Preliminary Structural Evaluation of the SMFR Core Support Structure

Chang-Gyu Park[a*], Gyeong-Hoi Koo[a],
[a]*Fast Reactor Technology Development Division, 1045, Daedeokdaero, Yuseong-gu, Daejeon, 305-353, Korea*
[*]*Corresponding author: chgpark@kaeri.re.kr*

1. Introduction

The advanced reactor concepts are needed to meet the waste management, further enhanced safety, nonproliferation, and resource challenges that must accompany the deployment of increasing numbers of nuclear power plants. The SMFR(Small Modular Fast Reactor) was developed jointly by an international collaborative effort to achieve technical consensus[1]. The SMFR has the design features of a pool-type arrangement, sodium coolant, 60 years plant life, 30 years core life, top reactor support and so on. In this study, the preliminary structural integrity for the SMFR core support structure including the inlet plenum and reactor vessel(RV) bottom head is investigated by using the ASME-NG[2] rules for a normal operating condition

2. Structural Descriptions

Figure 1 shows the overall SMFR reactor lower structure. The reactor lower structure mainly consists of the inlet plenum, core support structure and RV. The core support structure provides the restraint of the reactor core assemblies necessary to maintain them in their geometry during all modes of reactor operation transfers the weight loads of the reactor internal structures and core to the RV[3]. For the SMFR system, the core support structure provides support for the lower internals structure, the core assemblies, the core barrel assembly, the primary sodium inlet pipes, brackets, and baffles. The inlet plenum, located in the central region of the core support structure and below the core, receives primary sodium from the inlet sodium pipe and distributes it to the core via the core assembly[3].

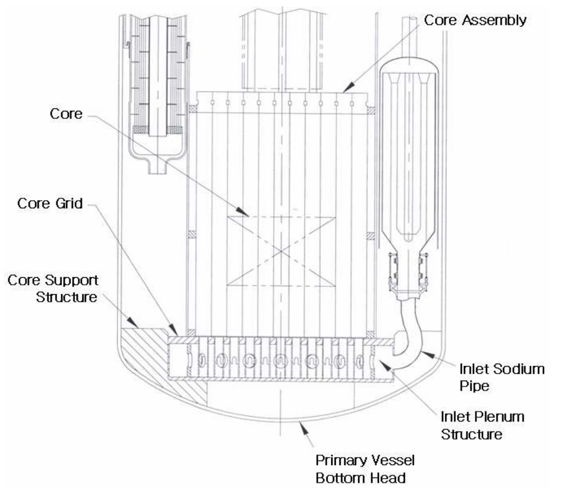

Fig. 1. SMFR core support structure

The core support structure of the SMFR consists of a steel web structure that is formed by the contours of the RV bottom head and becomes an integral part of the RV. The dimensions of the web structure are not determined yet, but in this study the web is initially assumed to be placed at an interval of 45° with a 5cm thickness. The RV inner diameter is 2.78m and its thickness is 5.0cm. Thicknesses of the upper and lower grid plate of the inlet plenum are 10cm and 4cm, respectively. The reactor lower structures are constructed of Type 316 stainless steel.

3. Structural Integrity Evaluation

The core support structure for the normal operating condition is designed to the requirements of the ASME B&PV Code, Section III, Division 1, Subsection NG, Core Support Structures because the core support structure is in the cold pool region under 400°C for a steady state.

3.1 General Assumptions

- The core support structure including the inlet plenum is in a low temperature region(355°C) during a normal operating condition.
- The structure temperature is the same as the coolant temperature.
- The reactor building incorporates a base isolation system and a seismic load is not considered in this study.
- The core dead weight is supported on the upper grid plate of the inlet plenum and the inlet plenum is welded to the core support structure
- All the dead weight of the primary coolant is uniformly distributed to the RV bottom head.
- The hydrostatic pressure of the primary coolant on the RV bottom head is assumed to be 0.1MPa.
- Assumed are the core assemblies including the storage fuel (130 tons) and a total weight of the internals(45 tons).

3.2 Loading Conditions

To evaluate the structural integrity for the core support structure, a representative operating cycle is assumed as shown in Fig.2. The coolant temperature of the reactor lower structure region linearly increases up to the steady state operating temperature of 355℃ for 12 hours and its steady state hold time for each cycle is 30 years. The cool-down operation occurs from the steady state temperature to the refueling temperature of 200℃ for 12 hours. Though the SMFR cycle length is

30 years, the number of load cycle is assumed to be 1000 conservatively.

