RESEARCH ON PREDICTION OF WIND ENVIRONMENT AROUND OUTDOOR GROUP OBJECTS

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ABSTRACT

It is difficult to model those complicated objects around buildings, which will obviously affect the flow patterns and temperatures of the outdoor environment. In this paper new method is concluded to solve this kind of modeling problems. Those centralized objects are treated as porous media which will also affect the air flow and turbulence. New source terms are coded into the model to simulate the characteristics. In this way, we can easily model as many as influential factors into the simulation and save much computational time and get a satisfactory result. Plants and buildings are modeled in this paper and some preliminary conclusions are drawn. Good simulation results proves the feasibility of the model.

KEYWORDS

Outdoor Environment, Drag Force Coefficient, CFD, Extra Terms

INTRODUCTION

CFD is used to simulate the micro environment around buildings. The major factor to influence the accuracy of simulation is the precision of the incoming flow boundary conditions. One of the difficult problems is how to simplify the boundary conditions. To resolve this problem, many description methods were developed.

Shuzo Murakami and Akashi Mochida developed a multi-scale simulation system to select the address of a wind power station. In this system, a stepwise and nested method is used to set the boundary condition: the larger scale simulation result is used as the boundary condition of the smaller scale. Compared with the boundary condition of a wind power station, the boundary conditions of a city crown are more complicated. However, both boundary conditions could be set with the stepwise and nested method.

Kazuya Takahashi and Harunori Yoshida simulated the wind environment and thermal environment around a district in Kyoto with the similar method. In order to set the reasonable incoming flow boundary conditions, they arrayed 10 standard district models in line, used the logarithmic gradient wind as the incoming flow boundary condition of the first district. After stepwise and nested calculation, the outcoming flow boundary conditions of the ninth district are used as the incoming boundary conditions of the studied district.

Li Lei used the speed and temperature from RAMS (a software) as the boundary condition of FLUENT and used the lowest layer temperature from RAMS as the temperature of the ground and building skin. In order to achieve the calculation stability, he used a district model which is set in a $600m \times 600m$ square with 200m blank boundary space. However, this method did not consider the influence from man-made thermal resource and buildings in blank space.

There is a contradiction between accuracy and time of outdoor envioronment simulation: if we consider the influence of the building group and plant group around the studied buildings, the simulation time will be too long; if we did not consider this influence, the simulation accuracy is too low. Because the existing methods can not resolve this contradiction, it is urgent to find a new way. This paper will develop a new method based on the recent research.

RECENT RESEARCH ON MODELING METHOD

Akashi Mochida and his partners described the plants, advertisement boards and traffic stream as source items. When they considered the plants, the plants were set as the source items in the κ - ε equation. The simulation result is congruent with the experimental data. When they considered the traffic stream, the whole traffic stream on one street was also regarded as one source item in the κ - ε equation.

Lin Boring used the same method, but the source item was set in the different way.

Due to the complicated shape and group characteristic of these group objects, it is difficult to develop the detailed model. Therefore, setting these objects as the source items is the feasible way to describe them.

This method could be used to describe all of the group objects, including buildings, plants, nannoreliefs, building units, crowd, traffic stream, etc. As for the larger scale, these objects could be regarded as the porous media, and these porous media could be coded into the κ - ε equation as the source items which affect the air flow and

temperature field. This method not only achieves the accuracy but also saves the simulation time.

REVISED PLANTS MODEL

Extra terms of plants model

In Lin Boring's Ph.D. thesis, a source item to describe the single plant is success to be used to simulate the micro environment around the buildings. This plant source item is coded into the speed item, κ item and ε item of the κ - ε equation.

The source item of the speed equation is:

$$F_d = -\frac{1}{2}C_d\eta au_iS \tag{1}$$

In this equation, S is the average speed, Cd is the drag force coefficient of the tree crown, a is the leaf area density of the tree crown, ηa is the shadow area of the leaf area on the vertical plane of the incoming flow.

The source item of the κ equation includes two parts:

the extra item caused by the influence of crown on the production of wake flow:

$$P_k = \frac{1}{2}C_d\eta aS^3 \tag{2}$$

the extra item caused by the influence of crown on the energy loss of the turbulant flow:

$$L_k = -2C_d\eta aSk \tag{3}$$

The source item of the ε equation includes two parts:

$$P_\varepsilon = \frac{\varepsilon}{k}C_{p\varepsilon1}C_d\eta aS^3 \tag{4}$$

$$L_\varepsilon = -4C_{p\varepsilon2}C_d\eta aS\varepsilon \tag{5}$$

$C_{p\varepsilon1}$ and $C_{p\varepsilon2}$ are experienced constants.

