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Creep-Fatigue Test for the Prototype of the IHTS Co-Axial Pipe Structure

Hyeong-Yeon Lee, Jong-Bum Kim, Seok-Hoon Kim, Se-Hwan Lee, Jae-Han Lee
KAERI, Dukjindong, Yuseong, Deajeon,305-353, Korea, hylee@kaeri.re.kr

1. Introduction

A validation test with the structural test model for the IHTS coaxial piping structure of the liquid metal reactor, KALIMER-600[1] is to be carried out this year. As part of the work, the structural test model has been designed and a preliminary analysis has been carried out.

The materials used in the test model are Mod.9Cr-1Mo, 316L and Alloy800H[2]. The creep-fatigue damage, creep-fatigue crack initiation and creep-fatigue crack growth are to be examined by using the assessment according to the procedures and experimental observations from the structural test. There are various types welded joints in the test model. Dissimilar metal weld(DMW)s were applied at two lines in the circumferential direction of the outermost cylindrical shell. The behavior of dissimilar metal welds between 316L stainless steel and Mod.9Cr-1Mo with buttering and DMW with trimetallic weld joints by using a Alloy 800H which has the mid value of the thermal expansion coefficients of Mod.9Cr1Mo and 316Lwere investigated. The structural specimen with a outer diameter of 500mm and thickness of 6.35mm is a welded cylindrical shell made of Mod.9Cr-1Mo and the height of the specimen is 800mm.

In the creep-fatigue test, the hold time is set to be three hours at 600°C and the primary nominal stress is 63MPa. The evaluation results for the creep-fatigue, crack initiation and crack propagation are to be compared with those of the observation images from the structural test.

2. Coaxial pipe structure in KALIMER

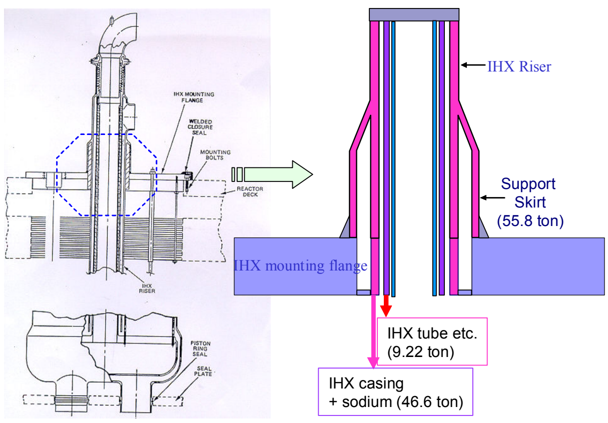

Fig.1 IHX support part in coaxial pipe structure

One of the weakest parts in liquid metal reactor operating at a high temperature above 500°C is the IHTS(intermediate heat transport system) coaxial pipe structure where duel pipes with many welded joints but there is no suitable method for an ISI(in-service inspection) for this double wall structure. The IHTS pipe support part is shown in Fig. 1.

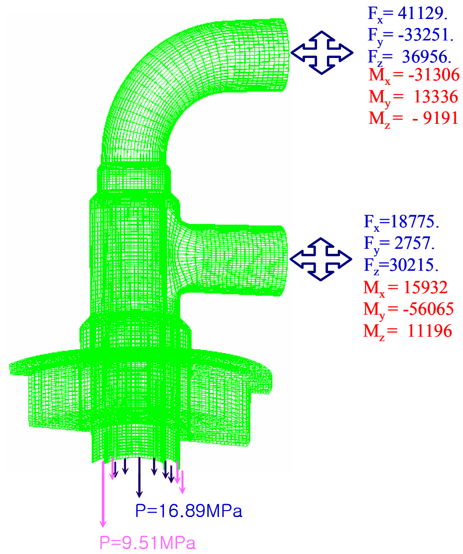

Fig.2 Finite element model of IHTS coaxial pipe structure and it system loads at cold leg and hot leg

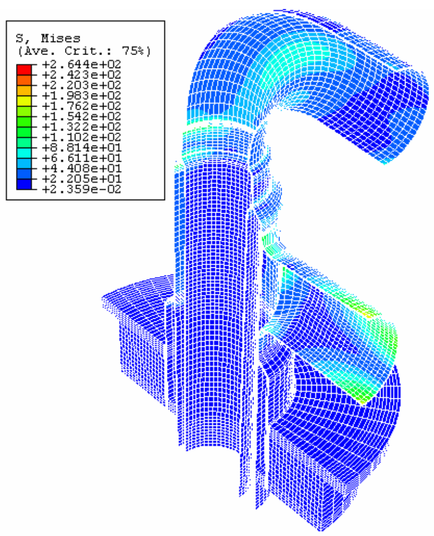

Fig.3 Finite element analysis results for IHTS coaxial

piping structure of KALIMER-600

The sizing of the IHTS coaxial pipe structure for KALIMER-600 has been carried out. The structure was modeled as shown in Fig. 2. The piping system loads determined from the IHTS piping analysis by using ABAQUS[3] and the pressure loads determined from the deadweight of the IHX are shown in Fig. 2.

