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RANS based CFD analysis for mixed flow trend evaluation of 61 fuel pin bundle in inner subchannel

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1. Introduction

In SFR with wire wrapped fuel structure, radial flow is formed due to axial flow. In general, it is difficult to reflect the physical phenomena of sub-channel units or less because the experimental correlation formula of the sub-channel units is used. This study tried to understand the tendency of mixed flow in the smaller scale than subchannel, and to compare and analyze the differences with experimental data.

2. Methods and Result

2.1 Selection of turbulence model

The characteristics of the built-in turbulence model were identified for the selection of the turbulence model. After that, the turbulence model was selected through comparison with the experimental data. Based on the experimental data provided by CD-adapco, the standard model and the quadratic model, and the quadratic model were compared, and the cubic model were compared. The Star-CCM+ program was used for this CFD analysis. As Figures 1, the quadratic model predicts the secondary flow well than the standard model.

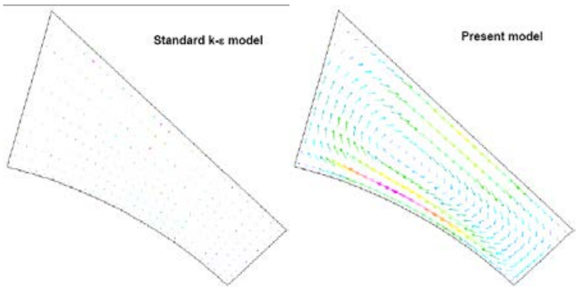

Figure 1 Secondary flow with the standard k- ε and the quadratic k- ε model

For the comparative verification of the quadratic model and the cubic model, the 180° bending flow analysis method (U-tube) was used. Figures 2 compare the velocity results of experimental values, standard, quadratic, and cubic models at the inlet (0° point), U-tube middle (90° point), and outlet (180° point), respectively.

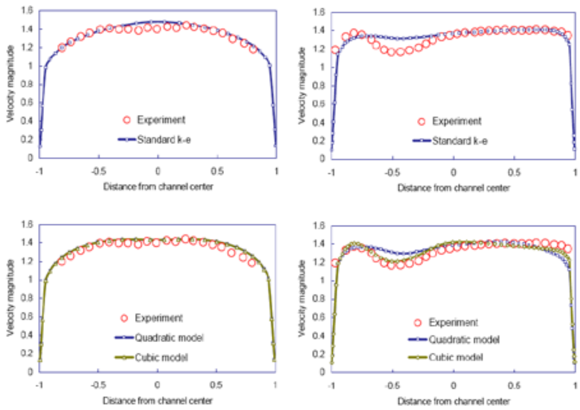

Figure 2 Velocity distribution comparison

As can be seen in the figure, the cubic model showed the closest analysis result to the experimental value. Therefore, in this study, an anisotropic cubic turbulence model was used.

2.2. Mesh sensitivity

The mesh sensitivity test was conducted to select an appropriate mesh size by comparing the pressure loss, the velocity and the flow distribution. To calculate the pressure loss, points before and after the fuel rod were selected, the pressure was measured, and the difference was calculated. Figure 19 summarizes the pressure loss of the flow analysis result. From Cases 3, 4, and 5, as the change in pressure loss decreased, the value showed a tendency to become constant. Considering the pressure loss, velocity, and flow distribution, it was judged that it would be reasonable to apply case 3.

