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Dynamic Characteristic Tests for a Submerged Cantilevered Cylindrical Structure

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1. Introduction

A structure immersed in a liquid shows a gain in mass from a viewpoint of the dynamic characteristic and thus it causes the decrease of its natural frequency [1]. A cylindrical structure is often applied in industrial equipment such as a storage tank and plant equipment such as pressure vessel and internal structures. A Upper Internal Structure (UIS) is one of a typical cylindrical structure in a Sodium-cooled Fast Reactor (SFR). Unlike the Pressurized-Water Reactor (PWR) system, the internal cylindrical structures in a pool-type SFR is partially immersed in a coolant and immersion level is dependent on the operation condition. Since the dynamic characteristic of an UIS according to the immersion level should be considered significantly in a structural design, corresponding experimental tests were carried out to assess its characteristics in this study. The dynamic characteristic tests for a cylindrical structure with respect to various immersion levels were carried out and numerical analyses were also performed for comparison.

2. Test Equipment and Measurement System

2.1 Test Equipment

The test equipment consists of a test model, a support structure and a water chamber. The test model is a cylindrical structure simulating the UIS outer shell. The UIS in an SFR provides lateral support and protection for control rod drivelines and instrument guidelines against the flowing sodium condition. In addition, it also promotes the mixing of primary sodium as it exits the core assemblies [2-3].

The test model is composed of a simple cylinder without any hole. A thick circular plate is welded to the lower end of the cylinder and its upper end is welded to the fixture to fix it on the support structure. The test model is made of stainless steel and its outer diameter and thickness are 165.2 mm and 2.8 mm, respectively. The overall length of a cylinder and the thickness of thick circular plate are 0.8 m and 0.1 m, respectively. A seamless pipe was used for a cylinder to exclude the welding effect and enhance the machining precision.

The UIS is welded to the rotatable plug installed on the reactor head and cantilevered downward into the reactor core without any horizontal support. Therefore, the boundary conditions of the upper and lower ends of the UIS are the fixed-end and free-end, respectively. To apply the fixed support boundary condition in a test, a support structure was prepared. It is composed of a horizontal support plate and a vertical column. The test model is supported by the support plate and they are fastened each other with bolts.

The water chamber to provide the liquid immersion level was prepared and placed inside the support structure. Its inner diameter is 0.3 m and it is made of stainless steel. The test equipment is shown in Fig.1

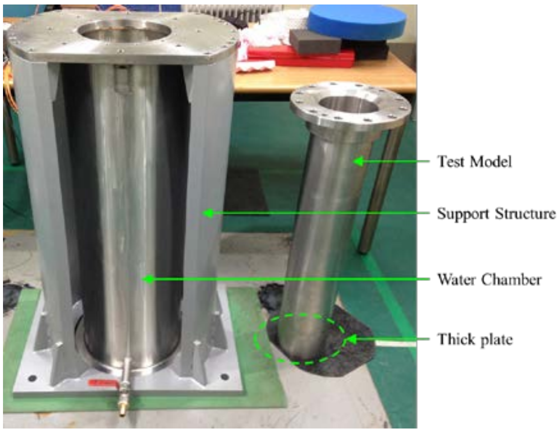

Fig. 1. The test equipment for dynamic characteristic tests.

2.2 Measurement System

Because the test was performed in-fluid condition as well as in-air condition, immersible integral cable type accelerometer were applied. Accelerometers were mounted on the test model and connected to the Front-End device (LMS SCADAS Mobile SCM02). The test data are collected in the PC system through the Front-End device. An impact hammer was used for the excitation.

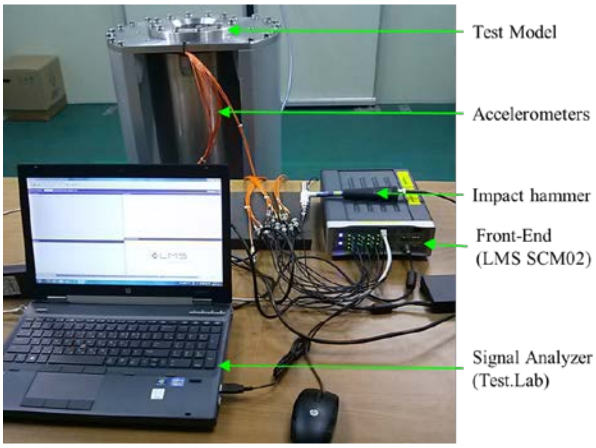

Fig. 2. The measurement system and test equipment applied in dynamic characteristic tests.

