Improvement of Conceptual Design of the IHTS Hot Piping Layout for SFR

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1. Introduction

In this paper, the improved conceptual design of the IHTS (Intermediate Heat Transfer System) hot piping system, which is required to be designed with consideration of the elevated temperature services, of the Sodium-Cooled Fast Reactor (SFR) is presented with relevant structural integrity evaluations by ASME-NH [1] and ASME-NB piping rules.

2. Conceptual Design for IHTS Hot Piping

As shown in Fig. 1 of the pre-conceptually designed Sodium-Cooled Fast Reactor (SFR), the IHTS hot piping system [2] is an important elevated temperature structure conveying hot sodium, which is almost reaching to design hot pool temperature, to the steam generator tubes.

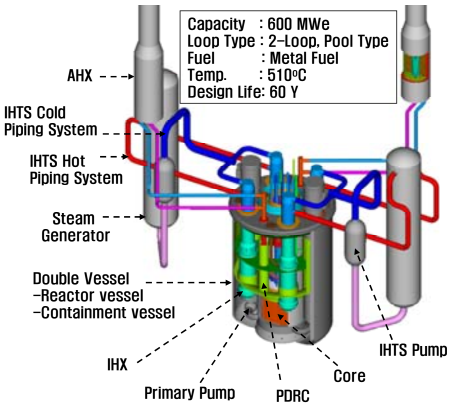

Fig. 1 Concept of Sodium-Cooled Fast Reactor

The targets for conceptual design for hot piping system are as follows;

- Minimized numbers of support due to elevated temperatures
- No mechanical snubbers due to seismic isolation design
- Minimize nozzle loads due to thermal expansion
- Consider special drainage problems
- Heat tracing

For the structural integrity evaluations in stage of the conceptual deign, the design loads can be considered to resist static and dynamic loads as follows;

- Weight effects (Dead weight)
- Loading, displacements, and restraints (Thermal expansion)
- Dynamic effects (Seismic loads)

To evaluate the structural integrity for given loading conditions, the combined ASME-NH and ASME-NB 3600 piping rules are used in this paper.

2.1 Previous Design Concept

As shown in Fig. 1, the IHTS hot piping system is arranged in same plane with short pipe length running to the steam generator. In this design concept, the layout of the hot piping is simple but the stresses at elbows are very high for the design conditions. The calculated resultant moment at elbow due to a combination of the dead weight and thermal expansion is 61 kN·m with assumptions of butt welding elbow. The results of the structural integrity evaluations by ASME NH is presented as

$$P_m = 153.7\,MPa > S_{mt} = 111.4 \quad at\,510^oC,\ 500{,}000h$$

and does not satisfy the ASME-NH design limit rule. The calculated seismic stress intensity value is 227 MPa. The main stress component affecting to seismic stress is a lateral Y direction seismic response due to the lower natural frequency less than 1 Hz, which is close to lateral seismic isolation frequency of 0.5Hz. Fig. 2 presents the seismic stress responses for each direction.

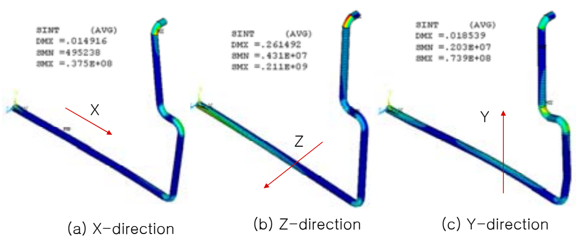

Fig. 2 Seismic Stress Responses

2.2 Improved Design Concept

To improve the structural integrity for a previous IHTS hot piping system, the general layout and piping length are revised to withstand the lateral seismic loads. Fig. 3 presents the proposed layout and dimensions. As shown in the figure, the stiffness of a lateral Z-direction is reinforced by making the Y-Z plane of layout.

