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Preliminary Thermal Analysis for the Steam Generator Tubes in the Small Modular Reactor

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1. Introduction

The steam generator is the heat exchanger to convert water coolant into super heated steam by absorbing heat produced in the reactor core. The steam generator, which has been being compactly designed for the Small Modular Reactor(SMR), has helical coil type steam generator tubes in contrast to general nuclear power plants. In this steam generator, the feed water is supplied from the feedwater line, and then distributed into 96 helical coil type steam generator tubes. After the super heated steam produced in the steam generator is corrected, it is finally discharged through the steam line.

The steam generator experiencing severe temperature change between in-operation and shutdown may cause structural problems by thermal expansion. Especially, a great deal of deformation in the very long steam generator will be produced, and the structural vulnerability on them is likely to occur. In this paper, the structural integrity of the steam generator is checked by numerical simulations.

2. Numerical Analysis

The numerical analysis is conducted by using commercial tool ANSYS [1].

2.1 Meshing

The configuration of the steam generator is shown in Fig. 1. The feed water lines and 12 modules will be made of two kinds of titanium alloys, and the ASME material (SA312-TP321) is applied to the other parts. For the numerical efficiency, the pipe element is applied to the steam generator tubes, and shell elements are used suitably to construct the finite element model. The mesh configuration of the finite element model is shown in the Fig. 2.

2.2 Contact and Applied Loadings

The most parts are bonded at each other, and the frictionless contact pairs provided in ANSYS are applied to all the parts which face adjacent to each other. However, the supports to constraint the deformation of the steam generator tubes are omitted because the excessive computational resource and time is required by a great mount of contact conditions. In order to consider this situation, the radial displacement for the steam generator tubes are constrained by establishing partially the cylindrical coordinates.

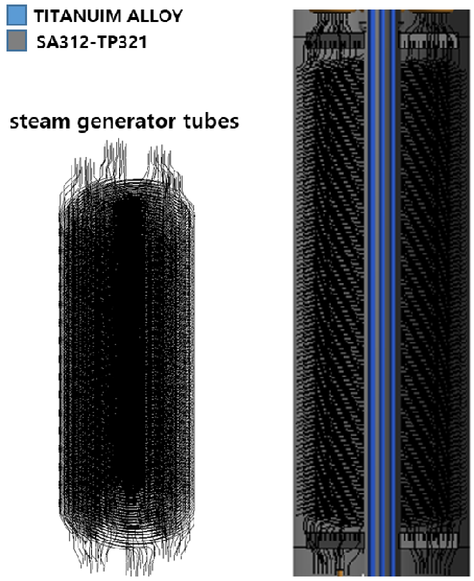

Fig. 1. Configuration of the Steam Generator

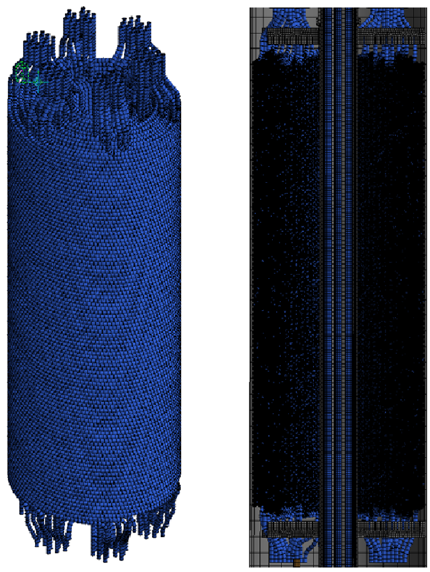
Fig. 2. Mesh Configuration of the finite element model

The Fig. 3 shows applied loading conditions. Because the correct temperature distribution in the steam generator tubes can not be predicted, the design temperature is imported to all the parts in the steam generator. Although the excessive thermal stress can be generated, it is thought that the conservatism is considered. In addition, the external pressure which is the pressure difference between inside and outside the steam generator tubes is applied to the steam generator tubes.

