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Design Evaluations of the accumulated inelastic strain for the Reactor Internal Structure in a ABTR

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1. Introduction

The Advanced Burner Test Reactor (ABTR) which is operating with the core outlet and inlet temperatures of 510°C and 355°C, respectively, is a 95 MWe (250 MWt) metallic-fueled pool-type SFR(Sodium Cooled Fast Reactor). The ABTR was developed at Argonne National Laboratory (ANL) as a first step in demonstrating the reactor based transmutation of transuranics as part of an advanced fuel cycle. The primary coolant free surfaces in a reactor internal structure are the critical position in the design of SFR. The hot and cold pool free surface regions can induce the significant thermal gradients along a reactor internal structure and result in the excessive ratchet strains and the creep-fatigue damages. In this report, the primary coolant free surface regions of a reactor internal structure, which are also subjected to the elevated temperature regions, are considered as the main critical locations to be evaluated. The inelastic and elastic stress analyses are carried out by using the finite element code ANSYS[1]. The accumulated inelastic strains are evaluated with the Code rules of ASME-NH[2].

2. Short Description of a Reactor Internal Structure

The core barrel and reactor internal structure assembly are a single integrated unit that provides the internal structure for the reactor core assemblies and provides a barrier between the hot and cold sodium pools. The core barrel is a right circular cylinder fabricated from stainless steel. It is attached to the inlet plenum and lower support structure. It also provides support for the core restraint system.

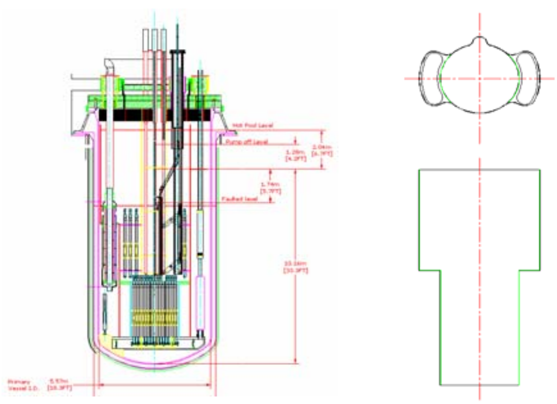

Fig. 1 Configuration of a reactor internal structure

The reactor internal structure is a barrier that separates the hot pool from the cold pool, and provides for communication of the hot sodium from the discharge of the reactor core to the inlet of the intermediate heat exchanger. It consists of multiple plates welded together that form a contoured shape around the intermediate heat exchangers and the upper internal structure. Fig. 1 shows the configuration of a reactor internal structure.

3. Finite Element Modeling

3.1 Constitutive Equation

It is important thing to use the proper constitutive model in the inelastic analysis. The proper constitutive

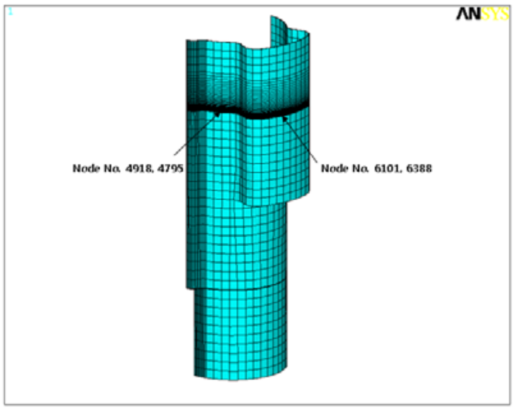

Fig. 2 Analysis Model of a reactor internal structure

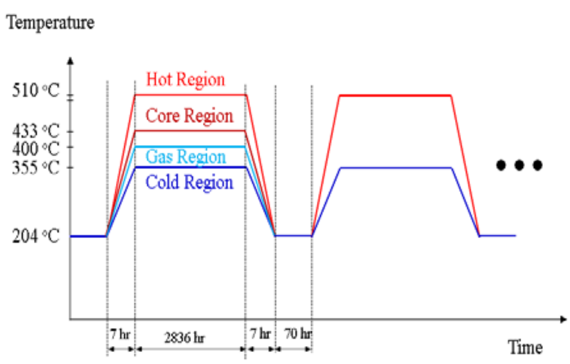

Fig. 3 Thermal loading condition

model should be able to simulate precisely the stress strain relation by considering the history dependent effects, time dependent behavior and rate dependent effect, etc. In the high temperature structural analysis of the SFR, the Chaboche constitutive model and the superposition model of the creep and plasticity are widely being used. In this paper, two kinds of constitutive equations are applied for the inelastic analysis of a reactor internal structure. One is the Chaboche plasticity model based on the kinematic hardening, the other is a combined model with the Norton time hardening formulation and the bilinear isotropic hardening.