The analysis result for the IHTS coaxial pipe structure is shown in Fig. 3, which shows that the maximum stress intensity of 264.4MPa under mechanical and thermal loads is within the allowable stress limit of 3Sm(=654MPa at 600°C for Mod. 9Cr-1Mo).

3. Details of the IHTS Coaxial pipe specimen

The test specimen and test facility simulating the above IHTS pipe support structure of KALIMER-600 is shown in Fig. 4. The structural test model is a prototype of the coaxial pipe structure with many welded joints as shown in Fig. 4. The material at the outer and mid shell is Mod.9Cr-1Mo but there are a few dissimilar metal welded joints between Mod.9Cr-1Mo and 316L stainless steel at the outer shell as shown in Fig. 4. Several through-wall defects are machined by using an electric discharge machining.

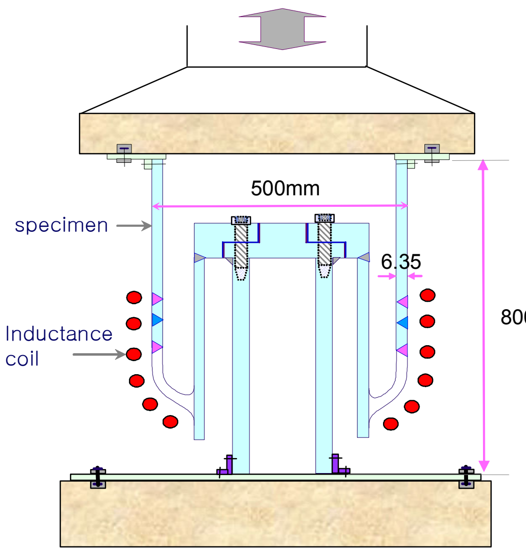

Fig.4 Schematic diagram of creep-fatigue test with the prototype of IHTS coaxial pipe support structure

4. Loading Conditions and preliminary analysis

The thermal cycles applied by using the inductance coil are shown in Fig. 4. The mechanical load of 50ton from the hydraulic actuator system is applied at each load cycle, which induces an axial nominal stress of 49.8MPa. The outer shell is to be heated by using the inductance coil up to 600°C and the hold time is three hours.

This type of creep-fatigue load is to be applied and the surface damage will be observed by a portable optical microscope, nondestructively. The preliminary stress analysis result under a mechanical load only for the test model is shown in Fig. 5 and a detailed thermal stress analysis will be carried out by using the measured temperature data.

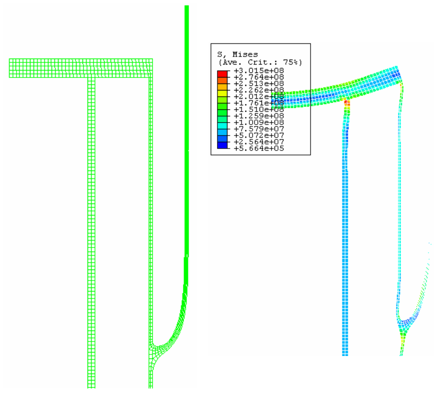

Fig.5 Finite element analysis model of the test model and its analysis results of Mises stress

5. Conclusion

In this study, a creep-fatigue structural test to be carried out with a coaxial pipe structure is outlined, which simulates the IHTS coaxial pipe structure of KALIMER-600. The sizing of the coaxial pipe structure and stress analysis has been carried out. The structural test model was designed and a stress analysis has been carried out. The creep-fatigue structural test for the coaxial pipe structure is to be performed and the damage due to a creep-fatigue load is to be observed by using an optical microscope. In addition the behavior of a dissimilar metal weld in terms of creep-fatigue damage and crack initiation is to be examined. Detailed analysis on the thermal stress and creep-fatigue behavior is to be carried with the measured temperature data in the structural test.

Acknowledgements

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References

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2. ASME Boiler and Pressure Vessel Code, Section III, Div. 1, Subsection NH, Class 1 Components in Elevated Temperature Service, ASME, 2001.
3. ABAQUS Users manual, Version 6.5, H.K.S, USA 2005.