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Development of Post-Irradiation Test Techniques for the Components of a Nuclear Fuel Assembly in a Hot Cell

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1. Introduction

The mechanical properties of the components of a nuclear fuel assembly are degraded during the operation of the reactor, through the mechanism of radiation damage. The properties changes of the components supporting the fuel rod in the fuel assembly should be quantitatively estimated to ensure the safety of the fuel rod during the operation. As a part of the procedures to establish a basic test database for the development of a domestic nuclear fuel assembly and the application to the nuclear power reactors, the post-irradiation test techniques for the several components of the fuel assembly were developed. The ability of handling the fixtures and the specimens by a manipulator and the reliability of test results in a hot cell were considered for the design of test fixtures and apparatus.

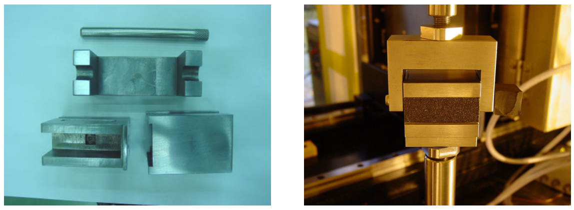
2. Post-Irradiation Test Techniques

Test techniques used to produce the irradiation data of the several components of a nuclear fuel assembly are described. They include the tests of the grid 1x1 cell, the spring of the grid plate, the inner/outer strip of the grid. The testing machine should have a capability of the tensile/compressive loading and unloading at a constant loading rate and up to a given displacement level. Regarding to the maximum load of the each specimen, the load transducer was selected and used. All the fixtures were designed and installed so that the loading line should coincide with the centerline of the specimen during each test. From the tests by using the techniques developed in this study, the load-displacement curve was obtained, and then the deformation behavior and the mechanical properties were examined.

2.1 Spring test of the grid 1x1 cell

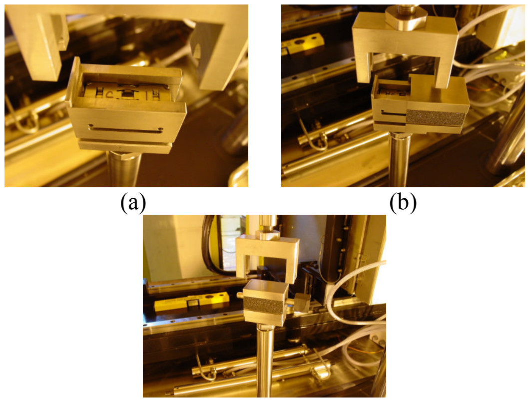
The fixture for the spring test of the grid 1x1 cell specimen consists of the lower fixture, the cover for the lower fixture, the loading rod and the upper fixture as shown in Fig. 1(a). Fig. 1(b) shows the fixture assembly installed in a hot cell.

All faces of the grid 1x1 cell specimen are adequately fixed in the lower fixture. And then, the compressive load is applied to the spring of the specimen up to a given deformation level at a constant rate under a displacement control as shown in Fig. 2. From a load-displacement curve, the applied load corresponding to a given displacement and the permanent deformation are obtained.



(a) (b)

Figure 1. Fixture for the spring test of the grid 1x1 cell specimen.

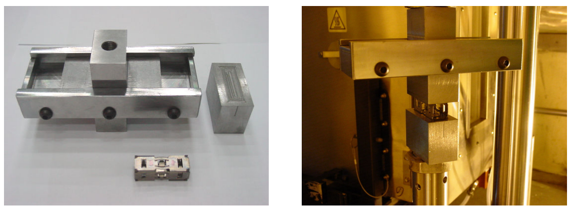


(a) (b) (c)

Figure 2. Specimen and fixture in a hot cell.

2.2 Buckling test of the grid 1x1 cell

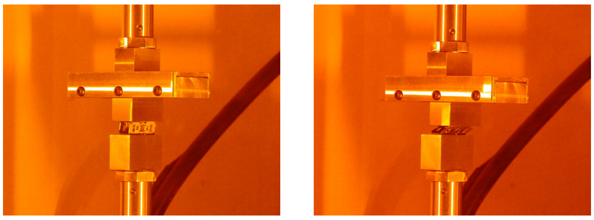
The buckling test of the grid 1x1 cell specimen is conducted using the upper and lower fixtures shown in Fig. 3(a). Fig. 3(b) is the buckling test fixture in a hot cell. The specimen is located between the lower and upper fixtures, and the compressive load is applied while the specimen is buckled. Load is applied to the specimen at a constant rate under a displacement control.



