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A Validation Study on a Computer Program of SIE ASME-NH

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1. Introduction

The design codes and assessment procedures such as ASME-NH[1], RCC-MR[2], R5[3], and DDS are developed or under development status to evaluate the high temperature structural integrity in the design of a nuclear power plant. It is very complicated to apply the ASME-NH rules by a hand calculation step by step to evaluate a high temperature structural integrity. SIE ASME-NH(Structural Integrity Evaluations by the ASME-NH rule) Code is a computer program of the ASME Pressure Vessels and Piping Code Section III Subsection NH rules. This program is expected to overcome the complexity of the ASME-NH applications and be very useful for a high temperature nuclear structural design[4]. This study is on a validation and the applicability of the SIE ASME-NH program with an example of a KALIMER-600 IHTS hot leg piping[5].

2. SIE ASME-NH Code

SIE ASME-NH is developed as a modular type and consists of several principal subprograms; main program, input data control program, primary stress limit evaluation program, total inelastic strain limit evaluation program, creep-fatigue damage evaluation program, material database programs, and stress intensity calculation program.

Time-dependent primary load limits for a design condition, service level A, B, C and D can be selectively checked by the primary stress limit evaluation program. This evaluation includes the primary membrane stress intensity limits, primary membrane plus bending stress intensity limits, primary membrane plus modified-bending stress intensity limits and the use-fraction sum corresponding to service levels. The deformation and strain limits for a structural integrity can be checked by using both the elastic analysis approach and the simplified inelastic analysis approach. The creep-fatigue damage evaluation can be carried out step by step in detail with compliance to the ASME-NH rules. The fatigue damages at the evaluation points of the structures are linearly summed for each cycle type and the creep damage evaluation during the steady state elevated temperature operation with multiple transient operating conditions having different peak metal temperature, durations, and primary loads can be performed by the method of a stress/temperature time-history envelop in the ASME-NH appendix T rules[4].

3. Application Example

3.1 Application model and loading cycle

As an example of a validation study of the SIE ASME-NH program, KALIMER-600 IHTS hot leg piping is selected. Fig. 1 shows the schematic drawing of KALIMER-600. The stresses and strains are induced by the thermal expansion and internal pressure of a piping. The piping material is a Mod.9Cr-1Mo with a required design lifetime of 240,000 hours at an elevated temperature operation. The thermal stress through the thickness is ignored because the IHTS piping is insulated and thus the temperature gap between the inner and outer surface of a piping is negligible.

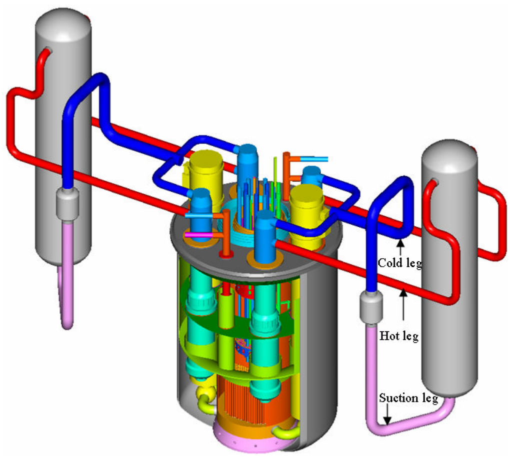

Fig. 1 Preliminary conceptual design of KALIMER-600

The operating cycle to evaluate the structural integrity is assumed as shown in Fig. 2. It is assumed that the steady state operating temperature of the IHTS hot leg piping is 545℃ conservatively and the cool-down operation occurs from the steady state temperature to the refueling temperature of 200℃ for 12 hours by a linear variation.