Table I Used samples for mesh sensitivity evaluation

	Case 1	Case 2	Case 3	Case 4	Case 5
No. mesh	1.5 m	2.8 m	4.8 m	6.1 m	7.8 m

m: million

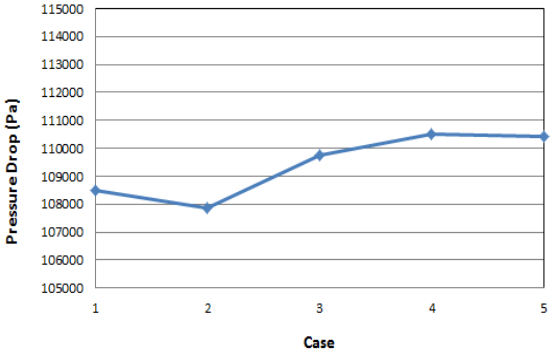

Figure 3 Pressure loss comparison

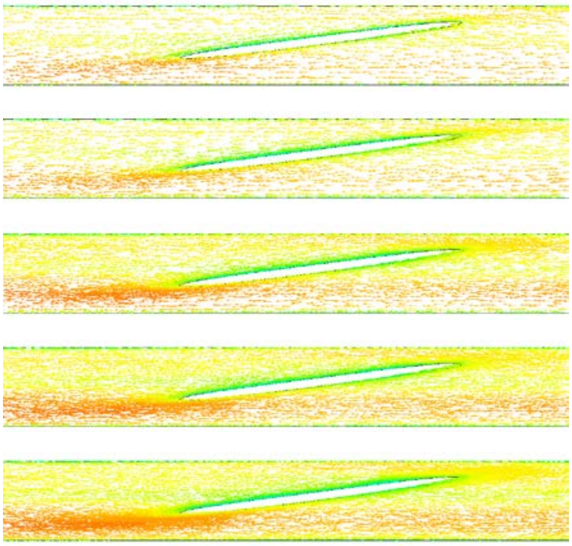

Figure 4 Tangential velocity of each case

2.3 Data collection

Surface averaged concentration data per subchannel were collected. In order to normalize the raw data, the same method as the post-processing method of the experimental data was used.

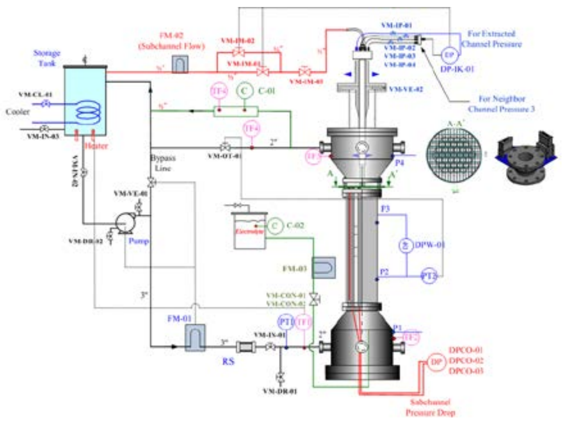

Figure 5 FIFFA experimental device

2.4 Experimental data

The experiment was conducted to evaluate the uncertainty of the design/analysis code for the SFR core design and to secure the reliability of the calculation results. A wire mesh measurement system was used to quantify the subchannel mixing characteristics.

The wire mesh sensor (WMS) installed at the exit of the FIFFA experimental device consists of an inner wire in the form of a square grid. The inner wire forms a transmission electrode layer and a response electrode layer (19×19 channels), and the wire intersection point is designed/manufactured to be located at the center of the subchannel.

In order to compare the experimental results, the raw data was normalized through a data processing program developed in-house. In the case of WMS, it was confirmed that the absolute values of the raw data were different even when the background fluid was filled. It was obtained for a certain period of time (10 seconds) and used for post-treatment. Considering the irregular type wire mesh sensor, the area represented by the measurement points was calculated as a weighting factor. This value was processed as follows

$$C_{j,n} = \frac{C_{j1} - C_{j0}}{\sum_j A_j (C_{j1} - C_{j0}) / (\sum_j A_j)}$$

2.5 Result and Discussion

CFD and experimental data in the inner subchannel showed similar trends. The secondary flow created by the wire wrapped effect activates flow mixing with the adjacent subchannels. It was confirmed that the flow mixing results were similar to the experimental results using the cubic k-ε turbulence model.

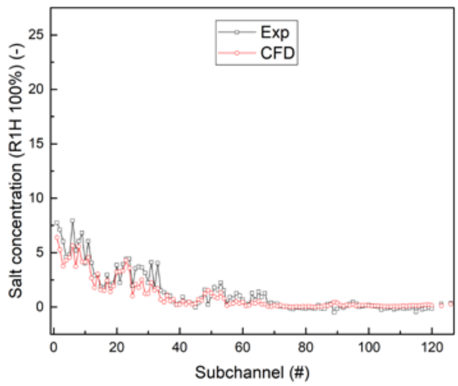

Figure 6 Experimental and CFD data comparison

3. Conclusion

In the SFR thermo-hydraulic design where wire wrapped fuel is used, the maximum cladding temperature is calculated using a subchannel-level correlation equation. For the physical understanding of subchannels, a study was conducted using this CFD, and it was confirmed that the inner channel mixes well with the adjacent channels due to the radial flow. It is expected that this information can be used as reference material for licensing, etc. in the future.

ACKNOWLEDGMENTS

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