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Fuel temperature estimation of MATRA code for SPERT-1D plate fuel during RIA

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1. Introduction

MATRA code developed by KAERI is capable of steady calculation as well as transient one such as reactivity insertion accident, flow transient. In transient analysis, heat flux is not directly given but derived from heat conduction in fuel using heat source supplied by neutronics. The conduction in MATRA code computes internal temperature distributions within heat conducting material and the surface heat fluxes to adjacent fluid channels. In conduction, orthogonal collocation is employed to an approximate polynomial solution with residuals method[1].

Typical subchannel codes developed to design the commercial LWR are mainly performed to validate on the rod type with ceramic fuel. On the contrary, there are few validations on the plate type with metal fuel. SPERT-1D test with a metal fuel of plate type generally used in the was to measure the fuel centerline and surface temperature during power transients by RIA.

Validations of the plate type fuel temperature calculation of MATRA code are performed to compare the SPERT-1D test results using equal heat transfer coefficient model. Fuel model of MATRA code was estimated to compare the fuel centerline and surface temperature with the transient experimental results.

2. Methods and Results

2.1 SPERT-1D test

The SPERT-1D destructive test of a plate type core constituted the first test conducted at SPERT as part of an overall program to investigate the destructive consequences of a RIA. The SPERT-1D core was comprised of 25 fuel assemblies mounted in a 5x5 array in a rectangular grid structure. Each standard fuel assembly contained 12 removable fuel plates. The four control rod and one transient rod fuel assemblies each contained only six removable fuel plates, the remaining six fuel plate positions being occupied by the two control blades and their housings[2].

A series of 54 step-initiated, self-limiting power excursion tests was carried out in the SPERT 1-D core, with initial asymptotic reactor periods in the range from 1310 to 3.2 msec. During this test, transient cladding surface temperature and centerline temperature were measured.

2.2 Methods of subchannel analysis

MATRA code model to calculate the SPERT-1D fuel temperature is briefly described as shown in Fig. 1. This model is consisted of single channel and single rod lumped in assembly size.

SPERT-1D test used to validate the fuel model in MATRA code induced a zero initial flow condition due to the pool boiling condition under 1 atm.

Subchannel code is general to be unable to calculate a zero inlet flow condition. Fuel temperature calculation can be validated to employ the equal heat transfer coefficient model in forced convection with same heat transfer coefficient in pool boiling because the present calculation is not need any precise flow condition adjacent fuel surface. Heat transfer coefficient at pool boiling was evaluated with Rohsenow correlation[3].

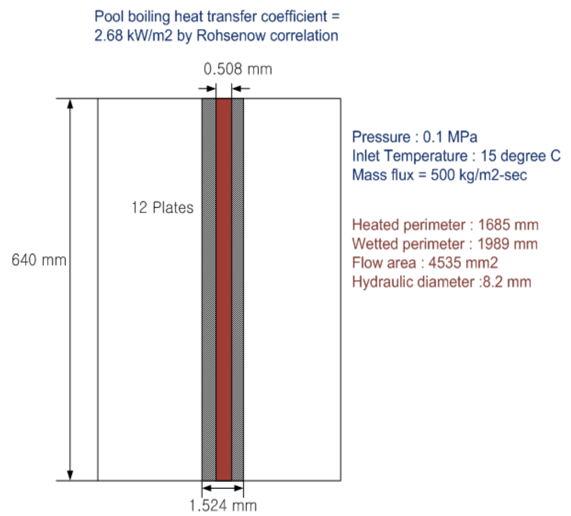


Fig.1. Description of MATRA analysis

Table I: Equal heat transfer coefficient model to calculate the fuel temperature on the SPERT-1D

