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Development of the Cooling Technology on TRU Fuel Pin Bundle during Fuel Fabrication Process (5)Development of heat transfer correlation for sub-channel analysis tool

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1. Introduction A low decontaminated fuel in which a trans-uranium (TRU) is included is used for Fast-Breeder Reactor (FBR) cycle system in Japan. When we fabricate a TRU fuel pin bundle, we wrap a fuel pin with a thin wire to keep a distance between fuel pins and lay it transversely. A TRU fuel has high decay heat because it contains Minor Actinide (MA), and we make air flow into the gaps vertically across the pin bundle to remove the heat. Therefore, it is important to establish an effective cooling technology to remove the heat in the fabrication process. For this purposes, we investigate the thermal-hydraulics behavior, especially in the cross-flow direction of a wire-wrapped fuel pin bundle which the fuel pitch divided by the pin diameter (so called P/D) is 1.1.

2. Enlarged partial model test In the previous work, we have showed that the enhanced wall treatment (EWT) and RNG k-ε model are the most appropriate for the thermal-hydraulics analysis of a P/D=1.2 fuel pin bundle system [1]. However, we do not know what kind of near wall treatment and turbulence model is the most appropriate for P/D=1.1case. In this work, we carry out the two-dimensional thermal-hydraulics analysis of the enlarged partial model test [1] which P/D=1.1 on some physical conditions by using FLUENT (Fig. 1) and compare with the experimental data. As a result, it is shown that EWT and RNG k-ε model are the most appropriate for P/D=1.1 system as in the case of P/D=1.2. Fig.2 is a part of our results, where SWT expresses standard wall function.

3. Development of heat transfer correlation for P/D=1.1 Fig. 3 is heat transfer correlation obtained by two-dimensional thermal-hydraulics analysis of an infinite staggered tube bundle system (P/D=1.1) using selected models and compare with Zukauskas and Grimison correlation [3, 4]. These results show that Grimison correlation (green line) is more similar to the analytical results (black square) than Zukauskas (blue line). Thus, we constructed heat transfer correlation by using Grimison type function, $Nu=0.66*Re^{0.53}$ (red line), so that it can reproduce analytical results.

4. Influence of de-centering We also investigate the influence of de-centering of a tube which may happen during manufacturing process. The dimension tolerance of a tube will be in range of 0.5 % of its diameter. Fig. 4 is an analytical result as a function of de-centering direction, assuming that 5% and 1% de-centering of its diameter for simplicity. We see that maximum about 20% change of Nusselt number can happen when tube has 5% de-centering while about 1% in the case of 1% de-centering. Considering dimension tolerance of de-centering diameter, we can conclude that de-centering has almost no influence for heat transfer correlation.

5. Conclusion We constructed the heat transfer correlation for TRU fuel pin bundle system (P/D=1.1) after selecting the most appropriate turbulence model and near wall treatment by comparing with experimental data. And we verified that the de-centering of tube has almost no influence to the heat transfer correlation.

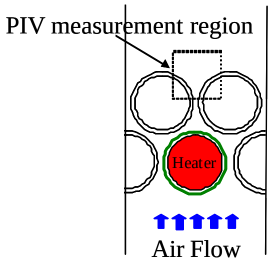

Fig.1 Enlarged partial model test (P/D=1.1)

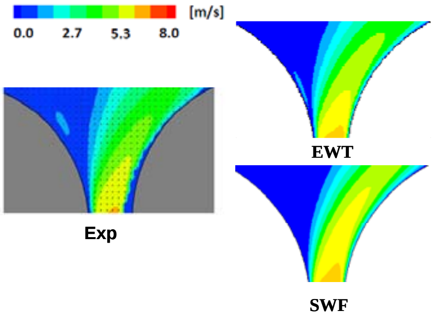

Fig.2 PIV measurement and calculational results

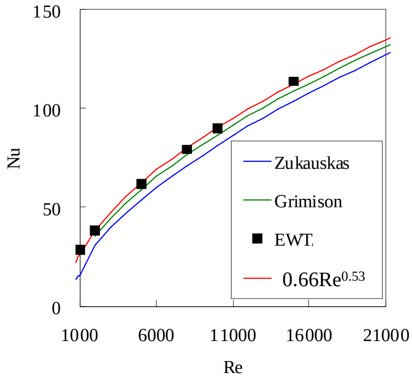

Fig.3 Heat transfer correlation (P/D=1.1)

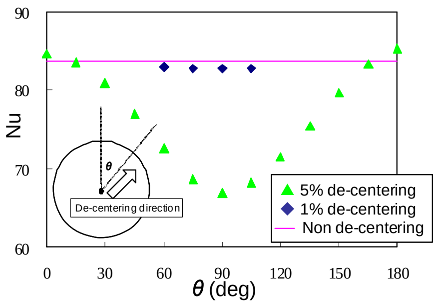

Fig.4 Influence of de-centering on heat transfer correlation

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