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Structural Integrity Evaluation for the Perforated Plate of a PCS Discharge Header Using Power Spectral Density Analysis

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1. Introduction

The structural integrity evaluation for the perforated plate of a Primary Cooling System Discharge Header (PCSDH) is very important in terms of nuclear safety. The main function of PCSDH is to discharge stably coolant into the reactor pool, a duct type PCS discharge header is placed at the end of the pool inlet PCS pipe. Many slots are made in the header to discharge the coolant slowly for minimizing disturbance of hot water layer by the flow mixing inside pool. The PCSDH is made of stainless steel 304L. The PCSDH is not connected to the PCS pipe to minimize stress caused by the thermal effect. This design is evaluated by CFD analysis not to affect the coolant distribution in reactor pool. Since the PCSDH does not perform any nuclear safety function, it is designed as Non Safety Class, Seismic Category II, and Quality Class T. The perforated plate installed inside PCSDH plays part in discharging the coolant slowly into the reactor pool. The perforate plate is affected by various loading such as seismic load, thermal load, flow induced vibration, and etc. Specially, the pressure induced by flow gives the main effect to the structural integrity of the perforated plate. The objective of this study is to show the structural validity of the perforated plate affected by a blow of turbulence flow through a power spectral density analysis. The analysis results will give an important basic data in designing the perforated plate inside the PCSDH.

2. Structural Design and Modeling

2.1 Structure Design

The PCSDH is composed of perforated plate, supporter, plate, nozzle, etc. The PCSDH is installed on the floor of the bottom of pool liner. The configurations of the PCSDH and perforated plate are shown in Fig. 1 and Fig. 2.

The fluid induced vibration caused by the coolant flow is the most generated in the perforated plate of the PCSDH. Since the static and dynamic hydraulic load is frequently applied during the life time of reactor, in order to avoid this excessive vibration, the perforated plate has to be designed. To address this problem, the reinforcing material was designed on the lower part of perforated plate and the configuration is shown in Fig. 3.

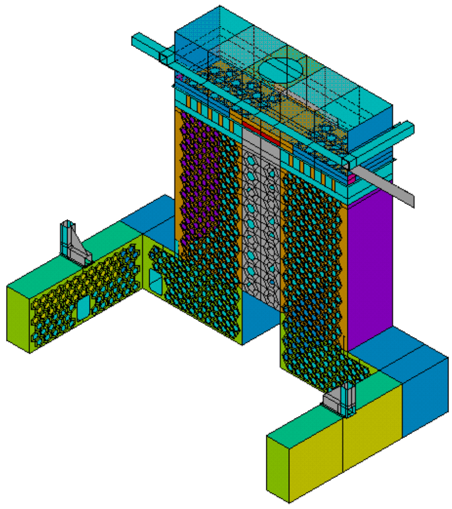

Fig. 1. Configuration of the PCSDH

2.2 Finite Element Model

The 3-D finite element model of the perforated plate of the PCSDH was developed by utilizing the ANSYS program. All parts of the perforated plate are modeled as solid elements and non-structural masses. The boundary conditions of the PCSDH are shown in Fig. 6 and Fig. 7. The fixed boundary conditions of the displacement and rotation are imposed on stiffener and outer region of perforated plate, since it is welded to the front and back plates of the PCSDH.

