1.8 POWER RAMP TESTING METHOD FOR PWR FUEL ROD AT RESEARCH REACTOR

ZHOU Yidong ZHANG Peisheng ZHANG Aimin GAO Yongguang WANG Huarong
China Institute of Atomic Energy, P.O. Box 275(64), 102413, Beijing, P.R. CHINA

Abstract

A tentative power ramp test for short PWR fuel rod has been conducted at the Heavy Water Research Reactor (HWRR)[1] in China Institute of Atomic Energy (CIAE). The test fuel rod was cooled by the circulating water in the test loop. The power ramp was realized by moving solid neutron-absorbing screen around the fuel rod. The linear power of the fuel rod increased from 220W/cm to 340W/cm with a power ramp rate of 20W/cm/min. The power of the fuel rod was monitored by both in-core thermal and nuclear measurement sensors in the test rig. This test provides experiences for further developing the power ramp test methods for PWR fuel rods at research reactor.

Key words PWR fuel rod Power ramp test Research reactor

1 Introduction

In order to develop high performance fuel assembly for domestic nuclear power plant, it is necessary to master some fundamental test technology. So a research plan on the power ramp testing methods was proposed. This research involves several key techniques such as the refabrication of the post-irradiated fuel rods, in-pile power ramping facilities and power measuring methods.

A set of power ramp testing facility was designed. The power ramp was realized by moving solid neutron-absorbing screen around the fuel rod. A tentative power ramp test for short PWR fuel rod was conducted at the Heavy Water Research Reactor (HWRR) in China Institute of Atomic Energy (CIAE) in May of 2001[4]. The test fuel rod was cooled by the circulating water in the test loop. The linear power of the fuel rod increased from 220W/cm to 340W/cm with a power ramp rate of 20W/cm/min. This paper gives a brief description of the power ramp method.

2 Test facility and techniques

The in-pile test rig[3] (Fig.2-1) was placed into the central irradiation channel of HWRR (Fig.2-2). The test rig consists of pressure pipe assembly, thimble, solid neutron-absorbing screen and its driving parts, test fuel assembly, etc. The absorbing screen is driven by a step motor and its control equipment linked with a PC. When the absorbing screen rises, the power of the fuel rod increases. The absorbing screen is a sandwiched pipe and the absorbing material is natural silver. Thermocouples are fixed at the inlet and outlet of fuel rod coolant respectively. Self-powered neutron detectors (SPND) are fixed near the fuel rod. The test fuel sample is a short PWR fuel rod containing fresh UO_2 pellets.

Before the formal power ramp test, the absorbing ability of neutron-absorbing screen must be determined. So another similar neutron-absorbing screen was fabricated and tested in the reactor at low reactor power (about 200W)[2]. During the low power test the relative neutron flux and the absolute neutron flux were measured corresponding to different position of the absorbing screen, which is necessary to determine the moving space and velocity limits and is also necessary to check the reliability of the reactor physics calculation codes[2].

In order to assure criticality safety of the reactor, some measures were adopted to manually or automatically stop the movement of the absorbing screen, even shut down the reactor, such as over-velocity protection, spacing switch, manual stopping button, reactor period protection inter-locked with reactor control system, etc. During the power ramp test, the control system of the absorbing screen worked well. The operators of the reactor could easily and efficiently operate the movement of the absorbing screen.

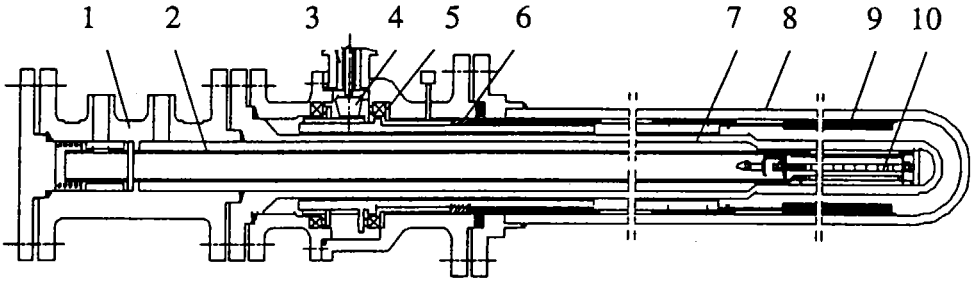

Fig.2-1 Configuration of the in-pile power ramp test facility[3]

1. Pressure pipe head　2. Hanging tube　3. Step motor　4. Gears
5. Transition section　6. Connecting pipe with worm　7. Pressure pipe　8. Thimble
9. Absorbing screen　10. Test sample

3 Test results

3.1 Test procedure

After the test rig was loaded into the central irradiation channel, the commissioning at the low reactor power (about 10kW) was carried out at first to measure the excess reactivity of the reactor and the equivalent reactivity of the test rig. Then the reactor power increased to 2350kW and operated at steady state for several hours. The automatic control system of the reactor was put into operation. In order to test the power regulating ability of the research reactor, the absorbing screen was raised step by step at first. Then the absorbing screen moved up and down continually three times at the same speed so as to acquire more measuring data. Finally the reactor power increased 20% while the absorbing screen was at the lower position to check the reliability of the measuring instruments. During the power ramp test, the power variation of the fuel rod could be realized by the movement of the absorbing screen.

