Predicting the Pressure Loss on a Spacer Grid Using One Cell Model

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1. Introduction

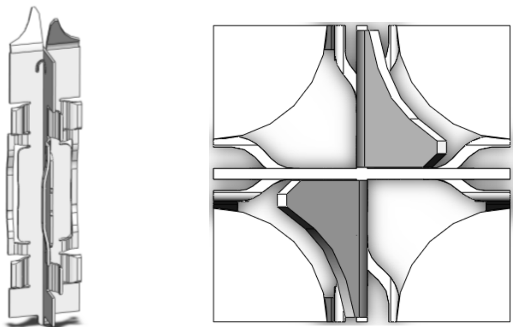
Pressure drop of each component is an important quantity to specify the characteristics of a nuclear fuel. It can influence the performance of a reactor and can cause failure of a fuel, etc. But the geometrical complexity makes the pressure drop calculation difficult. Because of this importance, lots of simulations and experiments have been conducted to predict the amount of pressure drop precisely. Most of this works are based on partial spacer grid model which is composed by several grid cells with RANS(Reynolds Averaged Navier-Stokes) or k-ε turbulence model. However, it is well known that RANS and k-ε model holds huge model effect which makes the simulation results inaccurate [2]. In the consideration of the geometrical repeation of the spacer grid, the full size grid might be described by a most dominant cell. Thus, this study employs one-cell grid model with k-ε turbulence model and LES(Large Eddy Simulation) to ensure accuracy and memory efficiency.

2. Method and Results

The geometrical model, specifications and the results of simulation are presented.

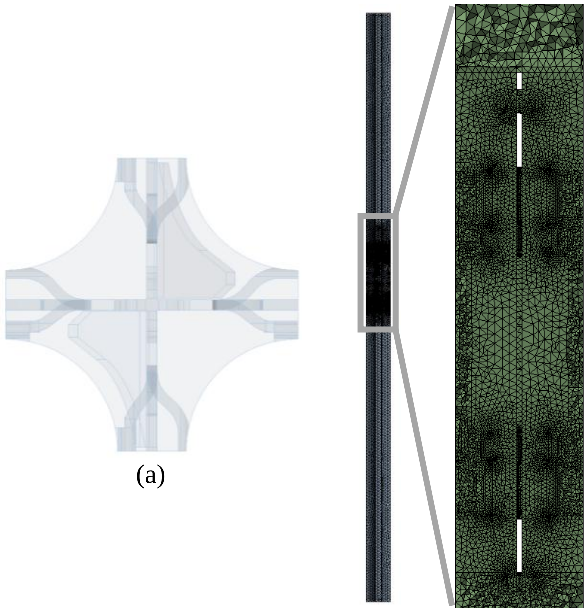
2.1 Spacer grid Model

The spacer grid is usually modeled as several cells to simulate fluidic fluctuation in CFD. One-cell spacer grid model may not enough to ensure this kind of deviation. However, for some quantities which can be specified by time average, like pressure, one-cell spacer grid model can be enough to demonstrate that quantity. In this study,



(a) (b)

Fig. 1 One-cell spacer grid model. (a) iso view(fuel rods are unshown), (b) top view



(b) (c)

Fig. 2 Mesh for one-cell model The number of mesh is 691618. (a) top view of fluid area, (b) mesh over view, (c) detail view of strap area

the typical cell(most dominant cell) is selected to represent the characteristic of the grid(Fig.1). There are 2 springs, 4 dimples and 2 mixing vanes. Leading and trailing flow distance is about 2~3 times of grid height. Ansys 13.0 Fluent is used for the calculation. Tetrahedral mesh is used and is refined based on curvature [1]. The number of mesh is the order of 1.0E5.

2.2 Numerical Method

k-ε turbulence model is widely used in many area, because it is the simplest complete turbulence model [2]. But it is well known that k-ε turbulence model does not fit for boundary layers with strong pressure gradients, since it tends to calculate more energy dissipation. This uncertainty is based on the concept of turbulent viscosity which is proven to be unreal property.