Fig. 2. Configuration of perforated plate in the PCSDH

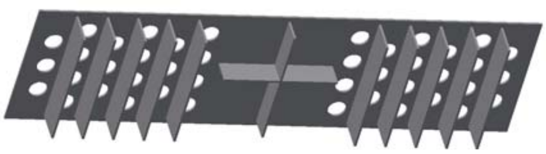

Fig. 3. Configuration of reinforced perforated plate in the PCSDH

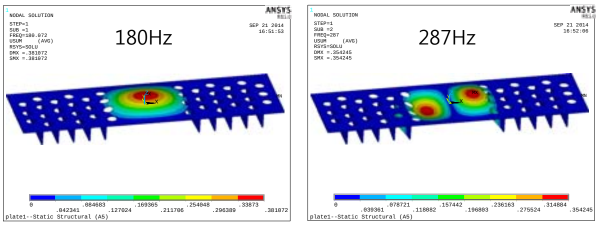

Fig. 4. Natural frequencies and mode shapes of perforated plate

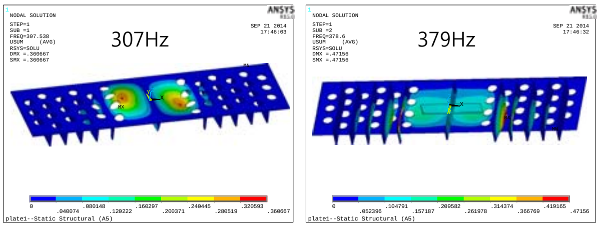

Fig. 5. Natural frequencies and mode shapes of reinforced perforated plate

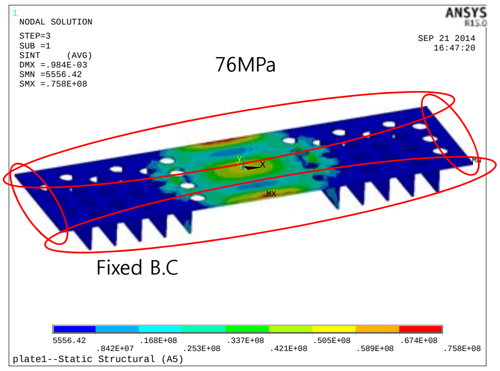

Fig. 6. Stress Intensity of perforated plate in the PCSDH

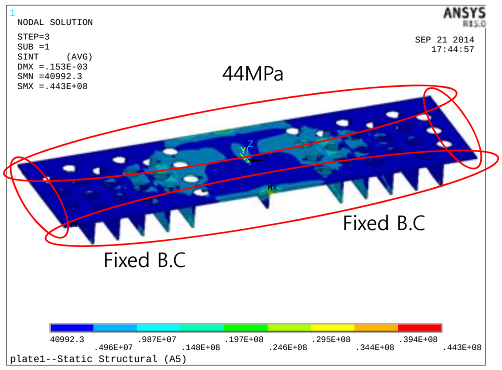

Fig. 7. Stress Intensity of reinforced perforated plate in the PCSDH

3. Numerical Analysis and Evaluation

3.1 Modal Analysis

To investigate the dynamic characteristics of the perforated plate, a modal analysis of the developed finite element model is performed. Typical measurements of the dynamic characteristics, natural frequencies and mode shapes are obtained. Fig. 4 summarizes two mode shapes in the structural model of the original perforated plate. The first and second natural frequencies are observed to be 180Hz and 287Hz, respectively. The natural frequencies of reinforced perforated plate represent 307Hz and 379Hz because the stiffness of perforated plate increases, reinforcing the plate with the stiffener.

3.2 Power Spectral Density Analysis

The random turbulence load is defined as the power spectral density, which is the form of the pressure square per frequency. The fluid induction hydraulic load was classified as the periodic and the random components as per the change or non-change over the time and it was assumed that the periodic and random components were no correlation. The power spectral density analysis as a method to obtain the statistical stress is widely used to evaluate the structural integrity of structure under the random pressure.

3.3 Structural Integrity Evaluation

The structural integrity of the perforated plate against the turbulence blow was evaluated by using the power spectral density. The maximum stress intensities of the original and reinforced perforated plate are 76MPa and 44MPa which is less than the structural design limit of 150MPa, as shown in Fig. 6 and Fig. 7, respectively. The weakest location is made in the center welding part between perforated plate and center position of PCSDH.

4. Conclusion

The structural integrity of the perforated plate against the turbulence blow of coolant flow has been evaluated. For this purpose, 3-D finite element models of the perforated plate of PCSDH were developed. A modal analysis and power spectral density analysis were then performed. From the structural analysis results, the maximum stress of perforated plate is below the structural design limit of 150MPa and the plate structurally withstand under the turbulence blow. Therefore, it is concluded that the perforated plate in PCSDH was safely designed in that no damage to the preliminary structural integrity and sufficient structural margin is expected.

Acknowledgements

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