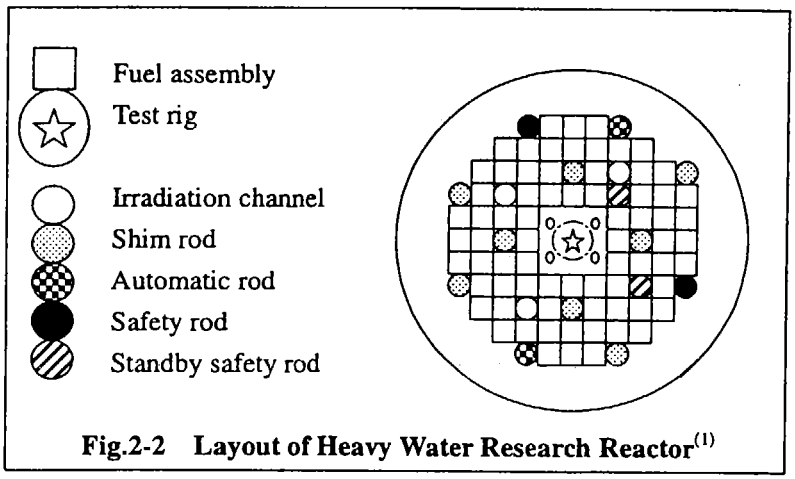

Fig.2-2 Layout of Heavy Water Research Reactor[1]

3.2 Power of the fuel rod

The data of the power ramp test measured by the thermocouples are listed in Table3-1. Through continual movement of the absorbing screen from the lower position to the upper position, the power of the fuel rod increased 50%, and the power ramp rate was 20W/cm/min.

During the power ramp test, the self-powered neutron detectors (SPND) also monitored the variation of the thermal neutron flux near the fuel rod (Table 3-2). The measurement results of SPNDs coincided well with thermal measurements.

Table 3-1: Power variation of the fuel rod during power ramps (Thermal measurement)[4]

Test series	Linear power (W/cm)		Ratio	Ramp rate (W/cm/min)
	Low (steady value)	High		
Step movement	246	369	1.50	~12
Ramp-01	225	350	1.56	21
Ramp-02	218	332	1.52	19
Ramp-03	218	336	1.54	20
20%$\triangle P_{reactor}$	216	269	1.25	~27

Table 3-2: Variation of thermal neutron flux during power ramps (SPND measurement)[4]

Test series	Thermal neutron flux (E+13 n/cm^2/s)		Ratio
	Low (steady value)	High	
Step movement	1.78	2.48	1.39
Ramp-01	1.77	2.46	1.39
Ramp-02	1.76	2.46	1.40
Ramp-03	1.75	2.43	1.39
20%$\triangle P_{reactor}$	1.75	2.12	1.21

The main purpose of the tentative power ramp test is to check the power ramp method, so the testing parameters of the fuel rod were very conservative. In terms of the in-pile measurement results of the absorbing screen and the calculation results of reactor physics codes, the velocity of the absorbing screen could be raised at least two times, so the power ramp rate of the fuel rod can reach the value of 50W/cm/min at least, if this solid absorbing screen is used and the test rig is in the central channel.

4 Conclusion

The first tentative power ramp test for PWR fuel rod is successful. The power ramp of the test fuel rod can be realized through the movement of neutron absorbing screen. Both the in-core thermal and nuclear measurement sensors in the test rig can monitor the power of the fuel rod reliably. This test demonstrates that it is feasible to conduct the power ramp test at the research reactor, also provides experiences for further investigation on the power ramp methods for PWR fuel rods in the future.

References

(1) ZHU Huannan, etc, Heavy Water Research Reactor, Publishing Company of Atomic Energy, 1988.

(2) ZHOU Yidong, ZHANG Peisheng, etc, Safety analysis report of power ramp testing program, Interior reference of CIAE, 2000.

(3) ZHANG Aimin, ZHAO Qinzhen, Adjusting device for power ramp test of PWR fuel rod, Nuclear Power Engineering and Technology, Vol.14 No.3, Sept. 2001.

(4) ZHANG Peisheng, etc, Summary of in-pile power ramp test for PWR fuel rod, Interior reference of CIAE, 2001