In the areas which need more accurate results, LES starts to be used recently as computer performance becomes better. LES uses more realistic functions which are called SGS(sub-grid scale) model. Since LES calculates large scale motions and uses model only for small scales that has universality, LES is more accurate than k-ε or other two-equation models. The smagorinsky model is used for this study.

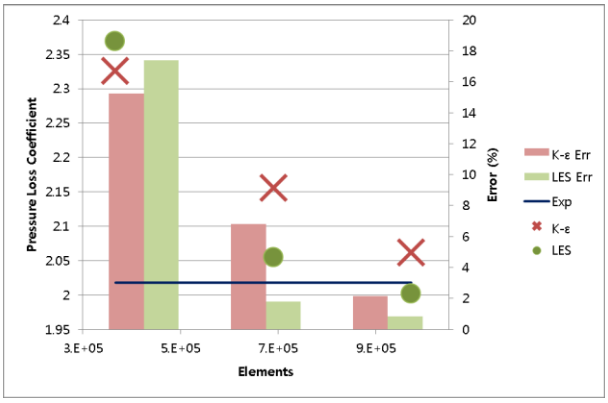


Fig. 3 Comparison of the pressure loss coefficient.

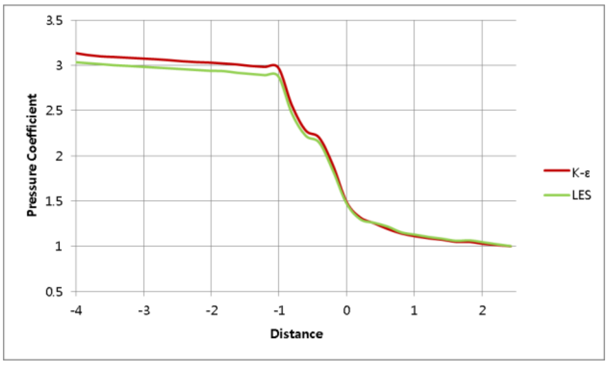


Fig. 4 Pressure coefficient of 691618 elements case along a streamwise direction. Distance is normalized by strap height. Strap area is -1 to 0.

Table I: Error rate of the simulation results

Elements	k-ε model (%)	LES (%)
367172	15.2	17.4
691618	6.8	1.8
972809	2.2	0.8

Periodic boundary condition is applied for lateral direction of the model and Reynolds number based on the diameter of the fuel rod is around 4.8E4.

2.3 Results

Fig. 3 shows the simulation result according to the number of elements. The pressure loss coefficient is defined as

$$C_p = \frac{\Delta P}{\frac{1}{2}\rho_\infty V_\infty^2}$$

Experimental result is acquired from VISTA facility in 2001. The 5x5 cell sized test sample is used for the experiment. Straight line without symbol in Fig.2 remarks this test result.

As expected, the error decreases with the denser mesh. In the case of coarse mesh, LES shows poor result because the model used in LES is not designed for energy containing range. However it shows appropriate results over certain amount of elements which can be conjectured the adequate elements number. Even the shape of the model is complex, LES performs well.

k-ε model overestimates the amount of pressure drop, as it is known. And the error decrease linearly with mesh number. Generally k-ε model gives poor results than LES for high resolution because of the limitation of the model effect.

Even it is the simulation result of one-cell model, it follows well the experimental results. This can be evidence that the typical cell of a grid can have representative characteristics.

3. Conclusions

Simulations using one-cell model are performed and it shows reliable results compared to experimental results. Thus one cell model can be appropriate to get result of quantity which can be acquired by time average. And the typical cell which composes the most of the grid can represent the entire grid for some quantities, such as pressure drop. This is plausible because the typical cell holds the largest portion of geometrical characteristics. Even high resolution mesh is required to get this result, the total amount of the mesh is much lesser than the full or partial model. This strategy can give some advantage in investigating the microscopic performance of grid, such as pressure distribution over a strap surface.

Acknowledgement

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