New modeling method

However, the number and distribution of the plants is too large to be described as the single plant models; with the increased number of plants, the calculation of radiation heat transfer between each surface needs more time. To simplify the modeling and save the calculation time, this paper will consider the chararctersitc of the plant group, use the way to develop the sinlge plant model to develop the plant group model.

It is the plant group not the single plant to be modeled. As we all known, the source item describes the source intensity per unit volum. As for

a plant group, the source intensity in the occupied room is fixed. Compared with the single plant, the occupied room is increased and the source intensity is decreased.
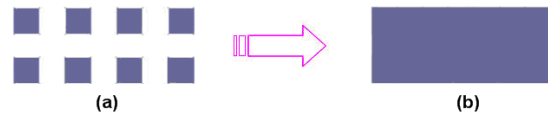

Figure 1 A different ways of modeling the plants. (a)model every plant (b)model all plants as one

In order to compare these two modeling results, the speed value and κ value behind the 5m of the plant group were compared.
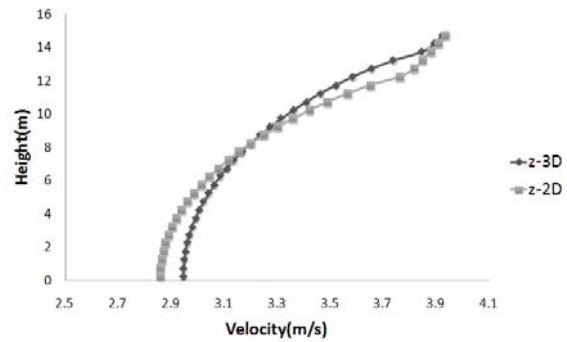
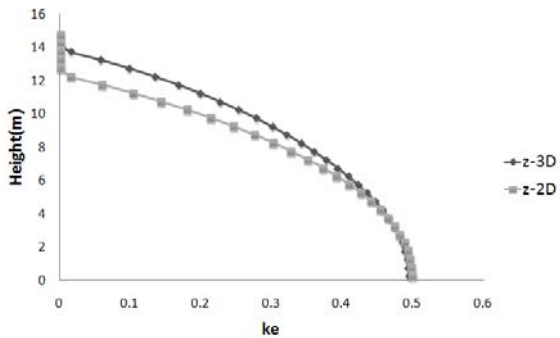

Figure2 velocity distribution in height direction

Figure3 κ distribution in height direction

The compared result shows: the simulation results of these two models are similar, in an other word, the accuracy of the porous media source model is close to the accuracy of the single plant source model.

REVISED BUILDINGS MODEL

Similarly, the building group could also be described as the porous media.

Firstly, correspondly with the drag force coefficient of the plant group, building group have a silimar drag force coefficient C_d, which means the average block function from building group to incoming air flow, or the average drag force from incoming air flow to building group. Secondly, correspondly with the leaf area density and shadow area ratio, building group have a shadow area ratio, which means the block area to the incoming flow. This paper apply the similar method to describe the plant group to

describe the building group, and compared the porous media model results with the detailed model result.

Modeling of buildings

The scale of the building is H=2m. Suppose the number of the columns in Y direction is unlimited, the number of the rows in X direction is n, the distance between buildings is D. The influence factors are n and D.
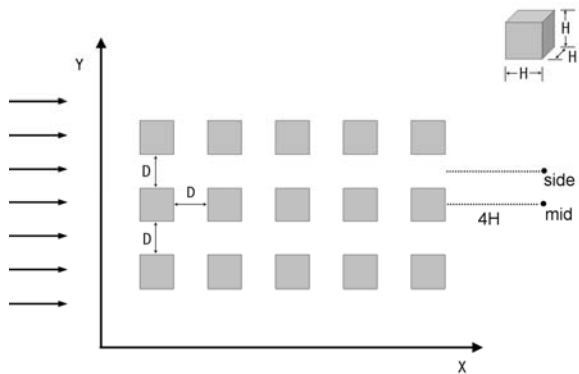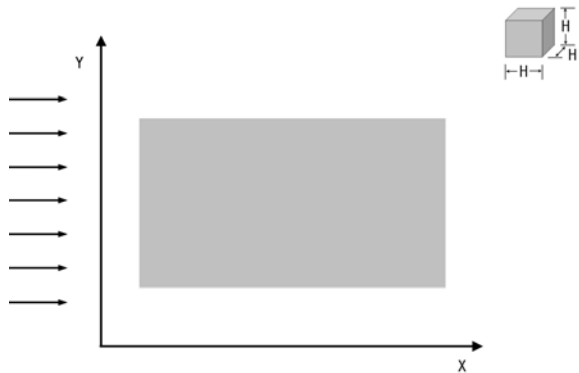

