A Comparison Study of the Benchmark Problem for the SIE ASME-NH Application

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1. Introduction

Gen-IV nuclear energy systems are required to accomplish economic enhancements such as a long design lifetime of 60 years and a high temperature operation over 500℃. The ASME provides the Subsection NH code for an elevated temperature design code for the nuclear class 1 components but its application procedure is very complicated to carry out by a hand calculation[1]. The SIE ASME-NH(Structural Integrity Evaluation by the ASME Subsection NH code)[2] program has been developed to overcome the complexity of ASME Subsection NH[3] application to nuclear component design. The main objectives of this work are to compare the evaluation results of this study with the reference results of the benchmark problem by using the SIE ASME-NH program and discuss the difference between both results. It may also contribute in developing a good understanding of the SIE ASME-NH application procedure to a design evaluation of elevated temperature structures.

2. Benchmark Problem

2.1 Description of Benchmark Problem

The benchmark problem is proposed through the SIE ASME-NH Users Seminar to compare with the evaluation results calculated by its users. The benchmark simulates the shell-and-tubesheet of a steam generator as shown in Fig.1. The shell has a radius of 3.0m and a thickness 10cm and the tubesheet has a 50cm of thickness. The used structural material is a Type 316 stainless steel and its mechanical and physical material properties follow the ASME Section II and Section III Subsection NH codes. It is simplified as an axi-symmetric analysis model by considering its cylindrical shape.

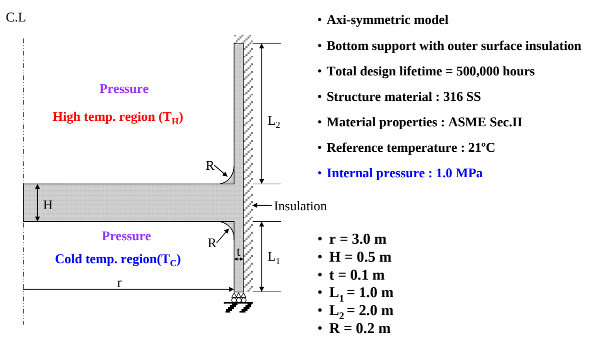

Fig. 1. Schematic drawing of an axi-symmetric model of the benchmark problem.

The operating life time is 500,000 hours and mechanical loading condition is a constant pressure of 1.0MPa on the inner surfaces of both upper and lower cylinder regions. It is vertically supported at the bottom surface of the shell and radial and axial displacements are assumed to be free expansion behavior. The outside surface of the shell is insulated and the heat loss does not occur toward the outer surrounding through the shell thickness direction.

2.2 Transient Cycle Event

The assumed representative thermal transient operating cycle event in the benchmark is a hot standby cyclic event as shown in Fig.2. The normal operating temperatures are assumed to as 550℃ and 450℃ for a hot and cold temperature region, respectively. As shown in Fig.3, the transient time for cool-down and heat-up operation is 5 hours. The number of occurrence is 1,000 cycles and thus the cyclic operating time under consideration of its 500,000 hours life time is 5,000 hours.

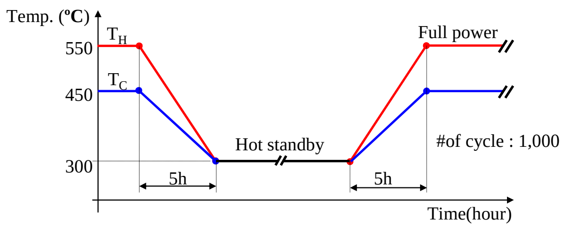

Fig. 2. Assumed hot standby thermal transient operating cycle.

3. Application of the SIE ASME-NH Program

3.1 Primary Stress Analysis

The applied primary load is an internal pressure of 1.0MPa and dead weight is not considered to conform to the loading condition of the reference work. The pressure is evenly distributed on the surface. Structural analysis is carried out by using the ANSYS[4] software with the PLANE82 two-dimensional structural solid element with an axi-symmetric option.

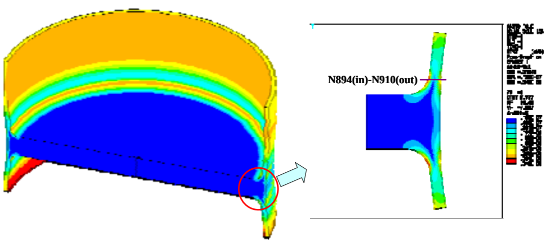

Fig. 3. Stress intensity contour for the primary load.

