Construction of in-situ creep strain test facility for the SFR fuel cladding

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1. Introduction

A Sodium-cooled Fast Reactor (SFR) is a reactor operated by high-energy neutrons that enables it to recycle the spent fuel from a conventional light water reactor. The fuel cladding tube is the most important safety barrier in fission nuclear reactors. It was occurred thermal creep and void swelling by fission gas at high temperature for service time. Ferritic-martensitic steels are being considered as an attractive candidate material for a fuel cladding of a SFR due to their low expansion coefficients, high thermal conductivities and excellent irradiation resistances to a void swelling [1]. HT9 steel (12CrMoVW) is initially developed as a material for power plants in Europe in the 1960. This steel has experienced to expose up to 200dpa in FFTE and EBR-II. Ferritic-Martensitic steel' s maximum creep strength in existence is 180Mpa for 106 hour 600℃, but HT9 steel is 60Mpa [2]. Because SFR is difficult to secure in developing and applying materials, HT9 steel has accumulated validated data and is suitable for SFR component. And also, because of its superior dimensional stability against fast neutron irradiation, Ferritic-martensitic steel of 9Cr and 12Cr steels, such as HT9 and FC92(12Cr-2W) are preferable to utilize in the fuel cladding of an SFR in KAERI. The pressurized thermal creep test of HT9 and FC92 claddings are being conducted in KAERI, but the change of creep strain in cladding is not easy to measure during the creep test due to its pressurized and closed conditions.

In this paper, in-situ laser inspection pressurized creep test machine developed for SFR fuel cladding specimens is described. Moreover, the creep strain rate of HT9 at 650^{o}C was examined from the in-situ laser inspection pressurized creep test machine.

2. Description of test machine

2.1 Current status of laser inspection test

The laser inspection method for the tube creep test has gained recognition over 20 years as a viable Non Destructive Testing (NDT) method for the steam reformers in USA [3]. Laser profilometry is a non-contact, non-destructive inspection technique which utilizes a low-powered laser to profile the surface of an object. In the case of steam reformers it is being used to profile the change of diameter.

The Laser Optic Inspection System (LOTIS) was developed by QUEST for the U.S. Navy in 1985 for the inspection of the diameter of oil cooler, condenser and chiller tubes. Since then, Laser profilometry has been utilized in numerous process plants around the world to inspect a variety of units such as, boliers, exchangers and reformers [4].

2.2 Description of laser inspection creep test machine

A schematic drawing of the laser inspection creep test machine is shown in Fig.1. The size of the equipment is 850x900x1200mm (WxDxH). The laser inspection creep test machine consists of a servo motor & ball screw unit for the linear motion, bush & guide shaft, laser sensor, sensor receiver, and furnace. The servo motor & ball screw unit was installed to move the laser sensor linearly without any vibration. The creep furnace was manufactured with a hexagonal shape, and it has two windows (6cmX4cm) at the both side of the furnace to penetrate the laser. A specimen holder was located between the laser sensor & sensor receiver at the center of the furnace, and its outer diameter can be measured by the laser sensor.

In the case of the transfer module of laser sensor, the maximum height is 800mm, and the maximum speed of the module is 10mm/sec. The LMI laser sensor (SLS 6000 model) was installed for the laser inspection. The measurement range of the sensor is 1100mm, linearity is <±3μm, measuring rate is 2.3 kHz and the minimum resolution is 0.1μm.

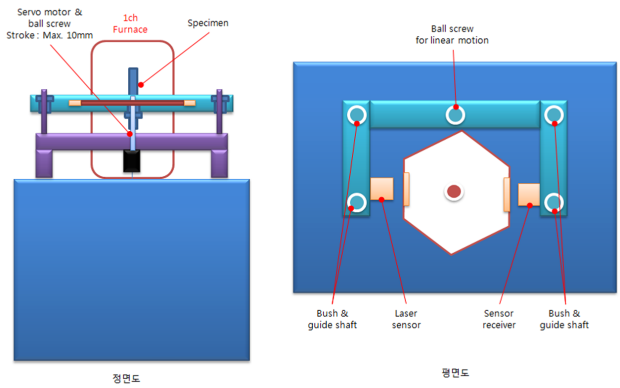

Fig. 1. Schematic drawing of laser-inspection creep test machine.

The procedure of the laser inspection tube creep test is as follows. When the specimen is installed in the equipment, the furnace is inserted from the top of the specimen. When the temperature is stabilized at the target temperature, the tube is pressurized at the target hoop stress. During the creep test, the outer diameters of the tube creep specimens are measured periodically, by moving the laser sensor to the window and scanning the creep tube inside the window. This sequence is automated with a computer program.

2.4 Test result of the laser inspection creep tester

Fig. 2 shows the time – strain curve of the HT9 cladding that obtained from a laser inspection creep tester at 650°C. In this result, the sampling rate of displacement is 0.1 per min, and the movement speed of the sensor for measuring is 2mm/min. In this result, it can be seen that the specimens are moved into a stage of secondary creep, and the rate of secondary creep can be clearly obtained from this curve. However, there are some noises in the curve. There are some reasons for the noises in the creep curve. First, the movement speed of the laser sensor would be to fast that can cause little vibration of the laser sensor. Second, the measuring rate of the laser sensor is not suitable for the measurement. When these problems corrected based on the test results, more accurate strain rate data of the fuel cladding specimens would be obtained by the laser inspection creep test machine.

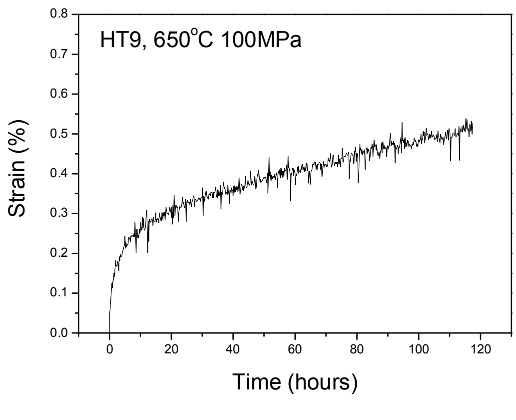

Fig. 2. Creep strain curve of the HT9 fuel cladding obtained from a laser inspection creep test machine.

Besides the noise, there are still other problems in the laser inspection creep test machine. Because of the existence of the window in the furnace, it is hard to obtain a large uniform zone with the stabilized temperature. This problem can be solved by reduce the size of the windows and changing the size of the specimen. The more modified conditions of the equipment will be discussed from the preliminary test results.

3. Conclusions

In this study, in-situ laser inspection creep test machine was developed for the measuring the creep strain of SFR fuel cladding materials. The design and result of the equipment was successful, and the further modified test result will be obtained after the correction of equipment.

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