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Diameter and Ovality of Irradiated Nuclear Fuel Rods on Burnup Cycle

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1. Introduction

Operation conditions of nuclear reactors such as neutron irradiation, reactor temperature and pressure were accompanied with the dimensional changes of nuclear fuel rods in nuclear reactors. These dimensional changes are reported as creep, growth of nuclear fuels due to fast neutrons and PCI(pellet cladding interaction)[1-5]. In this study, the diameters of irradiated nuclear fuel rods from the bottom of nuclear fuel rods to the upper of nuclear fuel rods were measured with remote control using LVDT(linear variable differential transformer). Diameters and ovalities of irradiated nuclear fuel rods were measured, and these results were analyzed on burnup cycle, respectively.

2. Examination

2.1. Examination Apparatus

The apparatus of dimensional measurement of nuclear fuel rods consists of LVDT sensors for diameters and bow measurement of nuclear fuel rods. The open and close of the sensors of these LVDT were operated by step motor. These LVDT sensors were connected with control and digital display unit in outside hotcell. The signals of LVDT were figured through digital voltmeter and recorded on two channel recorder. The examination of diameter measurements of irradiated nuclear fuel rods was controlled, data acquisition and data analysis were performed with PC including 12 bit A/D.

2.2. Measurement Method

Dimensional system is calibrated by fabricated standard gauge. The relation formula between voltage of LVDT and diameter of nuclear fuel rod is as follows.

$$\text{Diameter} = 10.70 + (\text{voltage} - 1.31) \times 0.05/0.16 \qquad (1)$$

The diameters of nuclear fuel rods are measured using formula (1). The diameters and ovalities of nuclear fuel rods are measured with accuracy ± 15 ㎛ by connecting adapter between standard gauge and irradiated nuclear fuel rods. The diameter of irradiated nuclear fuel rod is measured each location 1 mm up to upper of irradiated nuclear fuel rod as irradiated nuclear fuel rod moves to down.

The diameters of irradiated nuclear fuel rod are defined as D1. After irradiated nuclear fuel rod are rotated by counterclockwise 90°, the diameters of irradiated nuclear fuel rod are measured according to the same as procedures. They are defined as D2. The diameters of irradiated nuclear fuel rod are measured each rotation 1° of orientations of irradiated nuclear fuel rod at location which the value of D1-D2 is big. These diameters are measured from rotation 1° of irradiated nuclear fuel rod to rotation 180°. The ovality of irradiated nuclear fuel rod is acquired from 180 diameters. The measured diameters and ovalities of irradiated nuclear fuel rod are analyzed on burnup cycle.

3. Results Analysis and Discussion

Figure 1 shows diameters of nuclear fuel rod which is burned for two cycles. The diameters of middle part of irradiated fuel rod indicated about 0.4% decrease than design value of diameter. Figure 2 shows diameters of nuclear fuel rod which is burned for three cycles. The diameters of middle part of irradiated nuclear fuel rod indicated about 0.6-0.8% decrease than design value of diameter.

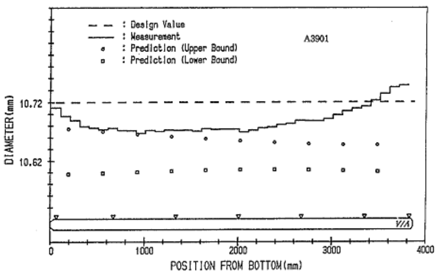

Figure 1. Diameters of nuclear fuel rod of two burnup cycles.

Figure 3 shows diameters of irradiated nuclear fuel rod which is burned for four cycles. Diameters of middle part of irradiated nuclear fuel rod indicated about 0.7 % decrease than design value of diameter. These diameter differences between middle part and lower, upper part of irradiated fuel rod are assumed to be due to swelling and densification of nuclear fuels. Figure 4 shows ovalities of nuclear fuel rod which is burned for two cycles. The ovalities of upper and lower part of irradiated nuclear fuel rod are smaller than those of middler part of irradiated nuclear fuel rod. These ovalities indicated from - 0.02 to 0.03mm. Figure 5 shows ovalities at location 240, 330, 2,720, 3,269mm of irradiated nuclear fuel rod which is burned for two cycles. Each solid line in Figure 5 indicates ovalities of irradiated fuel rod. The ovality at location 2,720 mm is smaller than that at 240, 330 and 3269 mm. Figure 6 shows ovalities of irradiated nuclear fuel rod which is burned for three cycles. These ovalities indicated from -0.04 to 0.03mm.

