Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 22, 2009

Sensitivity Study on Thermal Hydraulic Parameters of Research Reactor with Plate Type Fuel

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1. Introduction

This paper presents the preliminary core thermal hydraulic characteristics and safety margins for various core flow rates, core pressures, core inlet temperatures and fuel channel powers for a plate type fuel core with 47 MW power. These sensitivity studies were performed to determine the design values for the thermal hydraulic parameters.

2. Reactor core and primary cooling system

2.1 Reactor core and fuel

The reactor core located inside of the reactor vessel consists of a total of 20 fuel channels as shown in Figure 1. Two kinds of fuel assembly i.e., 23-plate standard fuel assembly(SFA), and 21-plate follower fuel assembly(FFA) are used.

2.2 Primary cooling system (PCS)

The nominal core power is 47 MW. At a nominal power operation, the reactor coolant is passed by 3 pumps and 3 heat exchangers of a 33% capacity each then it enters the upper plenum of the reactor vessel, and flows downward with a velocity of about 9.5 m/s through the fuel channels, and then it exits from the lower plenum of the reactor vessel to the decay tank.

3. Thermal hydraulic parameters for the core design

In a research reactor design, the following design parameters are generally considered in order to ensure a sufficient thermal margin as well as fuel integrity for a normal operation and accident conditions.

3.1 Critical heat flux ratio (CHFR)

Critical heat flux ratio (CHFR) must be maintained higher than a certain value for a steady state operation as well as a transient state to avoid a fuel failure following the occurrence of a critical heat flux. In this evaluation, the MCHFR design criterion is tentatively applied as 2.5 at the normal operating condition because the nominal design values are used as the input data.

3.2 Onset of a nucleate boiling (ONB) margin

The ONB margin is defined as a difference between the fuel surface temperature when a nucleate boiling begins and the actual surface temperature under a local cooling condition. The tentative ONB margin for this evaluation using the nominal design values as the input data is applied as 20℃.

3.3 Fuel temperature

The fuel temperature should be maintained below the design limit to prevent an excessive fuel swelling for the plate type fuel in the normal operating conditions. The tentative design limit temperature for this evaluation is applied as 180℃ considering the nominal design values as the input data.

4. Analyses

4.1 Analysis code and modeling

4.1.1 Analysis code

The thermal hydraulic calculations and analyses were carried out using COOLOD-N2 code[1]. The COOLOD-N2 calculates the ONB temperature, the CHF, the saturation temperature and pressure of coolant to evaluate the temperature margin against the ONB and heat flux margin against the CHF along the fuel plate which includes the hottest spot.

4.1.2 Analysis modeling

As pressure drop models in the upstream and downstream of the fuel assembly, those of the RSG-GAS[2] were applied. Total peaking factor (F_Q) of the core was conservatively assumed as 3.0 and the axial power distribution in a fuel assembly is adopted as the cosine shape. The radial heat flux distribution in a fuel assembly is assumed to be the same (radial peaking factor=1).

4.2 Design variables

The thermal hydraulic performances of the proposed core are evaluated to investigate the effects on the thermal margin for various coolant velocities, thermal powers, inlet pressures and temperatures. Analysis ranges for the design variables are shown in Table 2.

4.3 Analysis results and discussions

The thermal margins at the calculated conditions have been evaluated for an ONB, a CHF and the fuel temperature.

4.3.1 Flow velocity

The calculated thermal margins along with the flow velocities from 8.0 m/sec to 11.0 m/sec for the standard fuel channel are shown in Figure 2. It can be seen that the calculated ONB margin is 21.7℃ at the flow velocity 9.0 m/sec and the MCHFR is 2.52 at the flow velocity 8.0 m/sec. Considering the engineering and analysis uncertainties for the input data and others, we determined the optimum values for the flow velocity in the fuel region as 9.5 m/sec in average.

4.3.2 Core power

A variation of the thermal margins of the standard fuel assembly along with the core powers is illustrated in Figure 3. It is also confirmed that the design limits of the ONB margin and the MCHFR are satisfied up to the average heat flux of about 1.36 MW/m^2 and the maximum heat flux of about 4.1 MW/m^2 at the hot spot.

