Modal Analysis of a U-tube Model for the Steam Generator with Experiment and Computation

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1. Introduction

In the PWR (pressurized water reactor), the steam generator (SG) is a kind of heat exchanger that transmit the heat energy from the reactor to the secondary circulation water-vapor mixture. SG is a tower consisting of many U-tubes fixed in the narrow space, inside of which flows the primary pressurized water, and outside the vaporized one goes to the turbine. Recently, the material of U-tubes is Inconel 690 [1].

The pressure drop in the U-tube generally increases due to corrosion and precipitation [2]. Especially, the fluid-structure interaction, or the fluid-induced vibration is one of the main cause of wear of pipe.

In this paper, we constructed a reduced apparatus to model simply the effect of fluid-structure interaction [3], shown in Fig. 1(a) as a schematic. The U-tube is located to measure the vibration in the experimental setup.

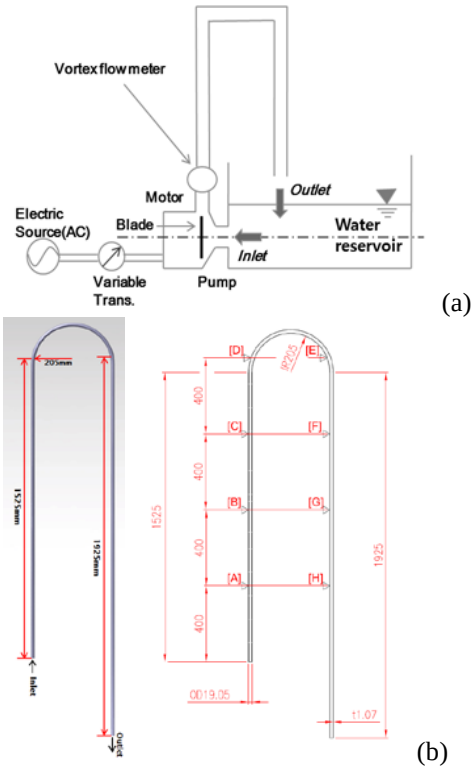

Fig. 1. Experimental Setup [2]

The size and dimension of the model U-tube is also given in Fig. 1(b), which is made of the real U-tube used in the SG of a nuclear power plant. Though the similarity scale is not considered here, but this experimental model displays the physics of fluid-structure interactions.

2. Methods and Results

In this section, experimental and numerical method used in the research is explained with some results.

2.1 Experimental Methods

With accelerometers located in [A] to [H] in Fig. 1(b), the time history of acceleration is measure and transformed to FFT (fast Fourier transform) data in the frequency domain: Fig. 2.

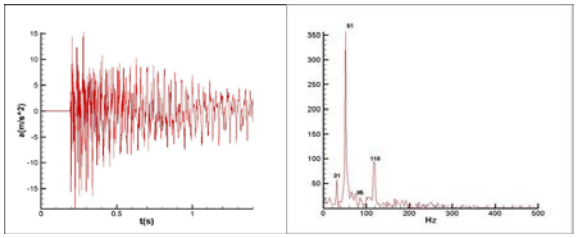

Fig. 2.Time History and Its FFT Data

2.2 Preliminary Data

The U-tube model is hanged on the ceiling of laboratory, and with hammer this model is forced to vibration. The frequency is measured in experiment, and the mode shape is visualized with the numerical simulation using a commercial code, COMSOL: Fig. 3.

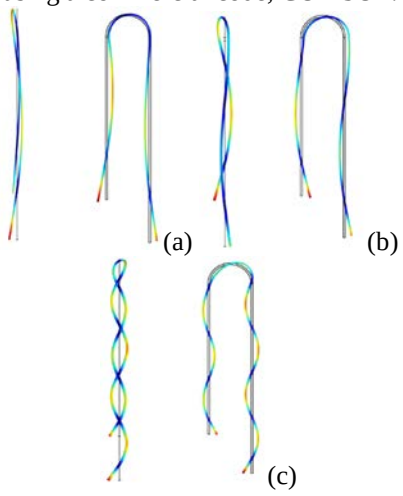

Fig. 3. Mode Shapes Computed: (a) Mode 1, 26 Hz, (b) Mode 2, 43 Hz, (c) Mode 3, 301 Hz.

Table I: Natural Frequencies (Hz)

Mode	Experiment	Computation
1	51	56
2	104	99
3	152	151

2.3 Comparison of Experiment and Computation

The boundary condition is set as Fig. 4 where the fixed point is the same as the experimental setup in Fig. 1. The structure is filled with water, and the added mass should be considered in this case. Table I is the comparison for the natural frequencies of leading modes.

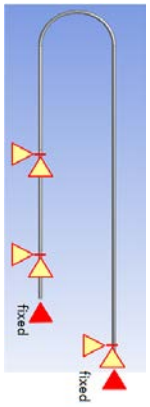

Fig. 4. Boundary Conditions

The corresponding mode shapes are also shown in Fig. 5, which are three-dimensional.

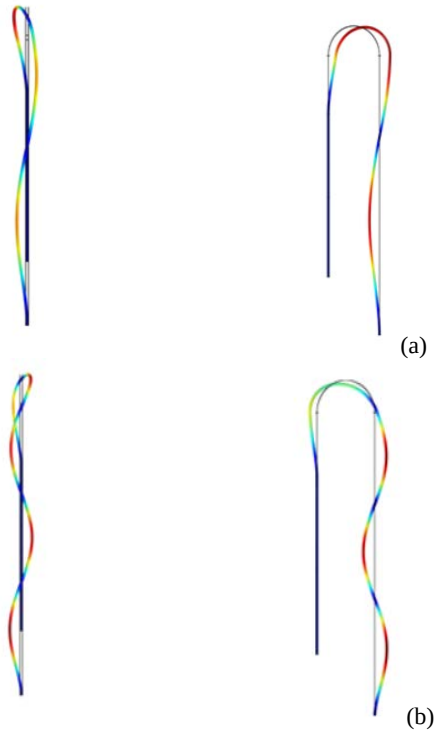

Fig. 5. Modal Shapes: (a) Mode 1, (b) Mode 2.

3. Conclusions

A simplified model for the U-tube of SG of PWR is proposed, and the experimental measurement is compared with computational result. Before the investigation of fluid-structure interaction, the isolated modes are studied for modal shapes as well as natural frequencies. The data lies in a reasonable range, and will be extended for the nonlinear interaction regime in the future.

REFERENCES

[1] C. H. Park, Heat Transfer Tube in Steam Generator of Nuclear Plant, Nuclear Industry, Vol. 33, No. 5, p. 51, 2013.
[2] J. H. Park, S. M. Chang, S. Y. Lee, G. W. Jang, The Correlation of Pressure Drop for Surface Roughness and Curvature Radius in A U-Tube, Journal of Computational Fluids Engineering, Vol. 20, No. 1, p. 39, 2015.
[3] G. H. Gim, S. M. Chang, S. Lee, G. Jang, Fluid-Structure Interaction in a U-Tube with Surface Roughness and Pressure Drop, Nuclear Engineering and Technology, Vol. 46, No. 5, p. 633, 2014