5 - 15   Recent Progress in Reactor Physics Group at IMP

Gu Long, Fan Qin, Li Jinyang, Wang Dawei and Qin Changping

In 2014, some of achievements have been obtained in reactor physics group at IMP supported by the Strategic technology pilot projects of CAS.

The reactor physics group was one of the major groups involved in the MeAWaT project in PSI in Switzerland, whose aim will manufacture one single prototype nuclear fuel with minor actinide elements. In this project, our group has mainly focus on neutronics design and thermohydraulic analysis for the new type of nuclear fuel. During the work in this project, one new relationship for the pressure drop of wire-wrapped fuel bundles has been proposed. The comparison result between Cheng and Todreas' correlations has been showed as Fig. 1 as following.
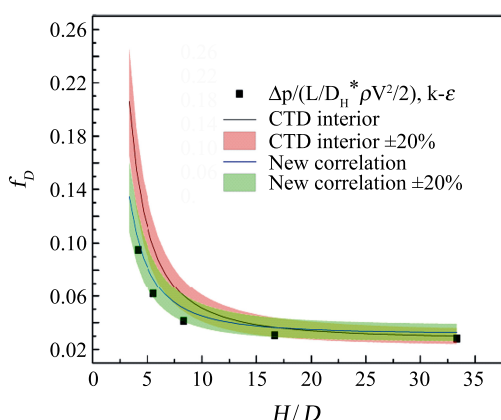

Fig. 1   (color online) Comparison of new correlation and Cheng and Todreas' correlations.
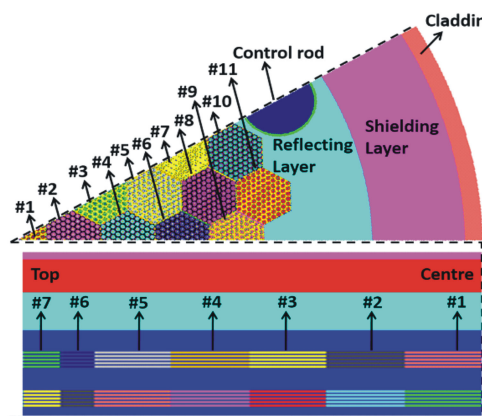

Fig. 2   (color online) 500MWth gas-cooled travelling wave fast reactor schematic.

In order to improve the utilization of uranium resources and decrease nuclear waste, a scheme of 500MWth Gas-cooled Travelling Wave Fast Reactor (GTWFR), as Fig. 2, has been designed. The 25 years burnup results show that GTWFR can use natural uranium or depleted uranium, with once-through cycle to improve the utilization of uranium resources and alleviate nuclear waste disposal pressure.

Reference

[1]   S. Chen, N. Todreas, N. Nguyen, Nuclear Engineering and Design, 267(2014)109.

5 - 16   A New Relationship for the Pressure Drop of Wire-wrapped Fuel Bundles

Fan Qing and Gu Long

In the project of MeAWaT[*], an innovative hollow pin is designed. For reactor design calculations, it is necessary to predict the hydraulic losses in multi-rod fuel bundles accurately[1]. And there is a long history for the use of spiral wire to maintain the pins in their position in fuel assemblies of reactors[2]. In this paper, a series of computational fluid dynamics (CFD) calculations are carried out on wire-wrapped pins, with constant pin length and different wire pitches. A new correlation is proposed.

The calculation region is built based on the geometry illustrated in Fig.1. The innermost pin and its surrounding hexagonal prism region are taken out as calculation region. In Fig. 1, there are two kinds of wire wrapped pins illustrated, one with a wire of one turn and the other with a wire of eight turns. Actually there are five kinds of wire-wrapped pins in this paper, the numbers of turns of which are one, two, four, six and eight respectively. The length of the pin keeps constant.

