Subchannel analysis of 12 by 12 FCM fuel assembly with narrow gap width

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1. Introduction

Fully Ceramic Micro-encapsulated(FCM) fuels with multiple layers are a high resistance fuel of releasing fission product. The fuel concept borrows the tri-isotropic(TRISO) fuel particle design from Very High Temperature Reactor(VHTR) technology to adapt it on the LWR design. The fuel particles would be pressed into compacts using SiC as the matrix material and would be reloaded into fuel pins for use in conventional or next generation LWRs.

In order to satisfy the neutronics characteristics, rod diameter of FCM fuel should be larger than the rod diameter of conventional PWR assembly, especially OPR-1000. From the preliminary neutron calculation, 12 by 12 tight lattice array is a strongly recommended assembly type because of only a similar subchannel shape and location in comparison with 16 by 16 assembly.

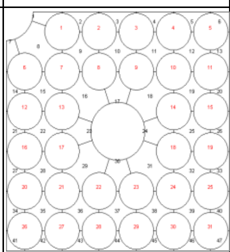
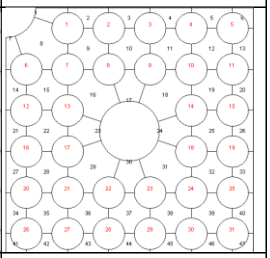
Present analysis is performed to investigate the thermo-hydraulic characteristics of tight lattice 12 by 12 assembly. The results are also compared with reference 12 by 12 assembly with the gap of 4mm.

2. Methods and Results

2.1 Geometry of 12 by 12 assembly

Subchannel analysis of 12 by 12 FCM fuel assembly are performed with various pitch of rod diameter as shown in Table 1.

Table I: Geometry and Operating Conditions of 12 by 12 FCM fuel assembly

Assembly	**P/D =1.08**	**P/D=1.3**
Geometry		
Rod diameter	15.94	13.15
Rod number	124	
Guide tube number	5	
Mass flux (kg/m^2-s)	5138.95	3378.46
Heat flux (kW/m^2)	967.37	1172.62

Mass flux and heat flux conditions of each assembly are determined on the equal volumetric flow rate and power condition of reference assembly condition.

2.2 Methods of subchannel analysis

Subchannel analysis to investigate the local thermo-hydraulic field is performed using subchannel code MATRA[2]. In order to perform large amount of scoping calculation, Pre- and Post-processor of MATRA are developed. Figure 1 shows the calculation sequence.

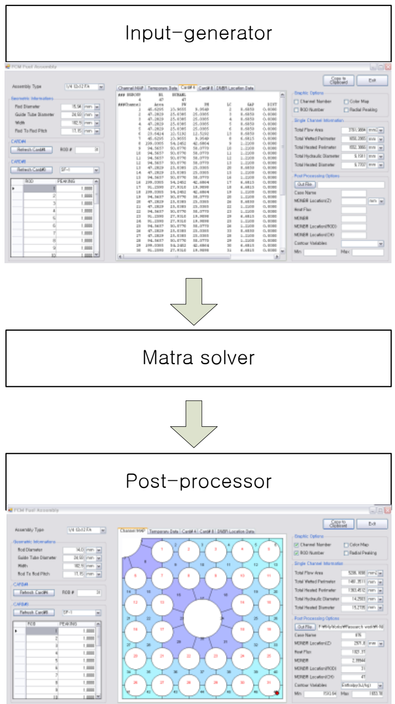


Fig.1. Description of MATRA analysis

Axial power distribution with typical chopped cosine shape and uniform radial peaking are implemented on the DNBR calculation. In the respect of a thermal design, DNBR correlation and turbulent mixing are applied using W-3 and typical design value of the mixing coefficient, respectively. Void fraction is evaluated using the Chexal-Lellouche correlation with Saha-Zuber Subcooled model. Pressure drops are calculated with the Blasius correlations and homogeneous two-phase multiplier.

