Evaluation of Fatigue for Inner Barrel Assembly of APR1400 Reactor Vessel Internals

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1. Introduction

The Advanced Power Reactor 1400 (APR 1400) Nuclear Power Plant (NPP) will be constructed in Shin-Kori Units 3 & 4. The APR1400 NPP which produces 1400 MWe is an evolutionary generation III pressurized water reactor and has 60- year design life.

The Reactor Vessel Internals (RVI) are main component of APR 1400 NPP to provide support structures for the core and to provide a flow path within the reactor vessel to guide the primary coolant through the core. The RVI give lateral and azimuthal constraints to the Control Element Assemblies (CEAs) and support the in-core instrument nozzles.

In this study, the procedure for performing fatigue analysis of the shroud tube region in RVI IBA per the requirements of KEPIC MNG [1] and design specificat-ion[2] is developed. This developed procedure may be applied to all RVI components. Also, this study reviews the stress concentration factor to determine fillet weld size of shroud tube to satisfy fatigue life.

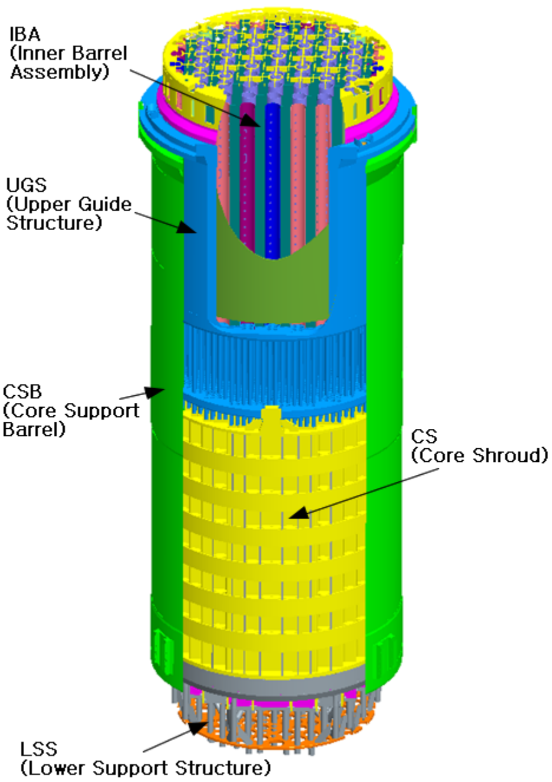

Fig. 1. Reactor Vessel Internals for APR 1400 NPP

2. Analysis and Result

2.1. Description of Inner Barrel Assembly

Inner Barrel Assembly (IBA) is consist of guide structure support system, CEA shroud tube, IBA Flange and IBA cylinder. IBA is located in RVI upper guide structure. The geometry model of IBA is shown in Fig.2.

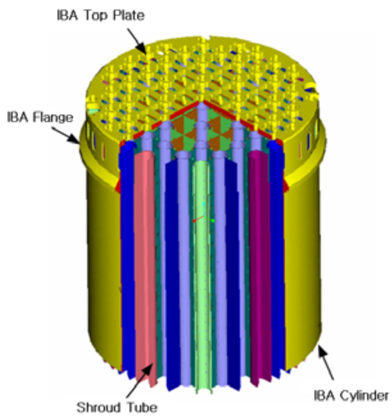

Fig. 2. Inner Barrel Assembly of Reactor Vessel Internals

2.2. General Method of Development

There is an industry-wide consensus that the KEPIC MNG fatigue approach has provided safety design against failure. The evaluation of fatigue is based on fatigue curve of stress versus number of cycles. The fatigue curve is shown in fig. I-9.0 of KEPIC MNZ [1].

The basis of the fatigue evaluation is that fatigue damage, caused by cyclic loading, is cumulative and that the summation of this damage during design life does not exceed 1.0. Fatigue damage is defined by a usage factor. The general rules are shown in fig. 3 that may be used to calculate fatigue usage factors for the APR1400 RVI IBA.

It is possible to perform a fatigue analysis of the RVI IBA components by calculating stresses for each thermal hydraulic transient data and following the general procedure of MNG-3222.4 [1]. However, because of the number of different transients and the complexity of the RVI, therefore, the procedure to perform the fatigue analysis of the RVI components is simplified by grouping the loading conditions. For APR 1400 RVI, the fatigue cycle type grouping has thirteen groups [4] and fatigue damage is calculated as each fatigue group.