One of the main issues is a support design which can accommodate the large thermal expansion for hot piping system operating in elevated temperature service. In this paper, the spring hanger type is considered to support the dead weight. Fig. 4 shows the selected location from the stress and displacement analyses for dead weight. From the support design, the maximum vertical deflection of 38mm is reduced to 4mm and the maximum stress for dead weight of 90MPa is reduced to 27MPa.

The tensional load at hanger support is calculated as 45.6kN and is acceptable in point of commercial support design specification.

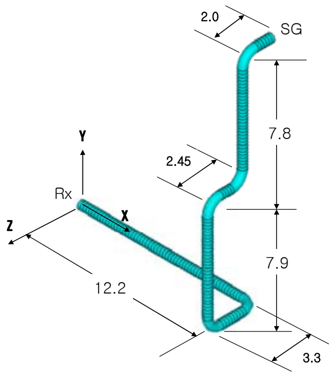

Fig. 3 IHTS Hot Pipe Layout

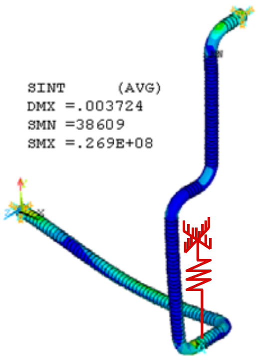

Fig. 4 Support Location

For the improved IHTS piping system, the structural integrity evaluations by the ASME-NH and NB are carried out. The calculated resultant moment at elbow due to a combination of design loads is 16 kN·m with assumptions of butt welding elbow. The results of the structural integrity evaluations by ASME NH is presented as

$$P_m = 41.3 MPa < S_{mt} = 111.4 \quad at\, 510^o C,\ 500{,}000h$$

and does satisfy the ASME-NH design limit rule with large margin.

To investigate the seismic stress responses, the floor response spectra obtained from the KALIMER-600 is used as shown in Fig. 5 [3]. The maximum peak is revealed at 0.5Hz of a seismic isolation frequency.

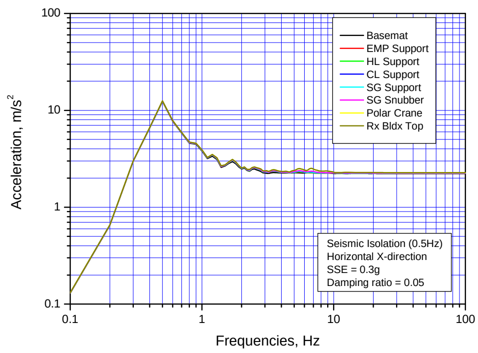

Fig. 5 Floor Response Spectra

From the seismic stress response analyses, the maximum seismic stress intensity is calculated as 92MPa. The maximum lateral Z-direction seismic stress response of 211MPa for previous design is reduced to 24MPa.

For the nozzle loads at IHX and SG, the improved design presents almost same as previous design for dead weight and thermal expansion load. However, a great reduction of nozzle loads is obtained for lateral seismic loads, especially moment component of My at IHX side, as shown in Table 1.

Table 1. Calculated Nozzle Loads

	Comp.	Fx	Fy	Fz	Mx	My	Mz
Previous design	IHX	1.8	0.2	30.8	47.9	404.4	2.6
	SG	0.6	1.2	18.5	100.7	60.9	15.2
Improved design	IHX	3.8	3.9	18.9	6.5	199.4	37.7
	SG	2.9	1.5	9.2	46.6	25.0	6.5

3. Conclusions

In this study, the improved conceptual design of the IHTS hot piping system for the SFR is investigated with structural integrity evaluations by ASME-NH and NB rules. From the results, it is found that the layout change to multi-plane is advantageous for structural integrity, especially against the seismic loads. The reinforcement of lateral stiffness increases the natural frequencies and eventually reveals a reduced seismic stress response at pipe and component nozzle because of a seismic isolation design. In the support design for hot piping system, it is not recommended to use the supports due to the elevated temperature of hot piping. However, it is necessary to reduce a large deflection and stresses caused by dead weight. In this paper, a spring hanger type support is introduced at one location and confirms the design feasibility.

ACKNOWLEDGMENTS

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