ANSYS Fluent[†] is applied to carry out the calculation. There are two kinds of fluid channels, one channel

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[*]http://www.ccem.ch/science/meawat

[†]ANSYS Fluent Academic Research, Release 15.0

between pins (referred as outer channel), and seven channels inside pins (referred as inner channels). For different kinds of channels, the inlets are set into velocity inlet and the outlets are set into pressure outlet. The six side surfaces of the hexagonal prism calculation region are set into periodic boundaries. Turbulent model used here is $k - \epsilon$, with scalable wall function applied.
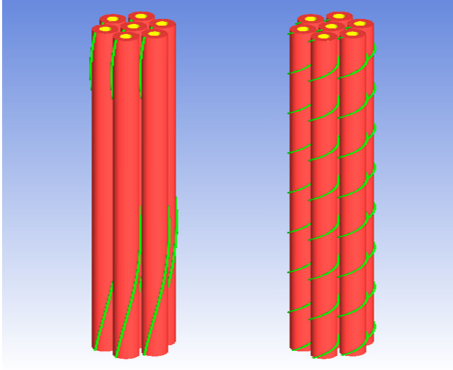

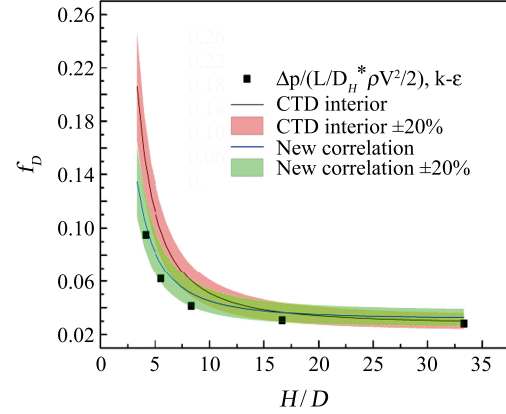Fig. 1   (color online) The geometry on which the calculation region is extracted.

Fig. 2   (color online) Comparison of new correlation and Cheng and Todreas' correlations (CTD interior).

Based on the CFD results in outer channel, a new correlation (Eq. 1) is proposed:

$$\Delta p = f \frac{L}{D_H} \frac{\rho V^2}{2} \left(1 + \alpha \left(\sqrt{1 + \pi^2 \left(\frac{D + D_{\mathrm{w}}}{H} \right)^2} - 1 \right) \right) \ , \tag{1}$$

where, $f = 0.316/\mathrm{Re}^{1/4}$ (Blasius equation, for $Re \leq 2 \times 10^4$ [3], L is the length of the pin, D_H is the equivalent diameter of outer channel, ρ is the density of fluid, V is the velocity of fluid, D is the diameter of pin, D_{w} is the diameter of wire, H is the wire pitch and $\alpha = 7.46$ is a dimensionless constant.

According to the latest review[4], among lots of correlations, only Cheng and Todreas's correlations[5] can be used for the H/D range presented in this paper. The new correlation (Eq. 2) is compared with Cheng and Todreas' correlations[5]. And the comparison can be seen in Fig. 2. In Fig. 2, f_D is calculated friction factor, and can be considered as $f(1 + \alpha(\sqrt{1 + \pi^2((D + D_{\mathrm{w}})/H)^2} - 1))$ in new correlation. As shown in Fig. 2, when wire pitch to pin diameter ratio (H/D) is large (say larger than 12), the new correlation is almost identical to Cheng and Todreas' correlation, and when H/D is small, the new correlation is more closer to CFD results. Because there are few experimental data reaching to the range of H/D less than seven[4], it is hard to say which correlation is better. The new correlation is simple, and if changed it into another form, it can be easily explained in physics. The length of wire L_{w} can be calculated by $L_{\mathrm{w}} = (L/H)\sqrt{H^2 + (\pi(D + D_{\mathrm{w}}))^2}$. Let ΔL denotes the length of wire length minus pin length ($L_{\mathrm{w}} - L$), the new correlation (Eq. 1) is turned into:

$$\Delta p = f \frac{L}{D_H} \frac{\rho V^2}{2} \left(1 + \alpha \frac{\Delta L}{L} \right) \ . \tag{2}$$

So the contribution of the wire to pressure drop can be explained as enhancing the characteristic length L into $L(1 + \alpha \Delta L/L)$, although it has a non-unity weight α.

In order to testify whether the new correlation is a general correlation, experimental data with H/D less than seven is needed, and it is better to perform CFD calculations with wire touching its peripheral rods.

References

[1]   K. Rehme, et al., Nuclear Technology, 17(1973)15.

[2]   K. Wakasugi, I. Kakehi. Journal of Nuclear Science and Technology, 8(1971)167.

[3]   X. Fang, Y. Xu, Z. Zhou. Nuclear Engineering and Design, 241(2011)897.

[4]   S. Chen, N. Todreas, N. Nguyen. Nuclear Engineering and Design, 267(2014)109.

[5]   S.-K. Cheng, N. E. Todreas. Nuclear Engineering and Design, 92(1986)227.