Pressure Drop Analysis of Square Array Bundle using CFD

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1. Introduction

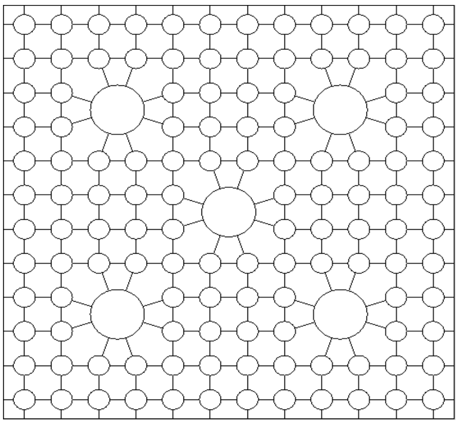
As a part of post-Fukushima actions, fully ceramic micro-encapsulated (FCM) fuel has been considered to replace the fuel for existing LWRs and it is expected to contribute the reinforcement of the safety of the LWRs. To design the FCM fuel bundle, as a one of the parameter study, the analysis of the pressure drop performance according to the bundle geometry is essential in side of the thermo-hydraulic design. The pressure drop performance investigations were already carried out experimentally and theoretically [1] however such a CE type 12 x 12 lattice array bundle with guide tubes was concerned in this study. Ten cases of rod distance ratios were selected and the bundle pressure drop versus a circular tube under the fixed velocity condition and the fixed Reynolds number condition are presented.

2. Fuel bundle and CFD model

2.1 12 x 12 fuel bundle and test cases

A 12 x 12 CE type fuel bundle has 5 guide tubes and fig. 1 shows its 12 x 12 CE type fuel bundle cross section view.

Fig 1. 12 x 12 CE type fuel bundle cross section



Ten rod diameter cases with one rod pitch were selected and table 1 shows the test cases.

Table 1. Test cases

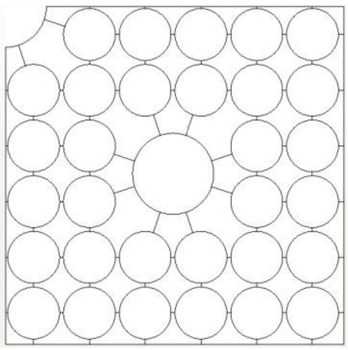
Case No.	Fuel Pin D.(mm)	Pin Pitch(mm)	p/d
1	17.007	17.150	1.008434
2	16.727	17.150	1.025303
3	15.940	17.150	1.075910
4	15.156	17.150	1.131528
5	14.446	17.150	1.187146
6	13.800	17.150	1.242764
7	13.209	17.150	1.298382
8	12.666	17.150	1.354000
9	12.166	17.150	1.409618
10	11.705	17.150	1.465236

Each case was calculated under the fixed velocity condition and three fixed Reynolds number conditions.

2.2 CFD Model

ANSYS CFX 13.0 CFD code was used in this study. The CFX model is 1/4 of the fuel bundle and the model consists of 47 bodies. Each body is a sub-channel of the fuel bundle. Fig 2 shows the CFX model cross section view.

Fig 2. 1/4 12 x 12 fuel bundle model cross section



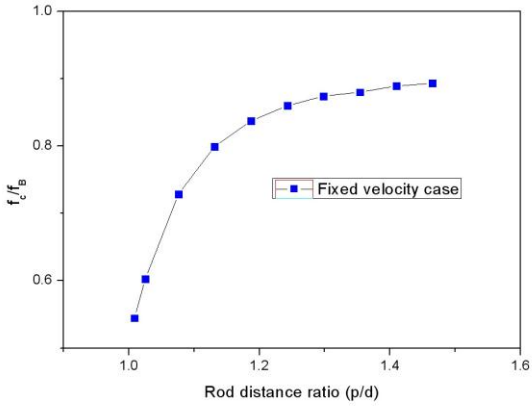
2.3 Fixed velocity condition and result

The inlet flow velocity was fixed as 2 m/s and friction factors using the Blasius correlation were calculated. The Blasius correlation is adapted to a circular tube under a turbulent flow condition within Reynolds number 10^5.

$$\text{Blasius correlation : } f = \frac{0.316}{\mathrm{Re}^{0.25}} \quad \ldots\ldots(1)$$

The difference of the results from the Blasius correlation and CFX was shown in fig. 3.

Fig 3. The result of the fixed velocity condition

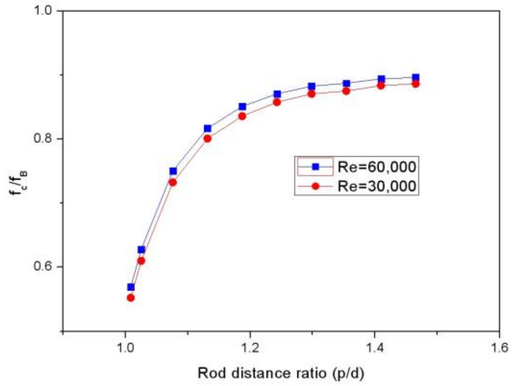


$$f_c / f_B = \frac{CFX \ \ friction \ \ factor}{Blasius \ \ friction \ \ factor}$$

2.4 Fixed Reynolds number condition and result

The selected Reynolds numbers were 3×10^4 and 6×10^4 respectively. And the Blasius friction factors were calculated as well. The difference of the results from the Blasius correlation and CFX was shown in fig. 4.

Fig 4. The result of the fixed Reynolds number condition



3. Conclusions

The pressure drop performance the 12×12 fuel bundle versus a circular tube was analyzed as a parameter study for development of the FCM fuel bundle. The aspect of the bundle friction factor shows good agreement with previous studies [2]. However the result of this study shows lower friction factor values than the previous study. The cause of the lower friction factor is expected that the configuration of rods and guide tubes is different from the previous studies.

The validation of the difference will be performed for further study. Consequently, these results support validity of the sub-channel analysis code developed by KAERI.

REFERENCES

[1] K. Rehme, Pressure drop performance of rod bundles in hexagonal arrangement, Heat Mass Transfer, Vol. 15, p. 2499-2517, 1972.
[2] Jun Ho Bae, Joo Hwan Park, Analytical prediction of turbulent friction factor for a rod bundle, Annals of Nuclear Energy, Vol. 38, p. 348-357, 2011.