Figure 4 precise model of buildings

Figure 5 simplified model of buildings

Result comparison

The observation spot is behind the 4H of the building group. The distribution of the speed field and κ value in height direction are compared.
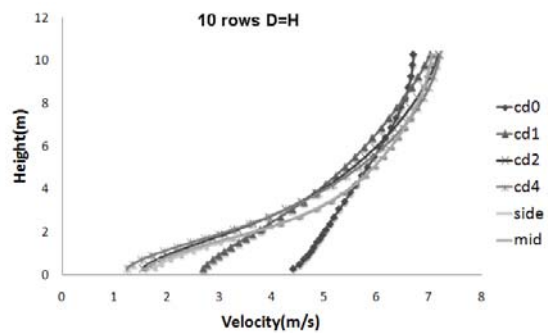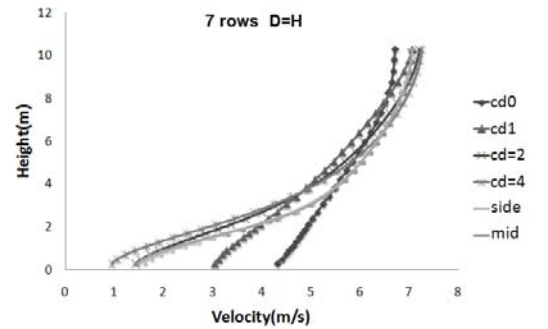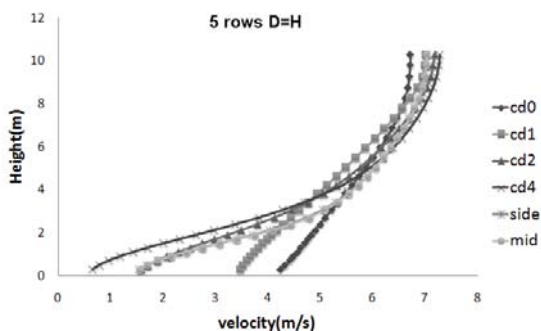
a)   Comparison of speed distribution

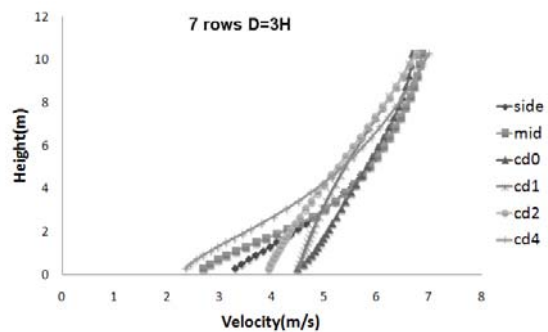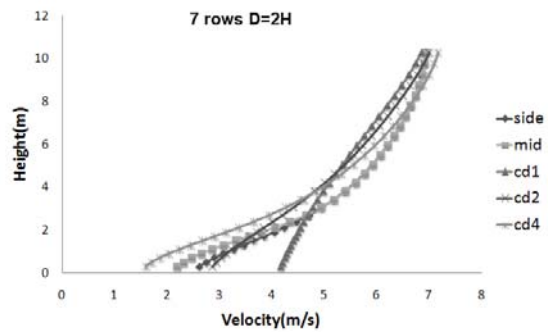*Figure 6 velocity distribution of different rows*

Figure 7 velocity distribution of different distance

According to the comparison result, with the change of the number of the rows, the results had no significant changes, which means there is no relationship between the number of the rows and the result. The distribuion curves show: the detailed modeling results is between $C_d=0$ and $C_d=4$, which means when C_d is between 0 and 4, the result of porous media source model could close to the detaield result. In this case, when $C_d=2$, the result of porous media source model is most close to the detailed result.

