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Analysis for structural integrity and system stability of design improved strainer installed in feedwater system

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1. Introduction

Main feedwater system of nuclear power plants (NPPs) supplies feedwater to steam generators from the deaerator storage tank during normal operation. Two motor-driven booster pumps and two turbine-driven pumps play a role in supplying the feedwater to the steam generator. In this system, the strainer is installed in front of the feedwater booster pumps, and its function is to prevent the tubes of high-pressure heater, low-pressure heater, and steam generator from being damaged by the influx of foreign material. However, since the strainer is vulnerable to reverse differential pressure, it may be damaged when the inverse flow path is formed during the operation and maintenance. This can lead to the inflow of foreign material and the loss of the integrity of the system and components. Recently, thus, improvement in the design of strainer has been attempted. This study performed the analyses to confirm the adequacy of design improvement in terms of structural integrity and system stability.

2. Analysis Methods and Results

In order to evaluate the adequacy of the design improvement of strainer, the pressure difference between the inlet and outlet of the newly designed strainer was analyzed under normal and design flow conditions with assumptions of 0% and 50% clogging. The stresses of the strainer by pressure difference were calculated, and the structural integrity of the strainer was confirmed for different operating conditions. Also, the effect of strainer on the total head and NPSH of the pump and on the stresses in the piping system were evaluated.

2.1 Fluid flow and stress analyses

Flow analysis was performed to evaluate the pressure difference across the strainer. ANSYS code, which is a commercial finite element (FE) program, was used for the analysis. The analysis was performed at four different operating conditions, *i.e.*, normal and design flow conditions with 0 and 50% clogging. Fig. 1 shows a sample of analysis result. The analysis results showed that the maximum pressure difference was calculated to be 23.5 kPa. Considering that the pressure difference of the originally designed strainer is 337.0 kPa, it can be seen that the pressure difference of 23.5 kPa is low enough.

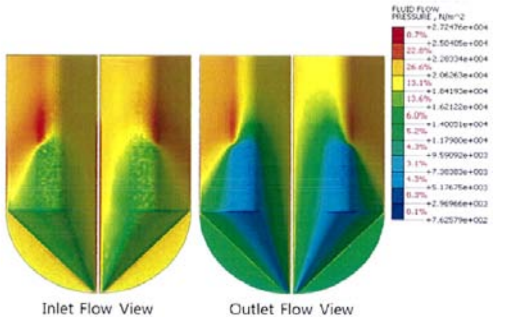

Fig. 1 Pressure distribution under normal flow condition with 50% clogged

The stress analysis was performed using ANSYS program using the different differences resulted from the flow analysis. Fig. 2 presents the sample of stress analysis. The results showed that the stresses applied to the strainer depended on the assumed operating conditions. For all conditions, however, the maximum stress in the strainer was less than the allowable stress limit of the material. Thus, this indicates that the design improved strainer has the appropriate structural integrity required by the design code.

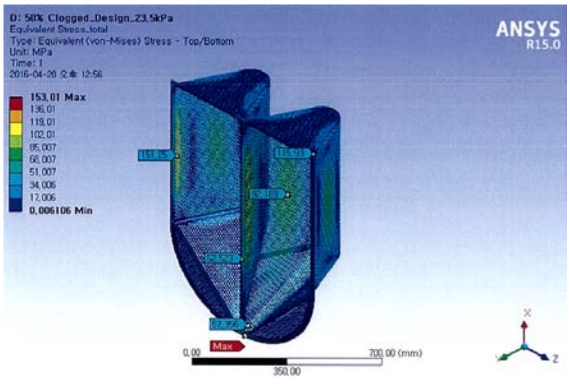

Fig. 2. Distribution of equivalent stress under design flow condition with 50% clogged

2.2 NPSH of feedwater booster pump

When a transient occurs due to a turbine trip or loss of one feedwater pump, cavitation can occur at the suction of feedwater booster pump. Thus, the NPSH of the feedwater booster pump under transient conditions was recalculated based on the design parameters provided by existing design reports and the pressure difference due to strainer calculated from the flow analysis in this study. The results showed that deign change of strainer decreased the NPSH (Net Positive Suction Head) of the feedwater booster pump under transient conditions. As shown in Fig. 3, however, NPSHav (the absolute pressure at the suction side of the pump)is still much higher than NPSHre (the minimum pressure required at the suction side of the pump to keep the pump from cavitation), so it is concluded that cavitation does not occur.

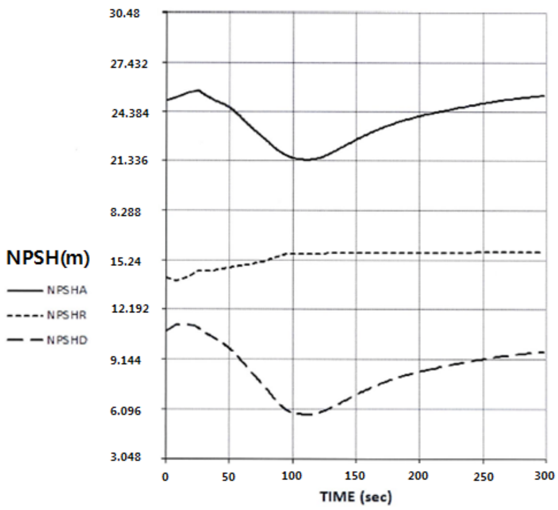

Fig. 3 Comparison of NPSHav and NPSHre under the transient condition of turbine trip

2.3 Evaluation of pipe stress

The stress analysis on the pipe installed strainer was performed to investigate the effect of design change on the integrity of piping system. PIPSYS/WINDOW program, which is a stress analysis program for piping system, was used for the stress analysis. In the analysis, the piping system from outlet nozzle of deaerator tank to inlet nozzle of feedwater booster pump was considered, and internal pressure, dead weight, and thermal loads were regarded as applied loads. As summarized in Table 1, for all loading conditions, the maximum calculated stress was less than the allowable stress of the ASME B.31.1 code requirement. Thus, it is indicated that the design change in strainer has no effect on the structural integrity of piping systems.

Table. 1 Comparison of maximum stresses with allowable stresses of code requirement

Cal. No	Node Point	Max. Stress(MPa)	Allowable Stress(MPa)
9-371-P397-FW401	11	48.61	103.42
	12	91.01	124.11
	13	112.38	226.86

3. Conclusions

This study conducted the flow and structural analyses of design improved strainer and the evaluations of NPSH of the feedwater booster pump and stress of piping system to confirm the adequacy of design improvement in terms of structural integrity and system stability. From the results of analyses, it was concluded that the design improvement of strainer has no negative effect on the structural integrity and system stability under normal and transient conditions.

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