FIV Estimation for the Reactor Internal Structure of SMART

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1. Introduction

It is necessary to confirm the possibility of flow-induced vibration of upper ICI guide tubes and CRA extension guide tubes, since they are exposed to the cross flow of the coolant.

This study will provide an estimation of the flow-induced vibration owing to the vortex shedding by carrying out a free-vibration analysis of the structures, not only in air but also in water using a commercial finite element analysis code, ANSYS, and also by comparison with the vortex shedding frequency.

2. Vortex shedding frequency and added mass effect according to coolant flow

2.1 Vortex Shedding Frequency

The Strouhal number (*S*) is the dimensionless parameter between the predominant frequency of vortex shedding and the free stream velocity divided by the tube outer diameter [1].

$$f_S = SU / D \qquad (1)$$

Where f_s is the vortex shedding frequency, *U* is the free stream flow velocity approaching the tubes, and *D* is the tube diameter. The Strouhal number for flow within the arrays of tube is given in Fig. 1. It was known that the Strouhal number depends on the tube diameter and the average flow velocity through the minimum area between the tubes.

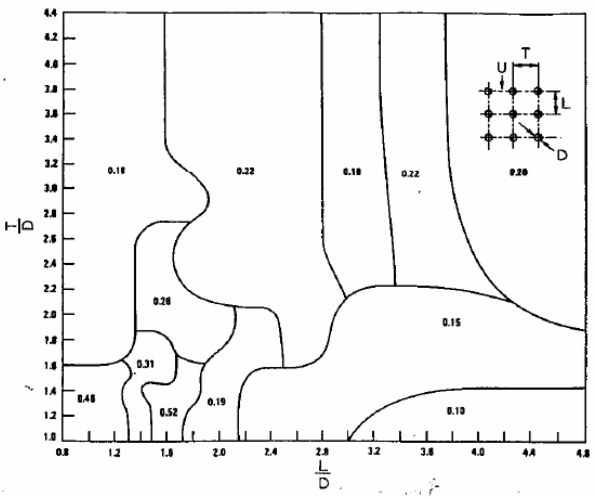


Fig.1 Strouhal numbers for inline tube arrays [1]

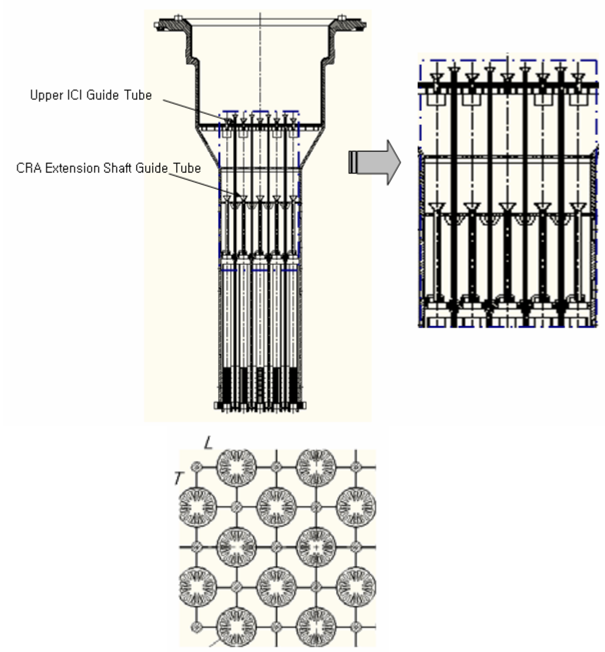


Fig.2 Aggregate shape of the SMART upper guide structure

Fig. 2 shows the schematic figure of the upper ICI guide tubes and the CRA extension shaft guide tubes of the aggregate shape of the SMART upper guide structure. The Strouhal number for the array of these tubes can be decided as *S=0.22,* based on the width (*T*) between the tubes and the length (*L*) between the tubes. The vortex shedding frequency for the ICI guide tubes and the CRA extension shaft guide tubes are determined by Eq.(1), respectively.

f_s =4.67 *Hz for* the ICI guide tubes,

f_s = 3.38 *Hz for* the CRA extension shaft guide tubes.

2.2 Added mass estimation

The added mass of the coolant for the single upper ICI guide tube and the single CRA extension shaft guide tube can be decided because the gap between the tube is wide enough to be considered as a single tube in an infinite coolant. Therefore, the total added mass of the coolant will be decided as

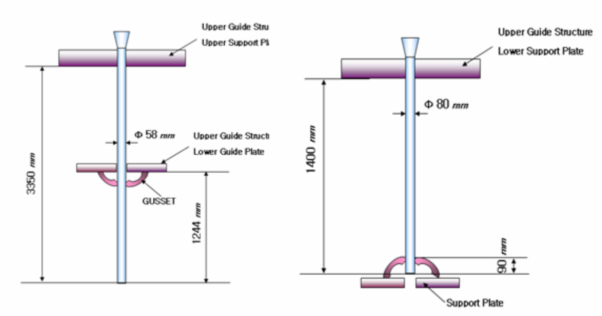
$$M_O = \rho_O \times V \qquad (2)$$

Where, ρ_O is the coolant density at a normal operating condition, and *V* is the displaced volume of the tube in the coolant.