With the difference of the distance between buildings, the change of the speed item with the change of C_d has the similar rules. However, "when $C_d=2$, the result of porous media source model is close to the detailed result mostly" is not for all the cases. When the distance between buildings is large, the idea value of C_d is between 2 and 4. Fortunately, it is always possible to find a C_d value to describe the porous media characteristic of the building groups correctly.
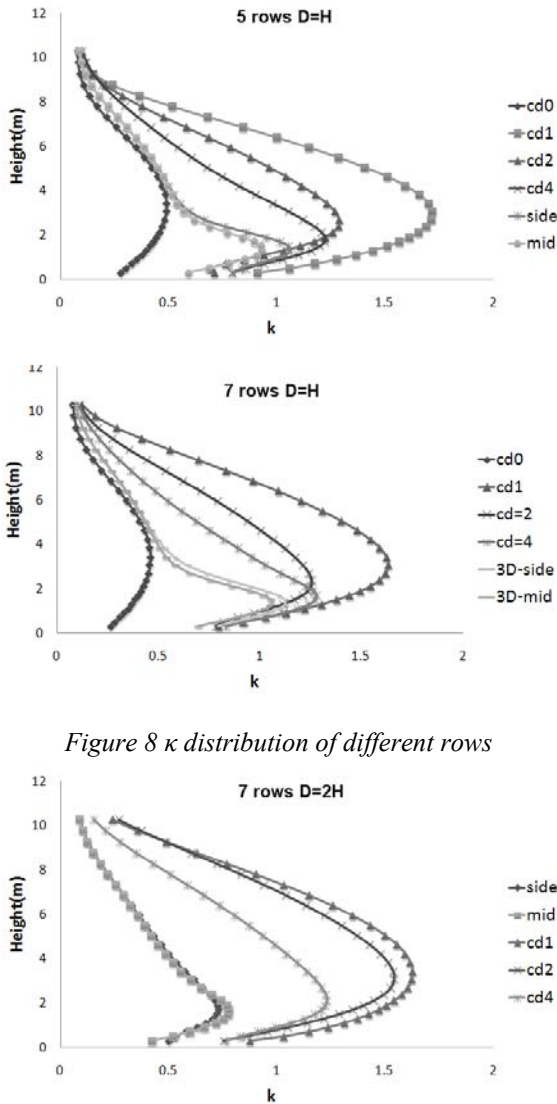
b)   Comparison of κ value distribution

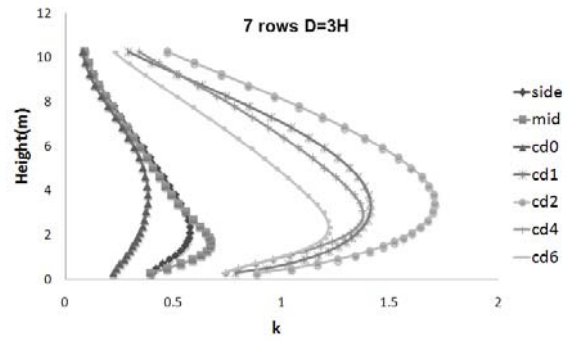

Figure 8 κ distribution of different rows

Figure 9 κ distribution of different distance

As the shown on the simulation result, the detailed model result is between $C_d=0\sim2$, that means, when $C_d=0\sim2$, the result of porous media source model is close to the detailed result mostly. However, this conclusion is conflict with the conclusion of speed distribution.

Discussion

We found the simulation results of speed item and κ item cannot close the detailed results simultaneously.

Considering the physical means of source item, the source item of the speed is the drag force caused by flow. That means the source item of the speed is physically accurate. When $C_d=2\sim4$, for all of the above cases, the speed of porous media modeling is congruent with the speed of detailed modeling.

Since when $C_d=2\sim4$, the deviation of κ value distribution is large, the source item of κ should be revised to keep both the speed result and κ result to close to the detailed result. Because the κ value of this source item is estimated too high, the possible revised way is to reduce the influence of the source item of κ value.

CONCLUSION

a) How to describe the group objects is the bottleneck to develop the numerical simulation on outdoor environment. In order to describe the group objects accurately, new method is necessary.

b) To simplify the complicated modeling and save the calculation time, this paper developed a porous media source model, which regards the group objects as the porous media on larger scale. In this model, the influence of group objects on incoming flow and temperature field is considered to gurantee the calculation accuracy.

c) The feasibility of porous media source model is proved by studying the plant group model and building group model. The plant group model is close to the detailed model; the speed distribution of the building group model is close to the detailed model; while the κ value distribution is not so close to the detailed model. Therefore, the source item of

κ value needs to be revised, and reducing the intensity of source item of the κ value is the first step.

d) In this paper, the group objects are distributed uniformly. The actual plant group and building group is more complicated, the characteristic in this paper cannot be use for all cases. Therefore, for the actual cases, the different porous media with different characteristics should be applied.

e) The next step is to revise the source item of building group to guarantee both the speed and κ value are close to the detailed modeling results. More research on different building distribution and other group objects will be conducted to increase the calculation accuracy and save the simulation time.

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