Figure 3 shows the calculated stress intensity contour. The critical section to evaluate the structural integrity is an upper fillet junction composed of Node 894 and 910 and the maximum total stress intensity is about 34MPa.

3.2 Thermal Transient Analysis

Figure 4 shows the temperature distributions at the major time points of the cycle event. The thermal transient stresses are calculated based on the transient heat transfer analysis results.

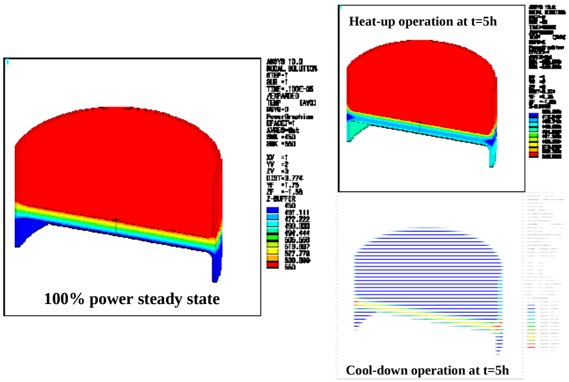

Fig. 4. Temperature distributions at each operating condition.

To evaluate the structural integrity of the elevated temperature structure according to ASME Subsection NH, the time points constituting the maximum range of the secondary stress intensity have to be determined. As shown in Fig. 5, the maximum stress intensity range occurred at the 5 hours after starting transient operation and its magnitude including the peak stress component is about 324MPa.

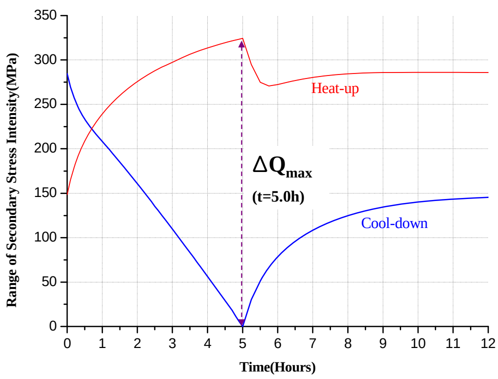

Fig. 5. Time-history of the secondary stress intensity range.

3.3 Evaluation results

The input data of the benchmark problem to evaluate the structural integrity by using the SIE ASME-NH program is prepared from the temperature and stress analysis results. Table 1 shows the evaluated results for the evaluation items. Though the evaluation is performed for the same problem, the result of this study is a little bit different from the reference result. For the primary stress, the stress intensity of inside node is higher than that of the outside for this study but reference result is just the opposite. For the Test No.B-1 of the strain limits, the reference is not calculated at the outside node due to the excessive effective creep stress but the present result shows the 0.0 at the inside node. The creep-fatigue damage for current work is not calculated due to the excessive effective creep stress and thus it is impossible to compare with each other. It is judged that the difference between both results is caused by the meshed FE model and the coolant thermal condition.

Table I: Evaluation Results for the benchmark problem

Evaluation Items		Inside Node		Outside Node	
		Reference	Present	Reference	Present
Primary stress limits (MPa)	P_m	5.9	7.6	5.9	7.6
	P_L+P_b	23.1	23.1	27.3	22.5
	P_L+P_b/K_t	18.4	18.8	22.5	18.3
Strain limits	Test No.A-1	1.65	2.45	2.31	2.26
	Test No.B-1	3.83	<u>0.000</u>	***	4.68
	Test No.B-3	1.86	1.35	1.14	2.40
Fatigue damage		0.14	-	-	-
Creep damage		3.33	-	-	-

4. Conclusions

Benchmark problem consisting of evaluating the structural integrity of an axi-symmetric model subjected to an elevated temperature by using the SIE ASME-NH program is studied. The evaluated result through this study is different from the reference result by as much as not to be negligible. It is mainly caused by the boundary conditions and FE analysis method applied in the problem. Additionally, the evaluation section for the comparison is not described in the problem and thus it may not conform to both cases. The assumed load condition is so severe that the creep-fatigue damage can not be compared with each other. Modifying a cycle event or structural geometry has to be followed and a further comparison study will be performed with it.

ACKNOWLEDGEMENTS

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REFERENCES

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[3] ASME Boiler and Pressure Vessel Code Section III, Subsection NH, ASME
[4] ANSYS Version 10.