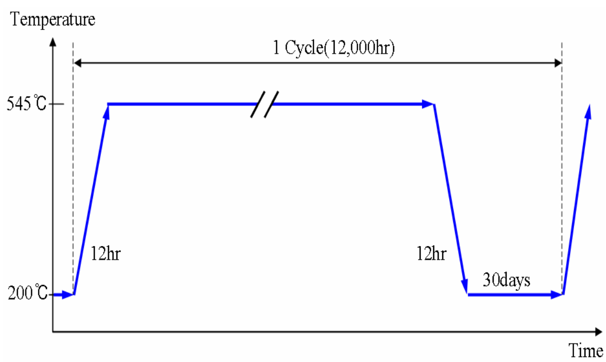

Fig. 2 Cycle type for a loading history

After a refueling period of 15days, the heat-up operation starts and the coolant temperature linearly increases up to the steady state operating temperature of 545℃ for 12 hours. The period of the refueling is 1.5 years(12,000 hours) and thus the number of cycles is 20 cycles.

3.2 Stress analysis

To evaluate the structural integrity per ASME-NH, the stress components as well as strain components have to be calculated. For the numerical calculations in this study, the commercial finite element program ANSYS[6] was used. Fig. 3 shows the finite element analysis results with boundary conditions for the steady state and refueling period, which mean the maximum and minimum stress intensity values, respectively by considering the primary loading condition and the secondary loading condition. The elastic strain components for calculating the maximum strain are calculated by considering the primary plus secondary loading conditions.

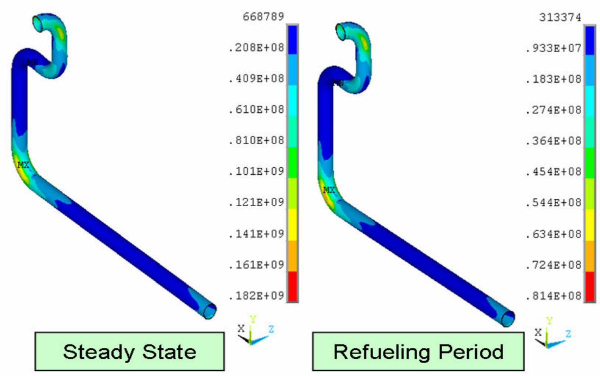

Fig. 3 Stress analysis results

4. Results Comparison

To confirm a validation of the SIE ASME-NH program, the structural integrity according to the ASME-NH rules is evaluated by a hand calculation. Since this study is on a result comparison, the critical locations don't have to be determined. The evaluation point is a part of a straight piping and assumed to be far away from a welding zone. Table 1 shows the comparison result per each case. As shown in Table 1, the SIE ASME-NH results are almost consistent with the hand calculation results for all the evaluation items except for the simplified inelastic approach. The inconsistency in the simplified inelastic approach results is induced by using the isochronous stress-strain curve. The stress and strain calculations using the isochronous stress-strain curve by a graphical hand calculation can contain somewhat of an uncertainty within the proper range value. It is also shown that the creep damage values in Table 1 are different because the time step size for a integration of the creep damage is not the same value.

Table 1. Comparison of evaluation results

	Evaluation Items	SIE ASME-NH	Hand-Calculation
Primary Stress Limits	P_m	3.794MPa	3.810MPa
	P_L+P_B/K_t	4.892MPa	4.893MPa
Inelastic Strain Limits	Elastic Approach	0.3229	0.3230
	Simplified Inelastic Approach	0.132%	0.0805%
Creep-Fatigue Evaluation	Fatigue Damage	0.00	0.00
	Creep Damage	0.191	0.2090

5. Conclusion

This paper is on the validation study of the SIE ASME-NH program for an elevated temperature structure. The application structure is a KALIMER-600 IHTS hot leg piping. It is confirmed that the SIE ASME-NH program is a very effective design tool to evaluate a high temperature structure and is helpful to save on the calculation time and obtain an accurate result. And it is also found that the evaluation results by the SIE ASME-NH program are very similar to the hand calculation results and the SIE ASME-NH result of an inelastic strain using a simplified inelastic approach does not quite correspond to the hand calculation results of that within a small elastic range.

This study is carried out by considering a only single cycle type and thus a validation study of the SIE ASME-NH program by considering the multi-transient operating cycles has to be undertaken. Also it is expected that the SIE ASME-NH program has to be complemented by a material module to satisfy the Gen IV reactor lifetime of 60 years.

ACKNOWLEDGMENTS

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