3.2 Modeling and loading Condition

Three dimensional geometry is modeled and a simple model without a mechanical seal between IHXs and a reactor internal structure is presented in Fig. 2. Two evaluation sections (A1 and A2) of the cold pool free surfaces through the thickness direction are evaluated to confirm the structural integrity of a reactor internal structure. The loads and time durations for the thermal analyses consider the refueling to full power operation condition based on the ABTR duty cycle events given by ref.[3]. The cycle type as shown in Fig. 3 represents the heat up and cool down operating condition from a refueling to a full power.

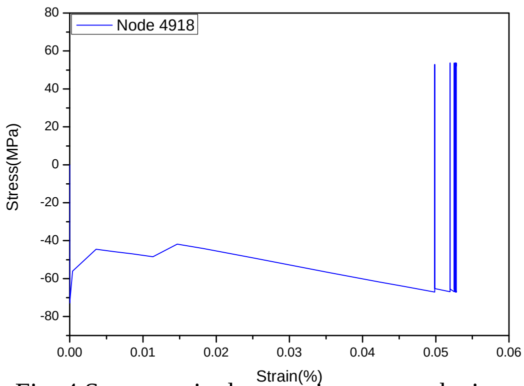

Fig. 4 Stress strain hysteresis curve at the inner surface of the evaluation section A1(Chaboche)

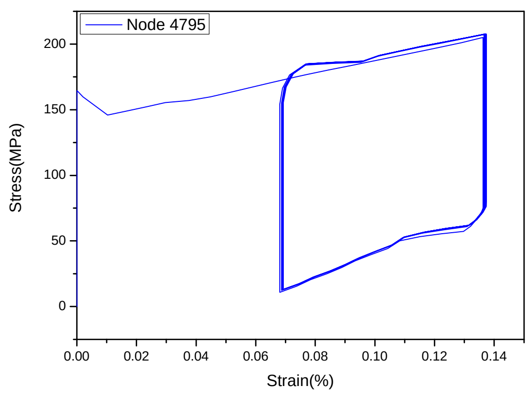

Fig. 5 Stress strain hysteresis curve at the inner surface of the evaluation section A1(Chaboche)

Table 1 Accumulated inelastic strains at the evaluation sections

Accumulated Inelastic Strains	Elastic	Chaboche	Creep+BISO
A1 Section	2.2321	0.4484	0.3870
A2 Section	2.1470	0.3391	0.3139

4. Results and Discussions

From the analysis results of the temperature time history, we can see that the maximum temperature at the inner surface and outer surface reaches 497 ^{o}C and 369 ^{o}C for 6 cycles, respectively. Fig. 4 and Fig. 5 shows the cyclic behavior of the stress strain variations at the inner and outer surfaces of the evaluation section A1firstly predicted by using the Chaboche constitutive model. The second inelastic analysis is carried out by using the Norton creep constitutive model with a bilinear isotropic hardening rule. The evaluation results for the accumulated inelastic strain are compared with the elastic evaluation results as shown in Table 1. From these results, it is confirmed that the elastic analysis results is more conservative than the inelastic evaluation.

5. Conclusions

The evaluation results by the elastic analyses appear to be more conservative than those by the inelastic analyses. In the case of the detailed inelastic analyses, the Chaboche plasticity model give larger inelastic strain than the creep model with the bilinear isotropic model

Acknowledgements

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REFERENCES

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[2] ASME Boiler and Pressure Vessel Code Section III, Subsection NH, ASME, 2004.
[3] I-NERI Technical Annual Report, Sodium-Cooled Fast Reactor Structural Design for High Temperatures and Long Core Lifetimes/Refueling Intervals, 2007-007-K, 2008.