4.3.3 Core inlet pressure and temperature

A variation of the thermal margins along with the core inlet pressures and temperatures are shown in Figure 4. The core outlet pressure was fixed to 0.21 MPa because of the NC flow gates and the core inlet pressure is controlled by the orifice located at the grid plate region. We selected the optimum inlet pressure based on the calculation results as 0.65 MPa with a margin even though the ONB margin in the case of 0.55 MPa was satisfied as 21℃. A thermal margin effect of the inlet temperature was relatively small.

5. Summary and Conclusions

The thermal hydraulics design analyses for a plate type fuel core have been performed to determine the optimum design values for the thermal hydraulic design variables such as core flow velocity, core power, core inlet pressure and temperature. Through these sensitivity studies, we could find that the nominal power operation with a coolant velocity larger than 9.5 m/s is ensured with a sufficient safety margin for the ONB and CHF. The core inlet pressure and temperature were reasonably selected as 0.65 MPa and 35℃.

REFERENCES

[1] Masanori Kaminaga, COOLOD-N2: A computer code for the analyses of steady-state thermal hydraulics in research reactors, JAERI-M-94-052, May, 1994.

[2] Marco Antonio Lucatero and Masanori Kaminaga, Thermal-hydraulic conceptual design of the multiple purpose research reactor MEX-15, JAERI-M-94-006, February, 1994.

Table 1 Core conditions during a normal operation

Core power	Design variables	Design values
Nominal 47 MW	Core inlet/outlet temp. (℃)	35.0/52.0
	Core inlet/outlet pressure (MPa)	0.65/0.21
	Average core velocity (m/s)	9.5
	Average heat flux (MW/m^2)	1.26

Table 2 Analysis ranges of design variables

Design variables	Analysis ranges
Average core velocity (m/s)	8.0~11.0
Core power levels (%FP)	90~130
Core inlet pressure (MPa)	0.45~0.85
Core inlet coolant temp. (℃)	25~45

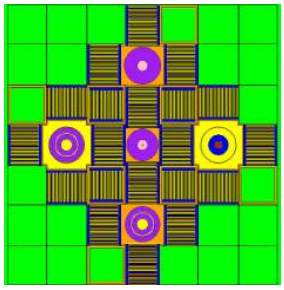

Figure 1 Cross sectional view of nominal core

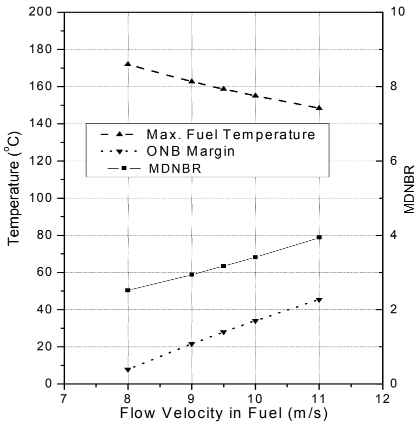

Figure 2 Variation along with the coolant velocity

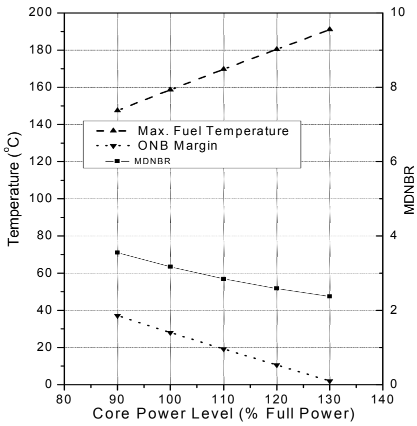

Figure 3 Variation along with core power levels

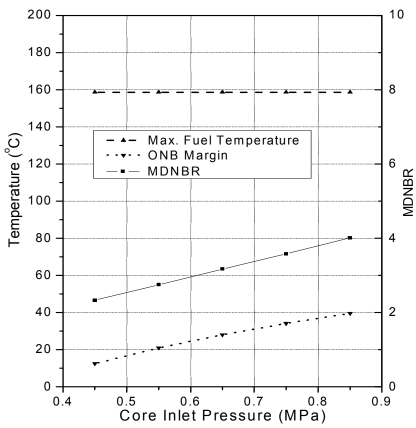

Figure 4 Variation along with core inlet pressure