Estimation of Fracture Parameters for Leak-before-Break Assessment on Elevated Temperature

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1. Introduction

Recently, It have made progress in the engineering to research and develop Sodium-cooled Fast Reactors(SFRs). But the liquid sodium, coolant of SFRs is chemically unstable and explosively interact water in the air, too easily. When the liquid sodium leaks this interaction may cause the fire that is harmful to safety of the reactor. Therefore, it is necessary to prevent against sodium fire in SFRs. Leak-before-Break(LBB) concept, had been devised for this purpose and has following advantage than Double-ended Guillotine Break(DEGB) design. If DEGB is excluded, the number of extinguish facilities and firewalls against the sodium fire can be minimize.

LBB concept, has been well established and had many experience in regard of light water reactors(LWRs). But LBB assessment to SFRs is more complicated because SFRs is operated on elevated temperature region. On this region, because creep damage occurs to material and grows defects LBB assessment to SFRs should be considering creep effects. The procedure and method for this purpose are provided RCC-MRx A16 that is France code. To calculate fracture parameters such as K and J are required to some coefficients and equations which have been limited in RCC-MRx A16. Thus, in this study obtained K and J using finite element analysis for the sub-model including the crack. In case of full-model, fracture parameters are calculated by the limit load option in RCC-MRx A16. The limit load for this option is obtained by finite element analysis. These parameters are used to LBB assessment that was conducted to IHTS hot-leg piping of SFR.

2. Geometry and Loading Condition

In this study, the object of LBB assessment is IHTS hot-leg pipe in PGSFR(designed by KAERI).

2.1 Geometry of IHTS hot-leg pipe

Geometry of IHTS hot-leg pipe of PGSFR is shown in fig.1. The diameter, thickness and bend radius of this piping are 559mm, 12.7mm and 838mm, respectively.

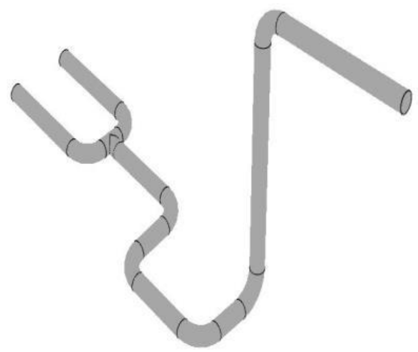

Fig. 1. Geometry of IHTS pipe

2.2 Loading condition

As shown fig. 2 operating and shutdown temperature are 528^{o}C and 200^{o}C, respectively. Heat up and cool down time are 12hours. An operation time is assumed to be 6720hours(280days). Pressure difference are 0.1MPa and 3.5MPa in operation and level A events.

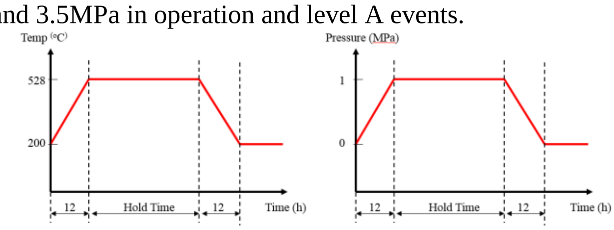

Fig. 2. Operation condition of PGSFR

Material of IHTS piping is 9Cr-Mo-V steel which is generally used for thermoelectric power plants. Properties of this material are recorded at RCC-MRx A3. In this study, finite element analysis and assessment were conducted using properties in RCC-MRx A3.

3. Result

3.1 Stress analysis

Temperature-displacement analysis is conducted without defect using Abaqus. Stress distribution and stress time history are shown in Fig. 3 and Fig.4. The assessment is performed about section 1 that is subjected to maximum stress and stress variation in the result of analysis.

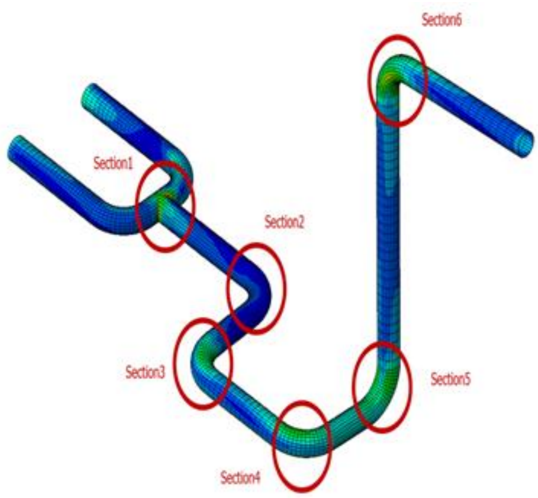

Fig. 3. Stress analysis result(contour)

