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Conceptual Design of the SFR Reactor Vessel

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1. Introduction

In this paper, the expected conceptual design issues for the reactor vessel of the Sodium-Cooled Fast Reactor (SFR) are investigated and discussed with relevant structural analyses.

2. Expected Conceptual Design Issues

For the pre-conceptually designed Sodium-Cooled Fast Reactor (SFR), the reactor vessel concept [1] is investigated to enhance the design rational. To do this, the expected structural design issues of the reactor vessel are proposed in this paper as follows;

- Issue 1: Junction design between head and cylinder
- Issue 2: Connection with head
- Issue 3: Bottom head design
- Issue 4: Fabrications

The detailed investigations for above issues are described and discussed in following sections.

2.1 Junction Design between Head and Cylinder

The reference dimensions for the reactor vessel are shown in Fig. 1. The height of the side cylinder is 16.5 m and the outer diameter is 11 m, then the slenderness ratio (L/R) is 3. This geometry dimension is apt to invoke the bending buckling behavior during seismic event deflected around junction region between reactor head and vessel cylinder [2]. Furthermore, the vessel is designed to have a thin thickness of 5 cm.

To prevent the structural instability of the reactor vessel against the seismic loads, it is required to investigate the need for the variable thickness vessel design. Fig. 1 presents the stress intensity (the maximum shear stress) contour for the 1g horizontal seismic load calculated with assumption of the quasi-static load with consideration of the internal weights. The Maximum stress is 21 MPa and occurs at the junction region but the level is very low enough to satisfy the ASME-NH rules [3]. Therefore, it is found that the variable sectional design reinforcing the junction region is not necessary.

2.2 Connection with Reactor Head

This issue is related with the realization of the reactor head design concept. To make a concept to fully access into the reactor inside by the opening of the whole reactor head, the previous concept of the fully welded reactor vessel and head is modified to the alternate concept of the bolted connection between the RV support flange and the reactor head. Then, the reactor is supported by the skirt type support structure as shown in Fig. 2. This concept will provide the possibility of the repair and replacement service inside reactor internals and the core support structures during unexpected conditions.

Fig.3 shows the stress analysis results for the same load condition of the section 2.1. As shown in the results. The maximum stress is reduced compared with that of the uniform section due to the stepped sectional area at flange region.

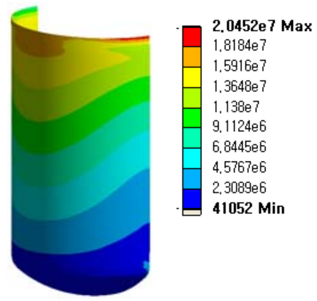

Fig. 1 Stress contour for a seismic load w/o flange

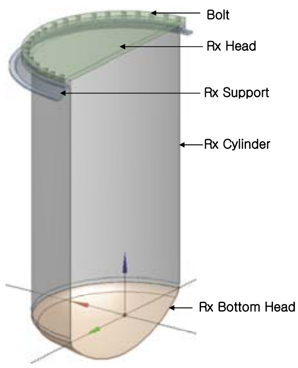

Fig. 2. Concept of the removable reactor head design

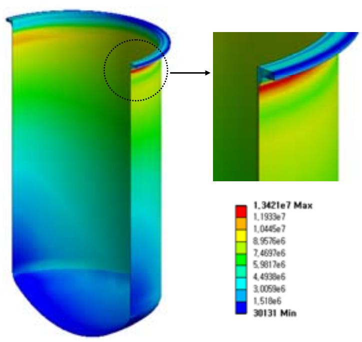

Fig. 3 Stress contour for a seismic load with flange

2.3 Rx Bottom Head

The basic concept of the core support structure is required to be separated with the reactor vessel. This makes the thermal expansion difference between the core support structure and the reactor vessel minimize. In this concept, the surface coating for the contact surfaces is one of the design issues. Since there are no welded parts in this region, the complicated and expensive in-service inspection works are not required. Therefore, the large economy design benefits are expected through this design concept.