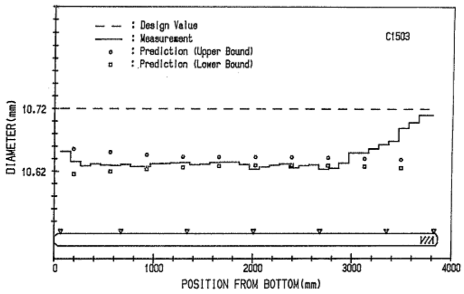

Figure 2. Diameters of nuclear fuel rod of three burnup cycles.

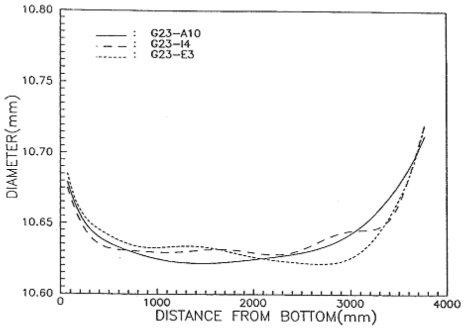

Figure 3. Diameters of nuclear fuel rod of four burnup cycles.

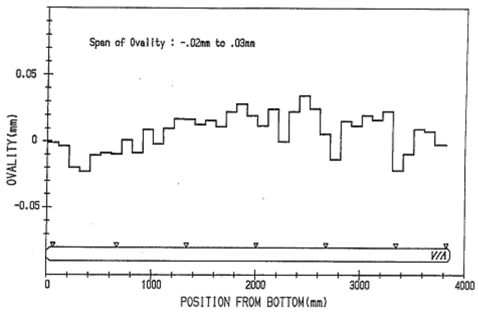

Figure 4. Ovalities of nuclear fuel rod of two burnup cycles.

Figure 7 shows ovalities at location 1,000, 1,765, 2,000 and 3,000 mm of irradiated nuclear fuel rod which is burned for three cycles. Each solid lines in Figure 7 indicates ovalities of irradiated nuclear fuel rod. The ovalities at location 1,000, 3,000 mm of irradiated nuclear fuel rod are smaller than those at 1,756, 2,000 mm.

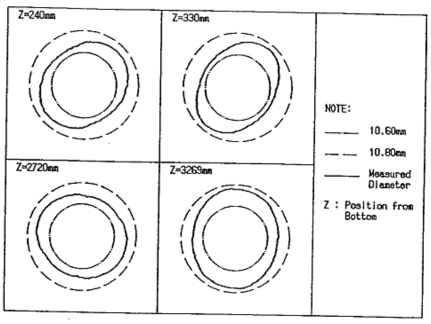

Figure 5. Ovalities on location of nuclear fuel rod of two burnup cycles.

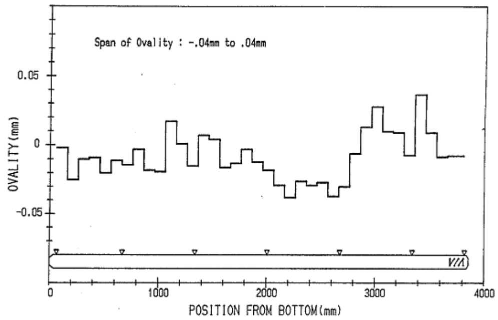

Figure 6. Ovalities of nuclear fuel rod of three burnup cycles.

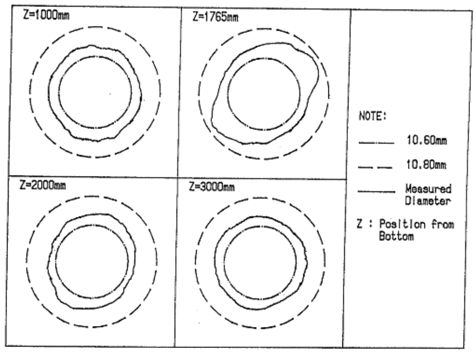

Figure 7. Ovalities on location of nuclear fuel rod of three burnup cycles.

4. Conclusion

The diameters and ovalities of irradiated nuclear fuel rod were measured using LVDT, and analyzed on burnup cycle. The diameters indicated gradually decreasing trend as burnup cycle increases. The ovalities of upper and lower part of irradiated nuclear fuel rod were smaller than those of middle part. The ovalities indicated gradually increasing trend as burnup cycle increases.

References

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