and postualated accidents. The GTs are attached to the spacer grid(SG)s by a mechanical welding, but diffculties in welding process of the IT with an irregauler cross section (called 'dimple') have decreased the fuel productivity. This paper is concerned with the differences of the modal characteristics of the grid cage according to the number of welding point of the IT. Three cases of the grid cage depending on the number of welding points of IT were tested using the lateral vibration test setup of FAMeCT (Fuel Assembly Mechanical Characterization Tester)[1]. Displacements at each grid elevation and an excitation force were measured during a swept sine test. The natural frequencies and mode shapes of the grid cage are obtained by a sine post processing. Comparisons of the results through the MAC suggest that there are no noticeable differences in the dynamic characterisitics of the grid cage according to the attachment condition of the IT.

2. Methods and Results

2.1 3 Cases of the Attachment Condition of IT

The grid cage consisted of 4 GTs, a center IT, 11 SGs and upper/lower end fitting assemblies. The 3 cases of the test grid cage were labeled as IT1, IT2 and IT3 which corresponded to the original cage(11 welding points), the cage having three welding points at SGs 3, 6, 9 and the cage having one welding point of the center spacer grid(SG 6). The welding point of IT was removed manually by hand tools.

2.2 Test Setup and Sine Sweep Test[2,3]

The grid cage was positioned vertically at the test stand mounted over a vibration isolation base and restrained at the top and bottom nozzles with core plate simulators of the reactor core support conditions. The test cage was compressed axially by 7.5 kN which simulated the in-core BOL cold condition. Strain-gauge type linear displacement sensors were used to measure the lateral displacement at each grid location. During the swept sine testing, an electro-magnetic shaker was attached to the test cage at the 6th grid location to apply the shaking force through the metal stinger (2mm diameter). The schematic of the overall test is also shown in figure 1. The shaker output frequency was varied from 3 to 60 Hz at a linear sweep rate of 0.02~0.05 Hz/s. The input from an electromagnetic shaker and the output from the linear gauges were stored on a data acquisition system (SYSTEM 6000) and were analyzed using I-DEAS TDAS.

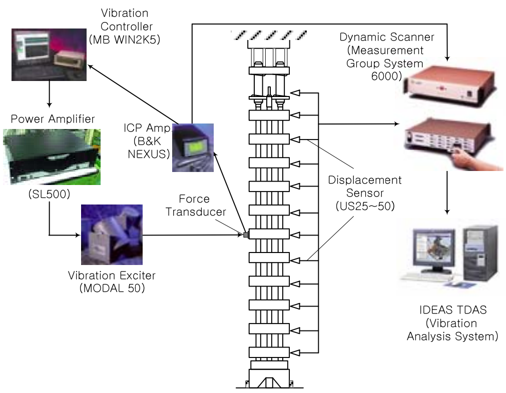
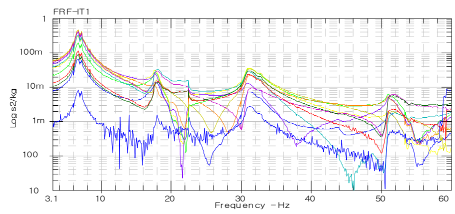


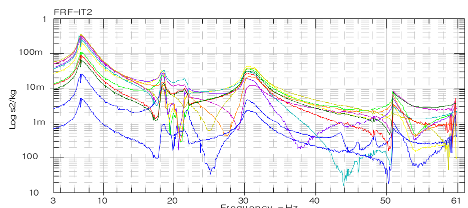
Fig. 1 Schematic Configuration of the Test Setup.

2.3 Frequency Response Functions

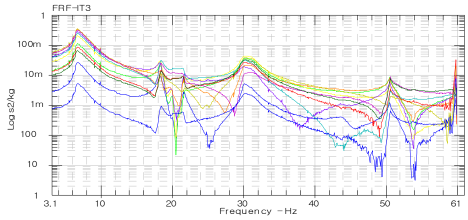
Figure 2 shows the frequency response functions measured at the each grid elevation.



(a) Case 1



(b) Case 2



(c) Case 3

Fig. 2 Frequency Response Functions of the grid cage according to the number of IT welding point to the spacer grid.

2.4 Modal parameters

Table 1 shows the natural frequencies and modal damping of the 3 cases of the grid cages. Maximum difference in the natural frequency is wihin the allowable range by 3.43% in the 2nd mode of IT2.

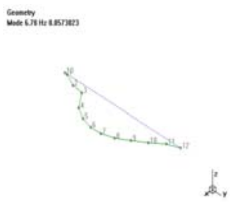
Table 1 Modal parameters of the grid cage

Case	Mode	ω^*(Hz)	ζ^*(%)	Diff. ω(%)
1 (IT1)	1 2 3 4	6.813 17.745 31.047 51.428	4.652 2.129 1.445 0.431	- - - -
2 (IT2)	1 2 3 4	6.919 18.354 30.475 51.201	3.059 0.896 1.468 0.873	1.56 3.43 1.84 0.44
3 (IT3)	1 2 3 4	6.761 18.323 30.454 50.677	7.664 0.689 3.039 0.521	0.76 3.26 1.91 1.46

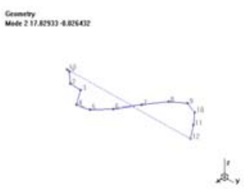
*) ω: natural frequency
ζ: modal damping ratio

2.5 Mode shapes

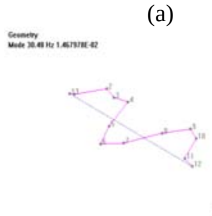
Fig. 3 represents the mode shapes of the grid cages from 1st to 4th lateral vibration mode.



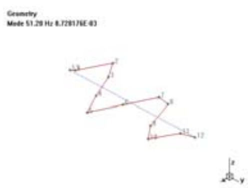
(a)



(b)



(c)



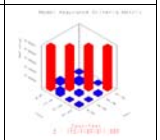
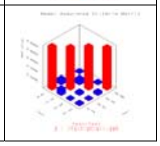
(d)

Fig. 3 Mode shapes of the grid cages;(a) 1st mode, (b) 2nd mode, (c) 3rd mode and (d) 4th mode.

2.6 Mode comparison through the MAC

Mode assurance criteria(MAC) was used to compare the similarity between the two test sets. Table 2 shows that the values of the diagonal elements in the MAC matrix have nearly 1.0 which means a perfect similarity.

Table 2 Mode comparison of the IT1, IT2 and IT3

Case		IT1				MAC graph
	Mode	1	2	3	4	
IT2	1 2 3 4	0.993 0.131 0.017 0.038	0.107 0.983 0.069 0.016	0.025 0.120 0.991 0.054	0.035 0.005 0.028 0.968	
IT3	1 2 3 4	0.995 0.131 0.020 0.036	0.116 0.975 0.052 0.018	0.022 0.122 0.991 0.057	0.026 0.005 0.035 0.966	

3. Conclusion

A grid cage with different numbers of the welding points fo the IT was tested using the lateral vibration test setup of FAMeCT. Frequency response functions at the 11 spacer grids locations were obtained from a swept sine vibration test and sine post processing. Natural frequencies, mode shapes and MAC were compared to each other. There were no noticeable differences in the modal parameters according to the attachment conditions of the IT to the skeleton. Therefore, it is suggested that a reduction of the welding points of the IT would have no effect on the structural integrity of the fuel assembly from the vibration perspective.

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