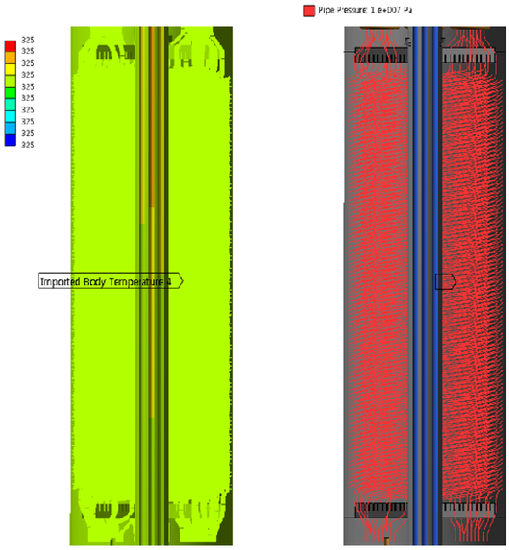

Fig. 3. Applied Loading

2.3 Analysis Results

The Fig. 4 shows the deformation on the steam generator where the unit is millimeter. As was expected, it can be checked that the thermal deformation on the steam generator tubes reaches a significant level.

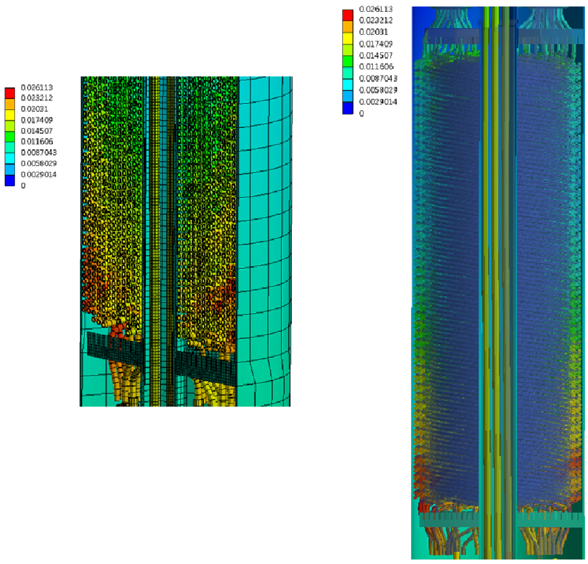

Fig. 4. Deformation of the Steam Generator

The structural integrity on all the parts except the steam generator tubes is preserved under the given loading condition. The stress on the steam generator tubes that axial and bending stress are combined is shown in Fig. 5 where the unit is Pa. Because the modules on the both sides suppress the thermal expansion release of the steam generator, the compression stress on the axial direction occurs; thus, the maximum stress is generated on the compression status. Based on the KEPIC MD [2], the stress intensity(Sm) corresponding to the applied temperature conditions is calculated by the experimental tensile data, and the stress intensity on the sharply bent steam generator tubes near the moduls exceed 3Sm regulated in the KEPIC MNB [3].

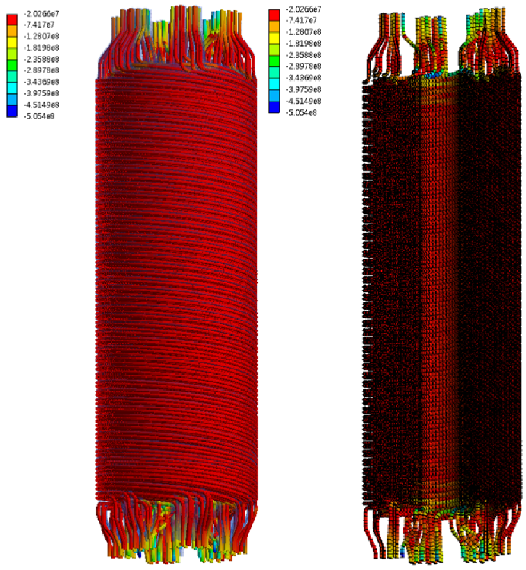

Fig. 5. Result of Pipe Stress

3. Conclusions

The preliminary analysis is carried out, and the structural failure is concerned since the thermal deformation on the steam generator tubes is strongly suppressed. Although the radial deformation on the steam generator tube are not allowed and the excessive temperature is applied, it can be concluded that the steam generator have to be designed to relieve the thermal expansion.

REFERENCES

[1] ANSYS 19.2 User's Guide.
[2] KEPIC MD, 2005 edition
[3] KEPIC MNB, 2005 edition