(a) (b)

Figure 3. Fixture for the buckling test of the grid 1x1 cell specimen.

The plate type roller bearing of the upper fixture is used for the lateral deformation of the grid 1x1 cell specimen. Fig. 4 shows the deformation behavior of the specimen during the test. From a load-displacement curve, the buckling load is obtained.

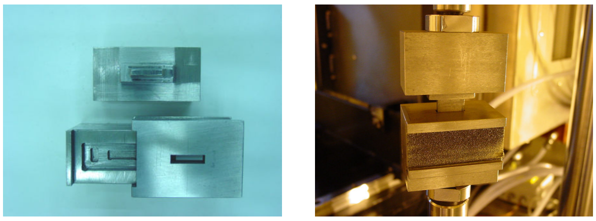


(a) (b)

Figure 4. Deformation behavior of the grid 1x1 cell specimen.

2.3 Spring test of the grid plate

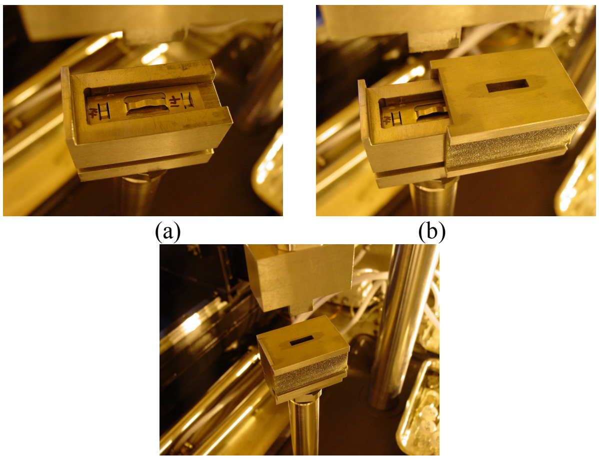
The fixture for the spring test of the grid plate specimen consists of the lower fixture, the cover for the lower fixture and the upper fixture shown in Fig. 5(a). Fig. 5(b) shows the fixture assembly installed in a hot cell.



(a) (b)

Figure 5. Fixture for the spring test of the grid plate specimen.

The specimen is adequately fixed in the lower fixture, and the compressive load is applied to the spring up to a given deformation level at a constant rate under a displacement control as shown in Fig. 6. From a load-displacement curve, the applied load corresponding to a given displacement and the permanent deformation are obtained.

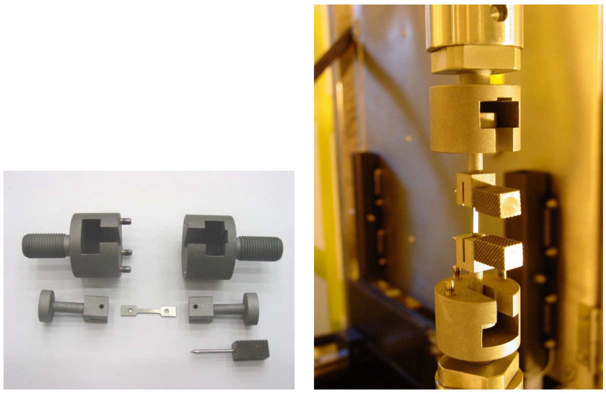


(a) (b) (c)

Figure 6. Specimen and fixture in a hot cell.

2.4 Tensile test of the grid

The tensile test of the grid materials is performed by using the pin-loaded tension specimen. The fixture for tensile test consists of the upper/lower grips and adapters and the loading pin shown in Fig. 7.



(a) (b)

Figure 7. Fixture for the tensile test of the pin-loaded specimen.

The specimen is inserted into upper/lower grips located at the specimen assembly kit (Fig. 8), the loading pins fix the specimen to the grip. The assembled specimen and grips is linked to the upper/lower adapters in Fig. 7(b). . From a load-displacement curve, the yield strength, the tensile strength and the elongation are obtained.

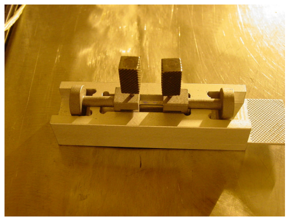


Figure 8. Assemble of the pin-loaded specimen.

3. Conclusion

The post-irradiation test techniques developed in this paper are applied to the estimation of the irradiation behavior of the specimen irradiated in a research reactor and obtained from the components of the fuel assembly operated in a nuclear power reactor. Through these tests of the components, the essential data on the fuel assembly design is obtained. These results will be used to update the irradiation behavior databases, to improve the performance of fuel assembly, and to predict the service life of the fuel assembly in a reactor.