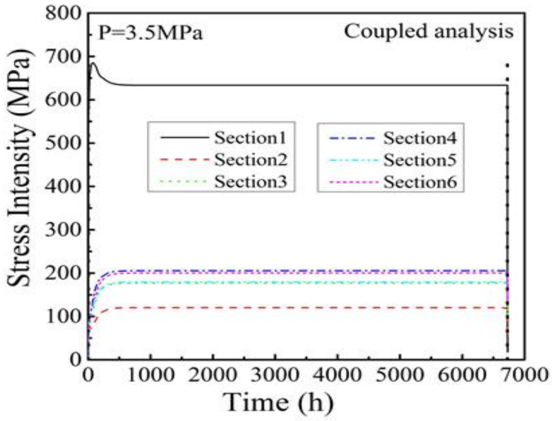

Fig 4. Stress Intensity history during 1cycle

3.2 Fracture parameters

In selected a region, a crack was assumed that crack exist on internal surface and lean on parallel to run direction. The a/t and l/a are equal to 0.5 and 3.

To estimate fracture parameter, Sub-model, is written which is include selected region and assumed crack. The sub-model and crack geometry are shown in fig. 5 and 6. Boundary condition is applied displacements from a result of full model analysis at three pipe ends.

Analysis is conducted for two cases. First case is considering only thermal load(200^{o}C). Second case is considering level A events(528^{o}C, 3.5Mpa).

Results of this analysis are summarized in table. 1. This result would be applicable to crack initiation assessment in RCC-MRx A16.

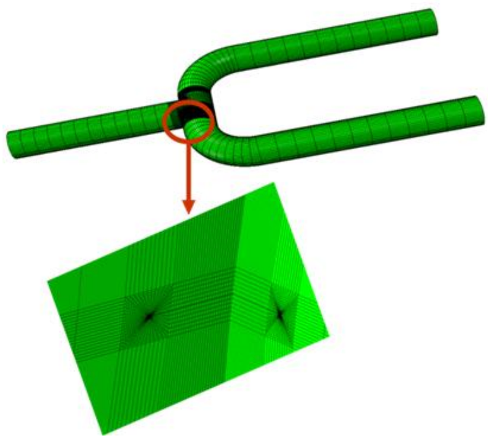

Fig. 5. Sub-model including assumed crack

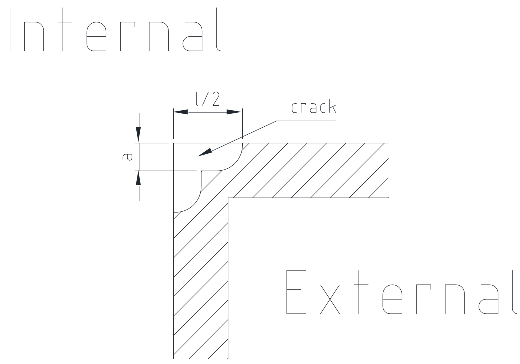

Fig. 6. Geometry of crack

Table I: fracture parameters from FE analysis

Load	$J_{elastic}$[MPa mm]	K_I[MPa √ mm]
thermal	19.54	20.9
Level A	1627.33	1682.92

4. Conclusion

In this study, fracture parameters for LBB assessment were estimated by finite element analysis.

This result will be applicable to LBB assessment of PGSFR.

REFERENCES

[1] RCC-MRx code Section III Subsection Z Appendix A16, “Guide for prevention of fast fracture, Leak Before Break analysis and defect assessment”, AFCEN, 2012

[2] Technical Appendix A3.18AS, “Properties Groups for products and parts in alloy steel grade X10CrMoVNb9-1 normalised - tempered or quenched – tempered”, AFCEN, 2012

[3] Technical Appendix A3.1S, “Properties Groups for products and parts in X2CrNiMo17-12-2(N) solution annealedaustenitic stainless steel”, AFCEN, 2012

[4] RCC-MRx code Section III Subsection B, “Class N1Rx Reactor Components, Its Auxiliary Systems and Supports“, AFCEN, 2010

[5] Technical Appendix A9, “Properties Groups for welded joints”, AFCEN, 2010