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Calculation of Permeability inside the Basket including one Fuel Assembly

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1. Introduction

The thermal evaluation must be included in the safety analysis report of spent nuclear fuel transportation and storage system. The geometry of nuclear fuel assembly is very complicated. Calculating of the exact geometry of the fuel assembly requires a lot of time and high performance cluster. In general, the porous media model and the effective thermal conductivity were used to simply the fuel assembly.

The methods of calculating permeability were compared considering the flow inside a basket which includes a nuclear fuel. Detailed fuel assembly was a computational modeling and the flow characteristics were investigated.

2. Methods and Results

2.1 Modeling of Spent Nuclear Fuel Assembly

A spent nuclear fuel assembly is loaded into the basket. The type of gas filled in the canister is the helium. The helium flowed upward from the bottom to the top of the basket due to the natural convection by the decay heat of the spent nuclear fuel. The complex geometry of the nuclear fuel assembly induced the shear stress on the helium flow.

The spacer grids were located repeatedly on the fuel rod except for the upper and lower end fittings. Considering the flow resistance inside the basket, the flow area and the flow resistance are in inverse proportion to each other. The height of the upper and lower end fittings are relatively short to total height of the fuel assembly. The flow resistance generated by the upper and lower end fittings is negligible. Therefore, the upper and lower end fittings were not considered on the fuel assembly modeling. The fuel assembly modeling is shown as Fig. 1.

2.2 Flow Characteristics inside the Basket

There is the upward natural convection inside basket due to the decay heat of the spent nuclear fuel. Instead of considering the natural convection flow, the constant inlet velocity condition at the bottom inlet of the fuel assembly is used. The range of the velocity is 0~0.1m/s. The assumption of the flow is forced and laminar flow.

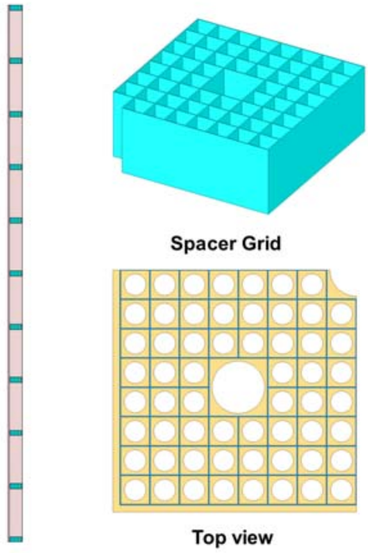

Fig. 1. Modeling of fuel assembly

As the height increases, the pressure drop linearly increased. The average velocity shows repeated same pattern but the magnitude of the average velocity doesn't change. The linear pressure drop means that the flow resistance by the wall is constant along to the fuel rod and the inertia resistance could be neglected. Therefore, only viscous flow resistance (permeability) is focused on.

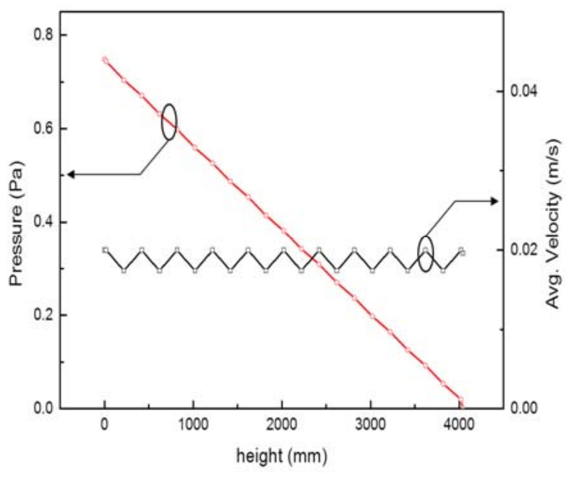

Fig. 2. Avg. static pressure and velocity with according to height

2.3 Evaluation of Permeability

The calculation of permeability were compared in three ways. First method is theoretical approach by using the friction factor. Second method is CFD calculation by the wall shear stress. Third method is CFD calculation by the pressure drop. Three methods are summarized in table 1.

Table I: Permeability Calculation

Method	Friction factor	Wall shear stress	Pressure drop
Permeability	$\frac{32}{D_h^2}$	$\frac{4\tau_w}{\mu V D_h}$	$\frac{\Delta P}{L\mu V}$

The calculation results are presented in Table 2. The result of friction factor method is 50% less than the results of wall shear stress and pressure drop. The assumption which is pipe laminar flow at the friction factor calculation could make such a difference. The characteristic length reflects the geometry length. It is impossible to calculate the exact shear stress by the complex geometry.

Table II: The Results of Permeability Calculation

Method	Friction factor	Wall shear stress	Pressure drop
Permeability	2.36E+05	5.17E+05	5.34E+05

3. Conclusions

The flow inside the basket which included a fuel assembly is analyzed by CFD. As the height of the fuel assembly increases, the pressure drop linearly increased. The inertia resistance could be neglected. Three methods to calculate the permeability were compared. The permeability by the friction factor is 50% less than the permeability by wall shear stress and pressure drop.

4. Acknowledgement

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