Therefore, the total calculated added mass for the single ICI guide tube is 5.93 kg, and the total calculated added mass of the single CRA extension shaft guide tube is 4.72 kg.

3. Analytical model and result

The finite element analyses were carried out by using an ANSYS code, based on the input data obtained in the previous section. Fig.3 illustrates schematic models of the upper ICI guide tube and the CRA extension guide tube used in the calculation. The lowest natural frequencies and mode shapes obtained by FEM are shown in Table Ⅰ~Ⅳ and Figs 4 and 5. As shown in the Tables, it is found that the discrepancies between the analytical and the FEM results are small.



(a) Upper ICI guide tube (b) CRA extension shaft guide tube

Fig.3 Schematic diagram of the reactor internal tubes

4. Conclusions

Since the fundamental wet natural frequencies of the upper ICI guide tube and the CRA extension shaft guide tube are far from the vortex shedding frequencies, it was confirmed that the possibility of resonance due to the vortex shedding of the coolant cross flow is low.

Table Ⅰ: Comparison of FEM and analytical natural frequencies (Hz) for the simplified model (neglecting gusset) of the upper ICI guide tube.

mode	Dry frequency (Hz)		Wet frequency (Hz)	
	FEM	Theory	FEM	Theory
1st	4.56	4.58	3.80	3.82
2nd	28.58	28.71	23.82	23.94
3rd	80.00	80.41	66.68	67.03

Table Ⅱ: Comparison of FEM natural frequencies for the real model (considering gusset) of upper ICI guide tube.

mode	Dry frequency (Hz)	Wet frequency (Hz)
1st	39.98	33.32
2nd	63.27	52.73
3rd	172.91	144.10

Table Ⅲ: Comparison of FEM and analytical natural frequencies (Hz) for the simplified model (fixed B. C.) of the CRA extension shaft guide tube.

mode	Dry frequency (Hz)		Wet frequency (Hz)	
	FEM	Theory	FEM	Theory
1st	195.83	202.18	183.28	189.26
2nd	520.86	556.87	487.49	521.28
3rd	978.67	1092.65	915.97	1022.83

Table Ⅳ: Comparison of FEM natural frequencies for the real model (considering gusset) of the extension shaft guide tube.

mode	Dry frequency (Hz)	Wet frequency (Hz)
1st	210.7	197.20
2nd	553.37	517.92
3rd	1022.80	957.26

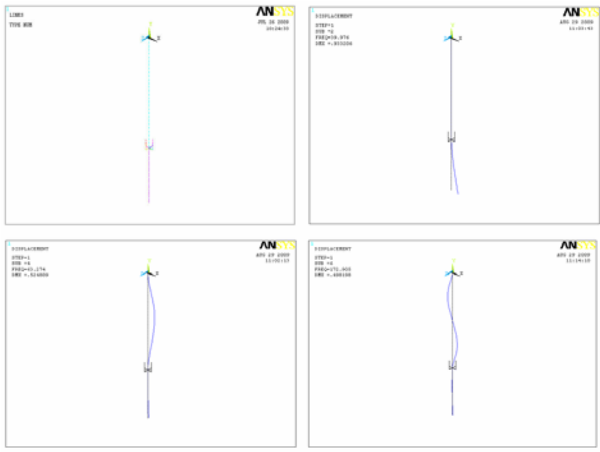


Fig.4 Mode shape of the upper ICI guide tube

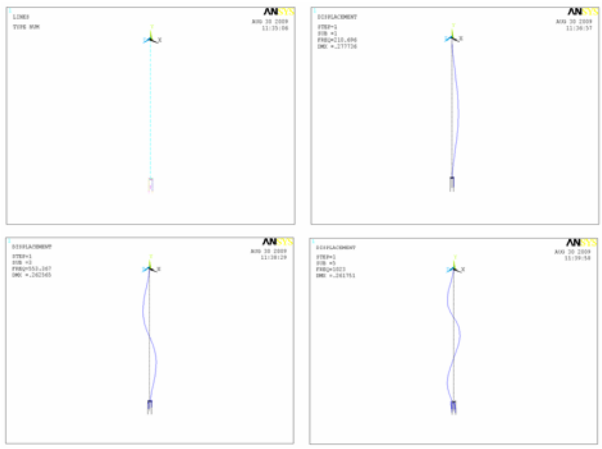


Fig.5 Mode shape of the CRA extension shaft guide tube

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[3] ASME Steam Table.