Comparison Study on Finite Element Model for Modal Analysis of the SFR High Temperature Piping

Chang-Gyu PARK[a*] and Jong-Bum KIM[a]
[a]*Korea Atomic Energy Research Institute, 1045, Daedeokdaero, Yuseong-gu, Daejeon, 305-353, Korea*
[*]*Corresponding author: chgpark@kaeri.re.kr*

1. Introduction

The ASME Code for design and analysis of PWR(Pressurized Water Reactor) Class 1 piping of relative low temperature region has been well established and it has been applied in the reactor plant industry successfully by using the computer programs developed. But for the high temperature piping of SFR(Sodium-cooled Fast Reactor) system, ASME Subsection NH Code provides the construction rules of nuclear facility Class 1 components in elevated temperature service[1]. ASME Subsection NH describes that the structural analysis for a piping component shall fully comply with the requirement of general rules until special rules for piping components are developed for an elevated service. Subsection NH requires the sectional structure analysis results and thus the 3-Dimensional(3-D) solid model for design by analysis should be applied. In this study, 3-D solid models for the Subsection NH rule are prepared and compared with their modal analysis result.

2. Description of the IHTS piping

The reactor system of this study is the ABTR (Advanced Burner Test Reactor) and it was developed at Argonne National Laboratory. ABTR is a 95MWe(250MWt) metallic-fueled pool-type SFR and core outlet and inlet temperatures are 510℃ and 355℃, respectively. Though both supercritical CO_2 Brayton and Rankine steam cycle power generation systems are under consideration for the ABTR, the IHTS (Intermediate Heat Transport System) is based on the S-CO_2 system[2]. The IHTS is composed of two complete independent loops as shown in Fig.1.

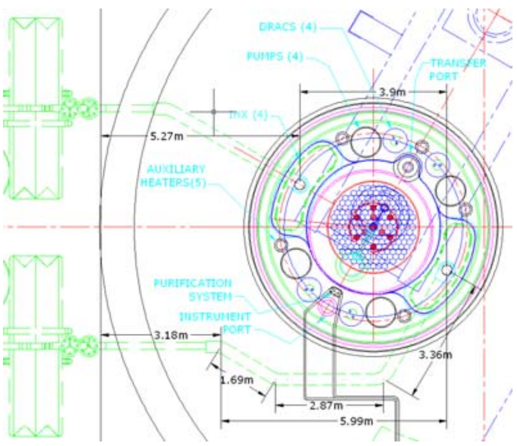


Fig. 1. Layout and dimensions of ABTR IHTS

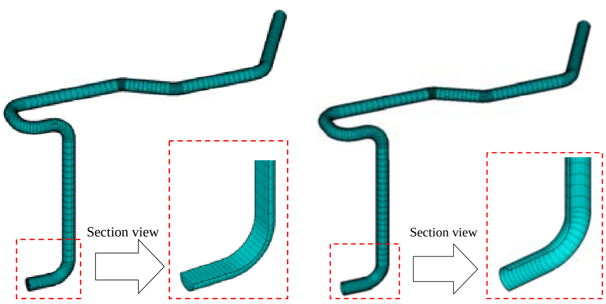
The hot leg piping connects to the secondary sodium outlet of the IHX directly to the PCHE sodium inlet. It is constructed from 40.6cm outer diameter, 1.27cm thick-walled 304 stainless steel piping. Its overall length per loop is about 20.9m.

3. FE Modal Analysis

3.1 FE Models

The FE(Finite Element) models proposed to compare the modal features of SFR piping are 3-D solid full model(Model-1) and 3-D simple solid model with equivalent material property(Model-2). Both are constructed from ABTR preconceptual design layout by using the ANSYS program[3].

Model-1 is composed of 3-D structure and 3-D fluid elements simulating piping and fluid in the piping, respectively. In ANSYS, element types for solid structure and fluid are SOLID45 and FLUID30. Model-2 is composed of 3-D structure element only and fluid element is not created. Instead, the fluid mass is reflected into the structure model by recalculating the structure density. Figure 2 shows the both FE models.



(a) Model-1 (b)Model-2

Fig. 2. Finite element shape of both models

3.2 Modal Analysis Result

The modal analyses are carried out by using the ANSYS program. Though ANSYS provides 8 ways of mode extraction method, modal analysis option for Model-1 and Model-2 are Unsymmetric Matrix Method and Block Lanczos Method, respectively. Some methods such as Block Lanczos Method, Subspace Iteration Method are not applicable for Model-1 because they do not support the FLUID element in modal analysis. But for the Model-2, it can be performed by all methods. The modal analysis results below 30Hz natural frequency are listed in Table 1. As shown in the Table, natural frequency of Model-1 is almost same as that of Model-2 within average 1.7% difference range. Figure 3 shows the comparison of deformed shape per each mode of both models. As shown in the Figure, the deformed shapes per modes show the almost same patterns.