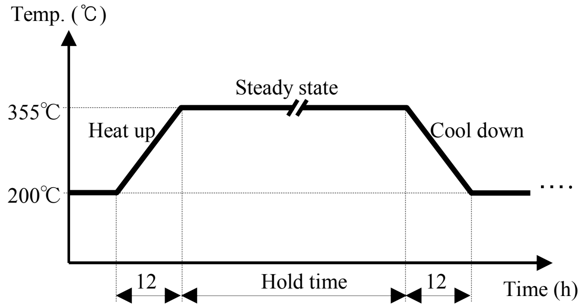

Fig. 2. Assumed cyclic thermal transient history

3.3 Analysis Model and Boundary Conditions

Figure 3 shows the 1/8 part FE model showing the dimensions and boundary conditions. As shown in fig.3, the dead weights are applied on the upper grid plate of the inlet plenum and RV is supporting all structural loads. The outer surface of the guard vessel is insulated and the temperature difference between the inner and outer surface of the RV is assumed conservatively as shown in Fig.3. The hydrostatic pressure due to the primary coolant is applied to the RV bottom head uniformly.

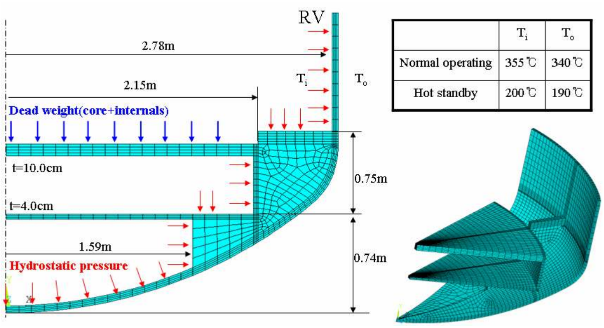

Fig. 3. FE model and assumed boundary conditions

3.4 Results

From the stress analysis result with the primary plus secondary loads for a steady state as shown in fig. 4, the most critical section is the junction region between the inlet plenum and the web structure of the core support structure. The maximum stress intensity value by the primary plus secondary loads is less than that by the primary load only. It means that the thermal load may yield the stress redistribution and decrease the stress intensity value.

Table 1 shows the structural integrity evaluations at the each junction part of the inlet plenum and the core support structure. As shown in Table 1, the primary membrane stress intensities for the inlet plenum and the core support structure exceeds the design limit value and the secondary load is less effect at the structural integrity in this design condition. The calculated number of allowable fatigue cycles for the inlet plenum and the core support structure from the ASME fatigue curve[4] is over 1×10^7 cycles. But the fatigue damage evaluations for this design condition are not applicable because the primary stress intensity limit is not satisfied first. Since current design concept of the inlet plenum yields a large vertical deflection of the upper grid plate, thus tie sleeves have to be installed between the upper and lower grid plates.

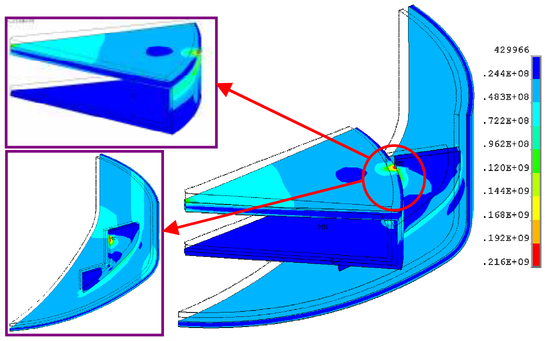

Fig. 4. Stress intensity analysis result from the primary plus secondary loads.

Table 1 : Structural integrity evaluation results by ASME-NG

Evaluation items	Inlet plenum			Core support		
	Cal.	Limit	Check	Cal.	Limit	Check
P_m	**118**	**115**	**Not**	**131**	**115**	**Not**
P_m+P_b	164	173	OK	151	173	OK
P_m+P_b+Q	209	345	OK	155	345	OK
Fatigue Damage	**-**	**1.0**	**N/A**	**-**	**1.0**	**N/A**

4. Conclusions

Preliminary evaluation of the SMFR core support structure is carried out in this study. The core support structure and the inlet plenum can not satisfy the design rule of the primary stress intensity limit. Therefore, it is necessary to propose a modified design concept and investigate a more detailed design condition to satisfy the structural integrity for a modified core support structure including the inlet plenum.

ACKNOWLEDGEMENTS

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

REFERENCES

[1] Y.I. Chang, et al., Small Modular Fast Reactor Design Description, ANL-SMFR-1, ANL, 2005.
[2] ASME B&PV Code Section III, Subsection NG, 2004.
[3] PRISM Preliminary Safety Information Document, GE, 1987.
[4] ASME B&PV Code Section III, Division 1, Appendices, 1998.