Transactions of the Korean Nuclear Society Spring Meeting
Kyungju, Korea, May 29-30, 2008

Measurement Technique of an Irradiation Stress Relaxation in a HANARO Fuel Bundle Guide Spring

Sangbok Ahn[a], Seungjai Baek[a], Dosik Kim[a], Yongsun Choo[a], Chungsung Lee[a], Heonil Kim[a], Wooseok Ryu[a]
Asif Waheed[b], Steve Palleck[b]

[a] PIE & Radwaste Division, Korea Atomic Energy Research Institute
1045 Daeduk-daero Yusung-gu Daejon 305-353, Korea, sbahn@kaeri.re.kr
[b] Fuel Design Branch, Atomic Energy Canadian Limited
2251 Speakman Drive Missisauga, Ontario, Canada, waheeda@aecl.ca

1. Introduction

The fuel bundle of a HANARO reactor constitutes fuel rods, a bottom guide, a top guide, a bundle guide spring (spring) etc. In these parts, the spring in a reactor contributes to supporting a bundle weight, maintaining the bundle at the fixed position against vibrations induced from coolant flows under a compression state. Neutron irradiations in the reactor cause stresses in the spring to be relaxed. It loses pre-loads in the spring, results to rotate the bundle, and increase the risk of bundle being ejected from the core by PCS flows. For the safe operation of reactor it is necessary to monitor the stress relaxation of the spring continuously. To measure the amount of relaxation in the irradiated spring the compression test techniques in a hot cell are developed. To account the stress relaxation amount the spring constant from compression test is introduced, and it is revealed to be a good factor to evaluate the relaxation amount.

2. Spring material and shape

The material of a spring is Alloy X-750. It is a precipitation hardened alloy which has been used in applications such as high temperature structural members for gas turbine, jet engine parts, and nuclear power plants. The spring has an hourglass helical configuration with an open-coil type. It is designed to store energy or to resist a force applied along the axis of the coil as shown in Figure 1. The specifications are wire diameter 2.33mm, free length 62.5 mm, 6.5 active number turns of the coils, and a total of 10.5 turns for the coils.

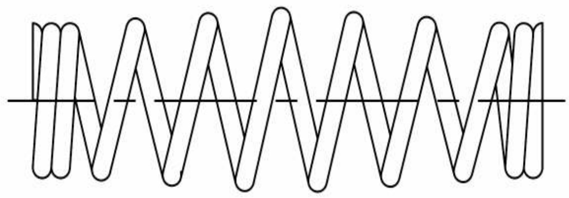

Fig. 1 Shape of the a bundle spring

3. Development of test techniques in a hot cell

The irradiated bundle is transported from the HANARO building to the IMEF using a cask. After transportation, the following techniques are developed and adopted.

3.1 Dismantling Technique of spring

The irradiated bundle is dismantled with a capsule cutting machine in a hot cell. It is cut out in the top position and separated fuel rods and the spring. Figure 2 shows the detailed work procedures to detach the springs.

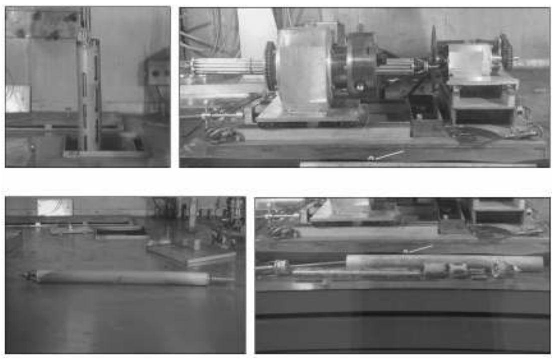

Fig. 2 Dismantling procedure for a spring.

3.2 Apparatus of test equipments

The universal testing machine installed in a hot cell shown in Figure 3 is used to conduct the tests. The machine is INSTRON-8562 model, which has 50 kN of a load capacity, 100 mm of a displacement. For the test , a load cell with a 10 kN capacity is used.

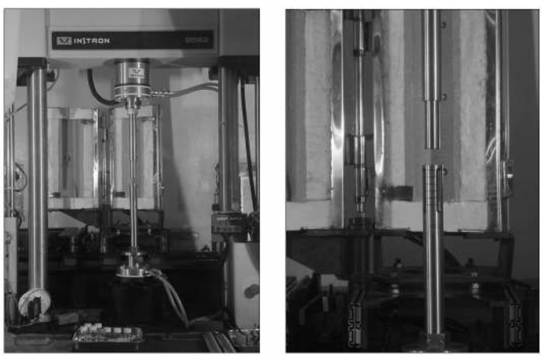

Fig. 3 Appearance of test equipments in a hot cell

The signal generated from a load cell installed in the cross head and an LVDT attached to the actuator in the machine during a test are simultaneously monitored and recorded. The Series-IX program supplied from the INSTRON Company controls the machine to a required test condition, and performs a data acquisition. The analog X-Y plotter is prepared for an emergency situation of losing test data, so as not to lose any data.