The natural frequency of the 1st mode is formed between 2.95Hz and 3.1Hz and is formed within the range of general seismic frequency (2Hz~10Hz). If it is considered that the natural frequencies of the reactor building is generally about 4.5Hz and the horizontal seismic isolation frequency is about 0.33Hz, the current piping layout might be weakened from the seismic load restrictively.

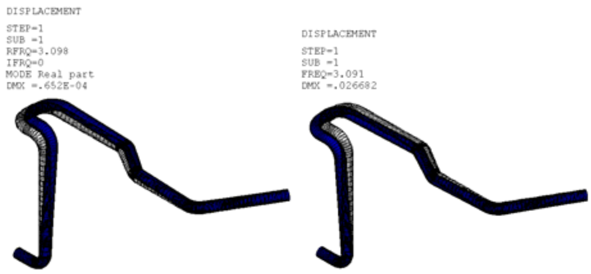
From this modal analysis, it is found that the modal analysis option of Model-1 using FLUID element type is very restrictive in view of analysis method, if ANSYS is used for FE analysis. But Model-2 is not less restrictive comparing with Model-1 in view of mode extraction method. ANSYS program supports the Unsymmetric Matrix Method as a modal analysis method for the FE model including FLUID element. But the Unsymmetric Matrix Method in ANSYS is not applicable in spectrum analysis. Therefore, 3-D simple model is strongly recommended if FE analysis is performed by using ANSYS program.

Table 1: Modal analysis results

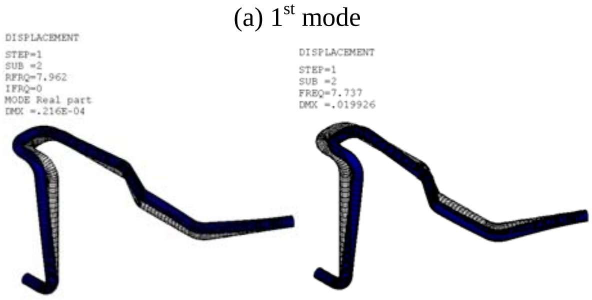
No. of mode	Model-1 (Hz)	Model-2 (Hz)	Mode description
1st	3.10	3.09	Horizontal
2nd	7.96	7.74	Horizontal
3rd	9.15	9.14	Vertical
4th	11.39	11.00	Mixed
5th	12.33	12.14	Vertical
6th	15.88	15.46	Horizontal
7th	21.76	21.53	Vertical
8th	29.19	29.80	Horizontal

3. Conclusions

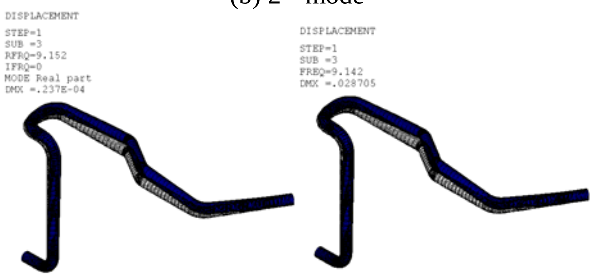
In this study, the finite element models to perform the modal analysis for the high temperature piping structure of nuclear facility by ASME Subsection NH are studied. Two FE models which are 3-D full model included FLUID element and 3-D simple model with equivalent material property are prepared. Both models show the almost same natural frequency and deformation patterns. The 3-D full model is very restrictive in view of analysis method and requires much time relatively in FE analysis compared with 3-D simple model. It is judged that 3-D simple model with equivalent material property is applicable in modal analysis because of its simple modeling procedure, usefulness in spectrum analysis and less calculation time with acceptable result.



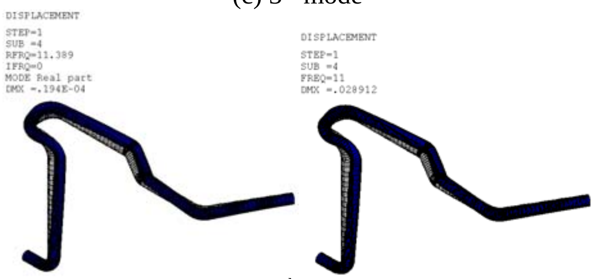
(a) 1st mode



(b) 2nd mode



(c) 3rd mode



(d) 4th mode

Fig. 3. Deformed shape comparison per each mode (Model-1, Model-2)

ACKNOWLEDGEMENTS

This Study was supported by the Korean Ministry of Education, Science and Technology through its National Nuclear Technology Program.

REFERENCES

[1] ASME B&PV Code, Section III, Division 1, Subsection NH, Class 1 Components in Elevated Temperature Service, 2010.
[2] Y. I. Chang, et al., Advanced Burner Test Reactor Preconceptual Design Report, ANL-ABR-1, ANL, 2006
[3] ANSYS User's Manual for Revision 10.0, ANSYS Inc.