The LMS Test.Lab software was applied to control the Front-End device and analyze the collected test data for natural frequency, mode shape, and so on. Figure 2 shows the measurement system applied in test equipment.

3. Dynamic Characteristic Tests

3.1 Test Results

Dynamic characteristic tests for a simple cylindrical structure with a top support condition were carried out in air and various immersed conditions in a liquid. The dynamic responses were measured at several axial and circumferential positions. The 1st mode was expected to be in a low frequency region less than 100 Hz from the result of the numerical analysis. The tests were performed for the various immersion levels in a liquid as well as in-air condition. Water was used as a liquid for immersion conditions. Immersion levels for tests were 20%, 40%, 60%, 80% and 100%.

Figure 3 shows the frequency response function and coherence function of the test performed in an air condition. As shown in Fig. 3, the magnitudes of coherence functions which verify the reliability of this test results was almost 1.0.

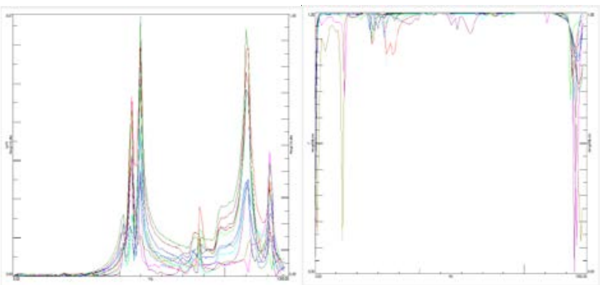

Fig. 3. Frequency response function and coherence function for the dynamic test in an air condition.

3.3 Numerical Analysis

Numerical analysis by using an FEM commercial software ANSYS [4] was carried out for comparison with the test results. Element types used in the numerical analysis were SOLID185 and FLUID30 for the structure and fluid, respectively. A numerical model was prepared and analyses were performed for the all conditions. Figure 4 shows the analysis results with full-shaped model.

Figure 5 compares both test and analysis results with respect to the immersion level. The dominating mode shape measured from the test was the 1st bending mode. Test results show that the natural frequency does not change linearly with respect to the immersion level as shown in Fig.5. The natural frequency shows a tendency to decrease as immersion level increases. But for over 80% immersion level, the natural frequency is almost stationary. This means that the effect of fluid added mass on the test model increases as the immersion level increases in the low immersion region while it becomes saturated for over 80% immersion level condition. From Fig. 5, it can also be seen that analysis results have a good agreement with test results for all immersion levels.

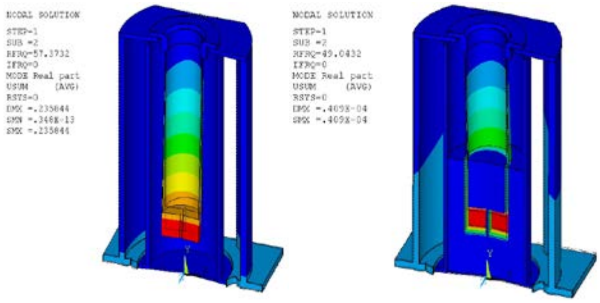

Fig. 4. Numerical analysis results for the in-air condition and 40% immersion condition in water.

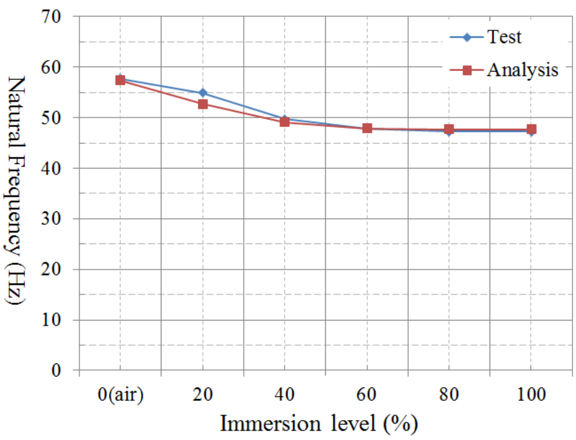

Fig. 5. Comparison of test and analysis results for the natural frequency of the 1st bending mode with respect to immersion level.

4. Conclusions

Dynamic characteristic tests for a cantilevered cylindrical structure were performed for the various fluid immersion levels. The natural frequency decreased as the immersion level increased due to the influence of the fluid added mass. For the test model, the natural frequency of the 1st bending mode decreased about 18% compared with that in an air condition. The decrement of natural frequency in the low immersion level is greater than that in the high immersion level. The numerical analyses were also carried out for comparison with the test result. Analysis results agreed well with test results and the effect of immersion level on the natural frequency of the test model was assessed.

Acknowledgement

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