2.3 Results of subchannel analysis

Subchannel in tight lattice bundle with the gap of 1.2 mm is investigated on the mass flux, enthalpy and quality distribution of radial plane where minimum DNBR occurred as shown in Fig.1. Maximum mass flux of tight lattice design is located at the subchannel around the large guide tube; however, minimum mass flux is located at the corner. Maximum value of enthalpy and equilibrium quality is located on the corner and side channels. Under the condition, minimum DNBR occurs at the corner. The trend of thermo-hydraulic field remains on the assembly design with large gap.

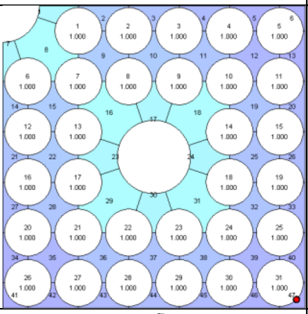
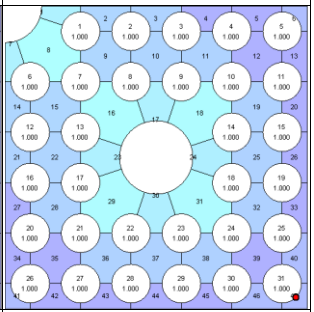
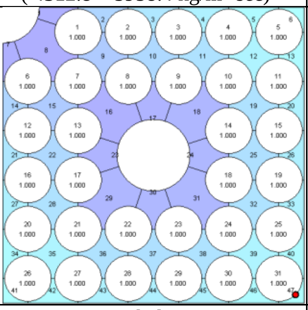
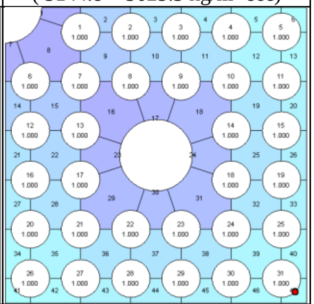
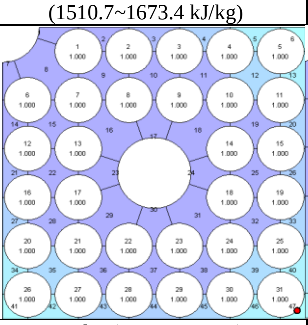
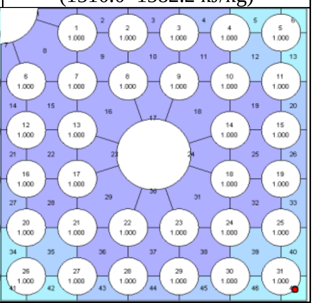
P/D=1.08	**P/D=1.30**
	
Mass flux (4312.8 ~ 5958.4 kg/m^2-sec)	Mass flux (3144.8 ~ 3625.3 kg/m^2-sec)
	
Enthalpy (1510.7~1673.4 kJ/kg)	Enthalpy (1510.0~1582.2 kJ/kg)
	
Quality(0.0 ~ 0.04735)	Quality(0.0 ~ 0.0034)

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

On the tight lattice bundle, difference of mass flux between corner and center channels is about 1645.6 kg/m^2-sec while mass flux of large gap case is 480 kg/m^2-sec. The ratio of the difference of tight lattice and large gap assembly described the non-uniformity is about 3. The similar ratio is also shown in enthalpy distribution. The level of non-uniformity will be increased with decreasing the ratio of pitch of rod diameter.

3. Conclusions

Subchannel analysis was performed on the tight lattice bundle of 12 by 12 square array. Systematic analysis tool was developed to perform the large scale of scoping analysis. Enthalpy and mass flux distribution was investigated on the subchannel of tight lattice bundle. Calculation results showed the tendency that the tight lattice bundle has more non-uniform mass flux and enthalpy distribution than that of a large gap bundle. New design feature and accurate analysis model will be required to reduce the non-uniformity of tight lattice bundle.

REFERENCES

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[2] Yeon-Jong Yoo, Dae-Hyun Hwang, and Dong-Seong Sohn, Development of a Subchannel Analysis Code MATRA Applicable to PWRs and ALWRs, *J. of KNS*, Vol. 31(3), pp. 314-327, 1999.