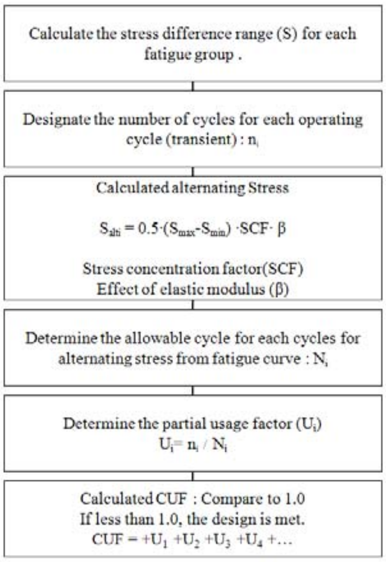

Fig. 3. General Procedure for Fatigue Evaluation

2.2. Stress Concentration and Effect of Elastic Modulus

Local structural discontinuities addressed Stress Concentration Factor (SCF). The SCF is calculated by Finite Element (FE) analysis using ANSYS [3]. The SCF can be obtained by calculating the ratio of maximum stress to nominal stress.

The FE model is considered for several fillet weld size which fillet size is proposed by manufacturing engineer. Fillet weld size is selected finally by recursive FE analysis. The results of two weld regions are listed in table I. Stress contours and three dimensional FE model of two weld region are shown in fig.4.

Table I: Result of FE Analysis for SCF

Weld Region	Fillet Weld Size (in)	SCF (Loading Type: Tension)	SCF (Loading Type: Bending)
A	0.07 (Min)	1.67	1.70
	0.25(Max)	1.99	2.14
B	0.07(Min)	1.45	1.33
	0.25(Max)	1.67	1.42

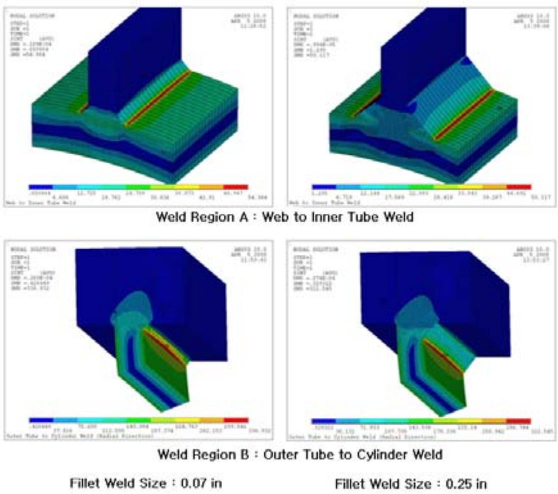

Fig. 4. Stress Contour of FE Analysis for Weld Region

The Effect of elastic modulus presents a modification for S_{alt} based on temperature. Each fatigue curve for fig. I-9.0 of KEPIC MNZ is defined by $E = 28.3 \times 10^6$ psi, but the operating temperature is less than of this. A ratio(β) of the two moduli will produce a ratio that is greater than 1.0. The S_{alt} must be multiplied by the ratio.

2.3. Results of Fatigue Evaluation

The results of fatigue evaluation are presented in table II. The CUF is less than 1.0 therefore, IBA shroud tube region meet acceptance criteria of KEPIC MNG. Fatigue group show representative four groups in the total group.

Table II: Result of Fatigue Evaluation for IBA Shroud Tube Region

Fatigue Group [4]	Stress Difference Range :(S_{max}-S_{min}) [ksi]	Alternating Stress :S_{alt} [ksi]	Number of for Each Fatigue Cycle : n_i	Number of Allowable Fatigue Cycle : N_i	Partial Usage Factor : U_i
I*	36.6	49.6	1	35385	0.0000
II	35.6	48.4	3425	40024	0.0856
III	29.8	40.5	22060	104342	0.2114
IV	50.1	68.0	20	7826	0.0026
Total Cumulate Usage Factor = 0.3250					
* Example: Fatigue Group I is normal operation with full power change and bolt-up combined with Type 2 Loss of Load.					

3. Conclusions

This study is to provide a simple procedure for performing fatigue evaluation of the APR 1400 RVI components including IBA shroud tube region per the requirements of KEPIC MNG. The conclusion is the below.

1. IBA shroud tube region for APR1400 RVI has been analyzed using developed simple procedure to show its safety of fatigue failure that meets the KEPIC MNG requirements.

2. The SCF based on the fillet weld size is calculated by FE analysis and the SCF is applied fatigue analysis. Also, IBA shroud tube will be manufactured by selected fillet weld size in the study.

REFERENCES

[1] The Korea Electric Industry Code (KEPIC), MNG and MNZ, 2000 Edition.
[2] Design Specification No. 3L186-ME-DD240-00, Rev.5, Design Specification for Reactor Vessel Core Support and Internal Structure for Shin-Kori units 3 & 4, 2010.
[3] Computer Code ANSYS, Release, 10.0.
[4] Calculation No. HC-121CN-131, Rev.0, Design Analysis for RVI Transient Methodology, 2009.