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Thermal Analysis Evaluation of Spent Fuel Storage Rack for Research Reactor

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1. Introduction

Spent fuel storage rack is to store spent fuel assemblies. The spent fuel storage rack is submerged in the designated pool for cooling. Due to the condition change of the pool water, the effect of thermal load on spent fuel storage rack must be analyzed and evaluated. In this paper, thermal stress analysis is performed and evaluated on a spent fuel storage rack.

2. Geometry of Spent Fuel Storage Rack

The spent fuel storage rack considered in this paper consists of racks and a support frame for the racks.

The support frame accommodates several racks. The support frame provides stable support to the racks Each rack has storage cell pipes to store and protect spent fuel assemblies. One spent fuel assembly is stored in a storage cell pipe. The bottom design of storage cell pipes allows pool water circulation for cooling of fuel assembly.

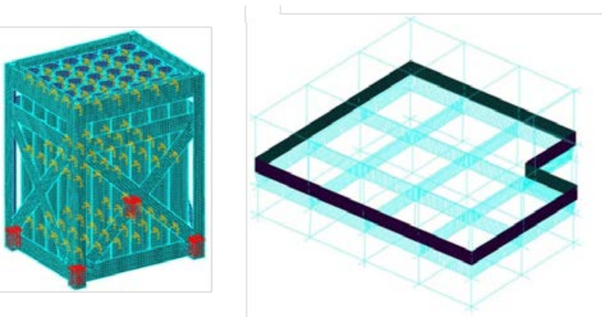

Fig. 1. Configuration of spent fuel storage rack

3. Methodology

The temperature loads are the loads resulting from the variation of pool water temperature. These loads can be caused thermal stresses in the structures due to the restraint of thermal deformation. The thermal analysis including a linear heat transfer and the thermal stress analysis is performed for the racks and support frame in the pool. In setting of temperature condition, conservative temperatures are applied. In this paper, fluid dynamics analysis on the pool water is not considered.

In this analysis, variation of pool water temperature is assumed to three values: Normal operation temperature 30 ℃, maximum normal temperature 50 ℃, and maximum design temperature 120 ℃. Boiling temperature of pool water with consideration of hydraulic pressure is applied to maximum design temperature conservatively.

The spent fuel storage rack is made of stainless steel. Material properties on ASME Section II Part D [1] applied for analysis at each temperature.

Computer Code used for the analysis is ANSYS.

3. Analysis Model and Boundary Condition

The rack finite element model is comprised of shell (SHELL181), solid (SOLID185) and beam (BEAM188) element. The element size is decided through the convergence evaluation result.

The support frame model is comprised of SHELL181 (for girdle and plate) and BEAM188. The element size is decided through the convergence evaluation result.

In the thermal stress analysis for a rack, the temperature conditions are as bellows: (see Fig.2, red color indicating a maximum temperature)

A-1) The maximum temperature is applied to the whole model of SFSR.

A-2) The maximum temperature is applied to one of the storage cell pipe.

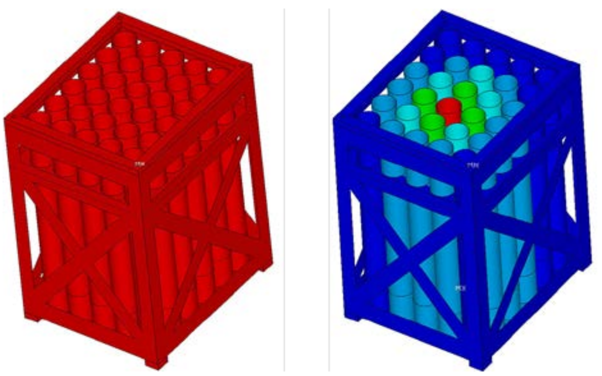

Fig. 2. Temperature conditions for the rack

In the thermal stress analysis for the support frame, the temperature conditions are as bellows: (see Fig.3, red color indicating a maximum temperature)

B-1) The maximum temperature is applied to the whole model of support frame.

B-2) The maximum temperature is applied to the corner of the support frame.

B-3) The maximum temperature is applied to the center of the support frame.

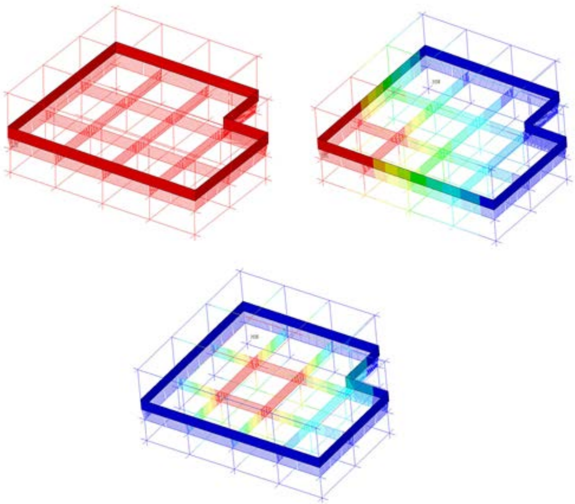

Fig. 3. Temperature conditions for the support frame

4 Analysis Result

For thermal stress evaluation of the spent fuel storage rack, load combinations and allowable criteria in ASME Sec. III NB-3220 [2] are applied.

In cases of A-1 and B-1, the same temperature applied on the whole model, thermal stress doesn't occur because there is no constraint about the thermal expansion. The support frame is located on the pool bottom in free standing type and the racks are located in the support frame with enough space. Thermal expansion was considered and reflected in the design of spent fuel storage rack in advance.

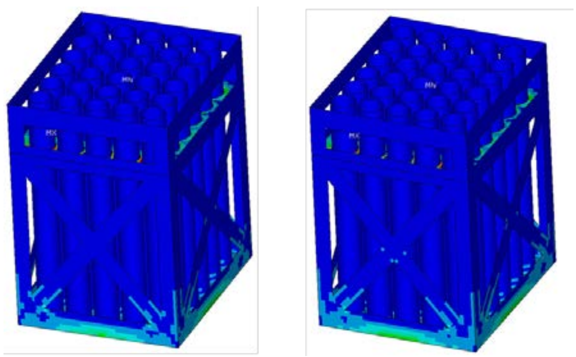

Fig. 4. Thermal analysis result for the rack

Thermal analysis results on case A-2 is shown in Fig. 4. Stress distribution aspect is obtained and maximum stress concentration occurs on the guide plate for storage cell pipes. Thermal analysis on case B-2 and B-3 is also assessed.

The result of thermal stress above is applied to a part of load combination and evaluated in accordance with ASME Sec. III NB-3220.

5. Summary

Thermal stress analysis is performed and evaluated on a spent fuel storage rack with consideration of pool water temperature variation. The thermal analysis including a linear heat transfer and the thermal stress analysis is performed for the racks and support frame and resulted stresses are within allowable criteria.

Acknowledgements

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REFERENCES

[1] ASME Boiler and Pressure Vessel Code, Section II, Materials and Specifications, American Society of Mechanical Engineers, 2004

[2] ASME Boiler and Pressure Vessel Code, Section III, Rules for Construction of Nuclear Facility Components, Subsection NB, American Society of Mechanical Engineers, 2004