The fixtures are designed and manufactured using heat treated SKD steel with over 40 of an HRC number. To avoid the friction between the upper and the lower fixtures during a loading, a gap of 1 mm between the fixtures is provided. The detailed shape is shown in Figure 4.

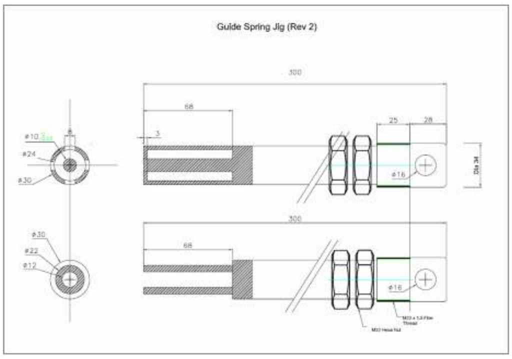

Fig. 4 Detailed dimensions of fixtures

3.3 Development of compression test procedures

Before the spring tests, the load cell is calibrated by a KOLAS certified company and the LVDT attached to the actuator is checked using the calibrator. The upper and lower fixtures are installed on the actuator and the load cell in the UTM. The spring is inspected visually. The test control program (Series-IX) is checked through the dummy spring test.

3.4 Length measurement technique

To measure the total length of the spring, a specially manufactured tool attached a vernier calipers is used in a hot cell. The calipers is manufactured by the MITUTYO Company, and the measurement range and precision of it are 0 ~ 300mm and 1/20 mm respectively. Figure 5 shows the shape of the measurement tool in a hot cell.

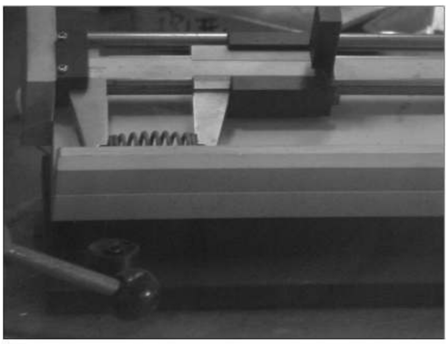

Fig. 5 Device for a spring length measurement

4. Application example of developed techniques

Figure 6 shows the modified load and displacement curves to position the loading points to be the (0, 0) origin from the raw test data. From the figure we can calculate the spring elastic constant, and the maximum endurable compression load. The calculated constant and the acquired maximum load from the figure are 8.87 N/mm, 291 N respectively. The constant acquired from a test is well agreed with 7 ~ 9 N/mm of a design value. The measured free length is 62.13 mm, and it is almost equal to the length of a new spring length.

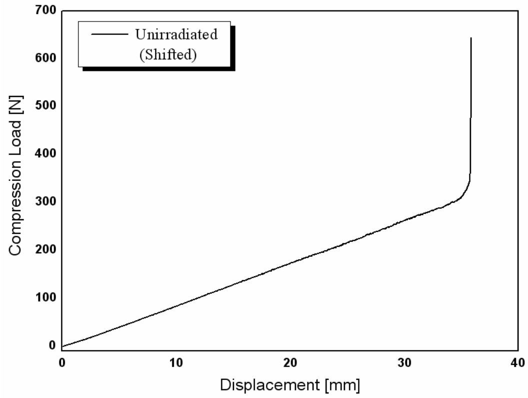

Fig. 6 Example of a test result when using the developed techniques for the unirradiated spring.

5. Conclusion

To measure an amount of stress relaxation for the irradiated HANARO bundle guide spring, the compression test techniques in a hot cell are developed. To verify the developed techniques, a compression test for the unirradiated spring is performed and successfully conducted. A spring constant using a developed techniques is 8.87 N/mm, and it is well agreed with a design value. The developed techniques will be a useful tool to evaluate the stress relaxation phenomena by neutron irradiations, and contribute to the safe operation of a HANARO reactor.

REFERENCES

[1] Design Specification of HANARO fuel bundle guide spring
[2] User Manual of INSTRON 8562 model.
[