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Performance Tests of the Out-pile Loading System using a Bellows

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1. Introduction

An instrumented capsule is one of the devices to investigate the irradiation effects of the nuclear reactor materials and components being used in a research reactor, HANARO. Among various capsules, a special capsule for in-pile creep and fatigue tests has been under development since 2002. A bellows was used to apply the constant load to the specimen in the creep capsule, and various studies have been performed to determine the specification of the bellows [1]. But the load's concept for the fatigue test is slightly different from the creep test. It is necessary to repeat a force with a constant period and amplitude during the life of the specimen. Thus, for the fatigue test using an instrumented capsule, it is important to realize the load's shape being applied to the specimen. A loading system by using bellows to apply to the actual fatigue capsule is developed [2] by modifying the previous system which was used for the out-pile creep test. In this study, to estimate the characteristics and the performance of the developed loading system, the out-pile test using a spring and a rigid bar specimen is performed, and it is found that the new loading system has a suitable function for the in-pile fatigue test.

2. Out-pile Loading System

The structure of the newly developed loading system is described in a previous paper [2] in detail. Thus we briefly describe the outward shape of the capsule and the main components related to the loading system here. The capsule mainbody made of STS 316L materials is a cylindrical shell, 60mm in diameter and 2mm in thickness and 870mm in length, and it includes all the components, which are necessary for the creep or the fatigue tests. Thus, the actual capsule for the in-pile creep tests is designed and manufactured by considering these geometrical restrictions [3].

Figure 1 shows the schematic diagram of the loading system using the bellows. The system consists of four main parts; a loading, a display panel, a helium supply tube and PLC control parts. The loading part includes the specimen, the bellows, the load carrying rod and the yoke et al.. When the helium gas of a high pressure is supplied to the bellows through the gas tube of 1/4 inch in diameter, the force due to the compression of the bellows is transferred to the specimen through the rod and the yoke. Next, the force of the specimen is eliminated when the helium pressure becomes zero. By repeating the above procedures a periodic load for the fatigue test can be realized. The bellows made of Hastelloy C-276 materials is 34mm in diameter and it is the same one as the 03S-07K creep capsule. Also, various components such as a regulator, a pressure transducer, a solenoid valve and a metering valve and MMI/PLC programs are used in the loading system. The load and the displacement of the specimen are measured by using a load cell and a LVDT (linear variable displacement transducers) respectively.

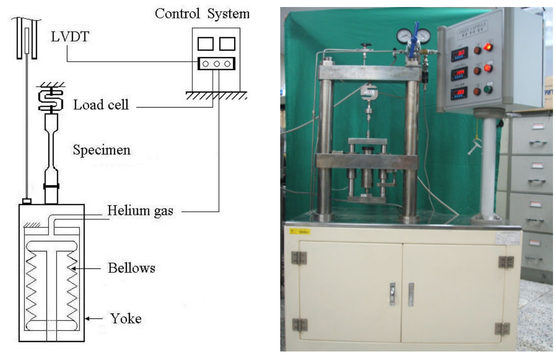

Figure 1. Schematic view and photo of a loading system

3. Performance Tests

In order to confirm the basic performance of the developed out-pile loading system, a test for a spring specimen and a rigid bar specimen is performed.

3.1 Spring specimen

First of all, we choose a spring specimen, which can obtain a large displacement to show the characteristics of the LVDT and the load cell sensors, and to confirm the wave shape of the signals.

Figure 2 shows the pressure, the displacement and the load time history (period: 10 sec, pressure amplitude: 3~7 kgf/cm^2). In this case the displacement shows a linear increment by increasing the pressure (or load). Because the periodic load of a triangular shape is designed for the fatigue test, the realization of the triangular shape's load by using the new system is first confirmed. As shown in Figure 2, the loading system creates a good shape of the triangular wave periodically, and the responses of the load cell and the LVDT also show good results. This means that it is possible to apply the loading system to the fatigue test by using the actual capsule. Although the detailed results are not described here, we confirm the realization of the holding time (Figure 3) and the controllability of the load's period by using a metering valve. Also, as a basic performance, the exhaustion of the helium gas depending on the pressure's amplitude and period is checked.

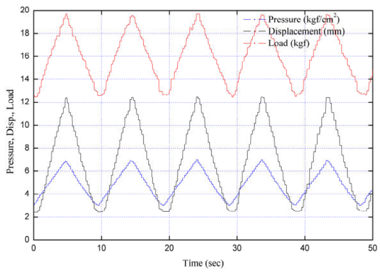

Figure 2. Pressure and displacement time history

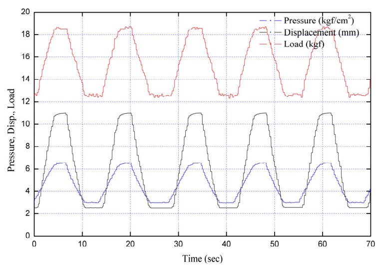

Figure 3. Effect of holding time(3sec.) on the wave shape

3.2 Rigid bar specimen

It is important that the relation of the load with the pressure is obtained because we don't know the actual load being applied to the specimen of the in-pile fatigue capsule during the irradiation test in the reactor in-core. The rigid bar instead of the spring or an actual tensile specimen is used for the performance test to obtain the relation between the load and the pressure.

Figure 4 shows the relation between the pressure in the p=3~50 kgf/cm^2 range and the measured load, and the trend equation of the measured data is as below;

$$F = 6.15p - 5.26 \quad (1)$$

Where, the p and F are the pressure and the load, respectively. The diameter of the bellows used in the loading system is 34mm, but the load calculated by dividing the pressure into the area of the bellows has a difference with the test results. The reason is because the area applied to the pressure in the bellows is actually smaller than 34mm due to the leaflet of the bellows. In case of 28mm in diameter when considering the leaflet size of the bellows, the calculated load is in good agreement with the test results. This equation can be used to obtain the information of the force acting on the specimen for the special capsule with the same bellows.

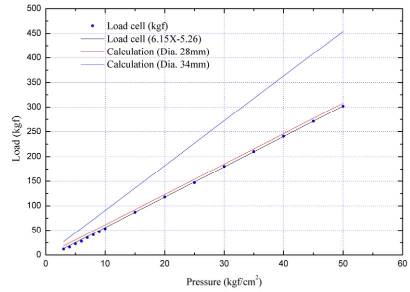

Figure 4. Relation of the pressure and the load

4. Conclusion

The loading system using the bellows simulates the periodic load of the triangular shape well, and a shape control including the amplitude, the holding time and the period of the load is possible by controlling the valves and using a MMI program. Thus it is possible to apply the concept of this system to the in-pile fatigue test. From results for the rigid bar specimen, it is found that the load increases linearly with an increment of the pressure as in the following equation; $F = 6.15p - 5.26$. It is expected that the loading system will be useful in designing the creep or the fatigue capsule for an irradiation test.

ACKNOWLEDGEMENTS

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