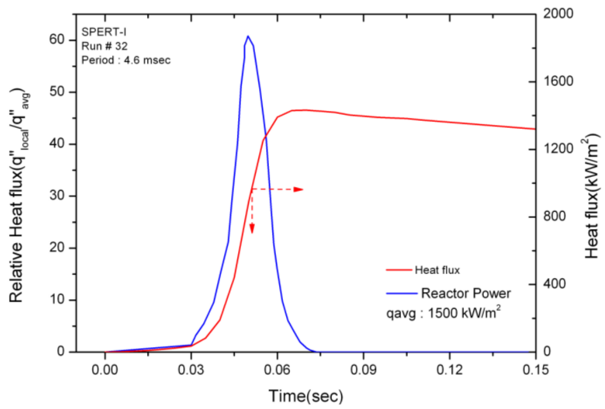
CASE	Reactor period	Heat flux (kW/m^2)	HTC-Rohsenow	HTC-Single	Mass flux (kg/m^2-sec)
1	6.0 ms	2500.0	4.47	4.40	950
2	4.6 ms	1500.0	2.68	2.62	500.0
3	3.2 ms	1500.0	2.68	2.62	500.0

Three cases in 54 test series are selected to validate the MATRA code calculation as described in Table. 1. Forced convective heat transfer coefficient and mass flux corresponding to the pool boiling heat transfer coefficient calculated on the test condition are derived in Table. 1. Derived forced convective heat transfer coefficients are used to compare the three test results.

Axial power shape and radial power shape use the calculation result using SIMMER-1 code results[4]. Power transient is simulated with the power forcing function with time evaluation.

2.3 Results of subchannel analysis

Calculation results of case 2 in table 1 are shown in Fig. 2. In this case, transient reactor power for an abrupt reactivity reaches 60 times of initial power in 0.05sec after starting test as shown in Fig. 2(a). Heat flux on fuel surface with power transient represents the red solid line in Fig. 2(a) and maximum heat flux appears after 0.015 sec of peak power.



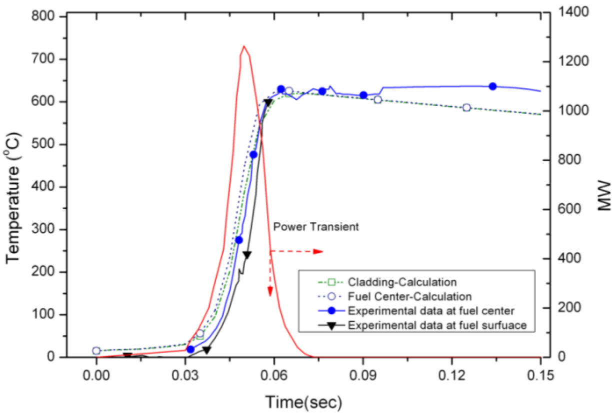


Fig.2. DNBR and Pressure drop results with various Fuel assembly arrays

As shown in Fig. 2(b), solid symbols represent the measurement result and hollow symbols are calculation results of MATRA code. Measurements of fuel temperature are at the fuel center point which assumed at the hot spot point. Maximum fuel temperatures occur with the same point of maximum heat flux. Maximum fuel centerline temperature was measured at the 629℃ and surface temperature was at 607℃. Calculated maximum centerline and surface temperatures are 626 ℃and 619℃ respectively.

After 0.09 sec, calculated centerline temperature decreased with time evaluation is different from the measurement centerline temperature remained the previous value. The discrepancy results in the constant bulk temperature with equal heat transfer coefficient model. Bulk temperature in pool boiling rises continuously to the saturation temperature. Present model using equal heat transfer coefficient maintains the forced convection to the bulk fluid due to the constant bulk temperature.

In spite of the limitation of model, present model is estimated in good agreement with the experimental result with the 11.2 % uncertainty.

3. Conclusions

For the sake of estimating a pool boiling using subchannel code, equal heat transfer coefficient model was developed. The main idea of the model substitutes the pool boiling condition to the equal forced convection heat transfer coefficient neglecting the detail flow condition. SPERT-1D test was used to validate the plate-type fuel temperature prediction of MATRA code. Present model using MATRA code shows the good agreement with the experimental test result in the very fast power transient case.

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