Fig. 4 presents the concept of the reactor vessel bottom head with the forged flange, on which the skirt core support structure is laid. As shown in the figure, the shear lugs on the top surface of the flange prevent the core and reactor internals to rotate but allow and guide the thermal expansion freely.

The stress analyses are carried out to investigate the maximum stress and deflection levels for the total dead weights which the reactor vessel is carrying out during the normal operations. The considered weights are as follows;

- Reactor vessel itself
- Reactor internals (300 tons)
- Core Assemblies (200 tons)
- Primary Coolant (500 tons)

The weights of the reactor internals and core assemblies are applied as an equivalent pressure on the top surface of the support flange and the weight of the primary coolant is converged to the equivalent density and applied to the reactor bottom head. Fig. 5 shows the analysis results for stress and deflection. The maximum stress is 49 MPa occurred at transition region between cylinder and bottom head and the maximum deflection is 2.1 mm at support flange. This is acceptable because the core support region is not under elevated temperature services during normal operations.

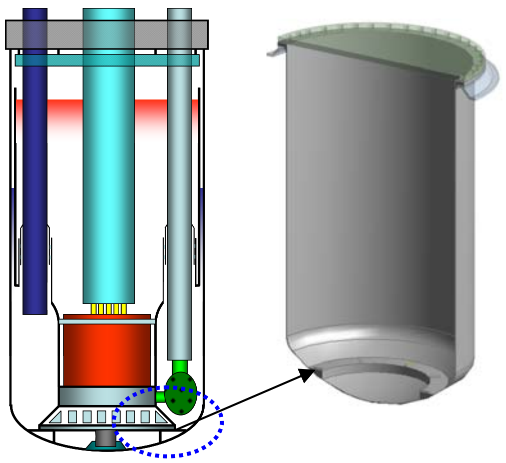

Fig.4 Concept of the core support flange

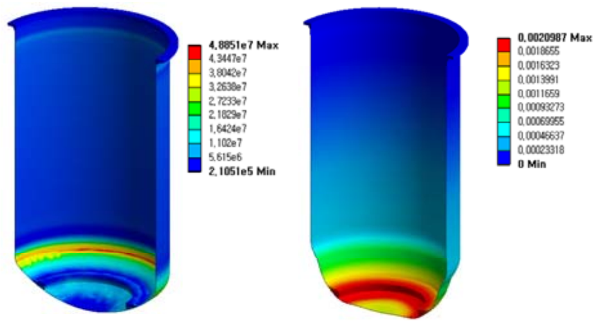

Fig. 5 Stress contour and deflection shape for dead weights

2.4 Fabrications

The best way for the reactor vessel is a dedicated factory fabrication with a single forging and assembling with the reactor internal. However, while considering reference dimension of the 11 m outer diameter, it is not easy to be done by single forging without welding. Therefore, the large cylindrical shell of the reactor vessel will be made of rolled and welded plate. The large diameter shell will be made by joining two plate sections with a long seam weld. The end of the long plate will be trimmed to the required length and weld prepped.

The bottom head will be made up of several forged segments including the core support flange. The segments will be formed, have weld preps prepared, and will be fit and welded together.

3. Conclusions

In this study, the expected conceptual design issues for the reactor vessel of the SFR are proposed and investigated. From the results, it is found that the variable sectional design is not necessary in the reactor vessel and the concept of the detached type core support structure reveals a good performance for the total dead weights applied to the support flange. To complete the reactor vessel design, more detailed structural evaluations for the 60 years design lifetime operating at the elevated temperature services will be performed according to the ASME-NH code.

ACKNOWLEDGMENTS

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REFERENCES

[1] D.H. Hahn, Y.I. Kim, etc, KALIMER600 Conceptual Design, KAERI/TR-3381/2007.
[2] G.H. Koo, B. Yoo, and J.B. Kim, "Buckling limit evaluation for reactor vessel of KALIMER liquid metal reactor under lateral seismic loads," Int. J. of Pressure Vessels and Piping, Vol. 78, pp.321-330, 2001.
[3] ASME BPV Section III, Division 1-Subsection-NH, Class 1 Components in Elevated Temperature Service, 2007.