World Academy of Science, Engineering and Technology
International Journal of Mechanical and Mechatronics Engineering
Vol:5, No:5, 2011

Using the V-Sphere Code for the Passive Scalar in the Wake of a Bluff Body

Y. Obikane, T. Nemoto , K. Ogura, M. Iwata, and K. Ono

***Abstract*—**The objective of this research was to find the diffusion properties of vehicles on the road by using the V-Sphere Code. The diffusion coefficient and the size of the height of the wake were estimated with the LES option and the third order MUSCL scheme. We evaluated the code with the changes in the moments of Reynolds Stress along the mean streamline. The results show that at the leading part of a bluff body the LES has some advantages over the RNS since the changes in the strain rates are larger for the leading part. We estimated that the diffusion coefficient with the computed Reynolds stress (non-dimensional) was about 0.96 times the mean velocity.

***Keywords*—**Wake , bluff body,V-CAD, turbulence diffusion

I. Introduction

ALONG Japan's highways, contaminants, such as NOx, biochemicals, and viruses, transported by vehicles sometimes cause serious problems. One of the most serious incidences was an outbreak of foot-and-mouth disease in Miyazaki Prefecture in early 2010. A possible cause of the outbreak was vehicles carrying contaminants. However, the dispersal mechanism is not yet known. Mud carried on the tires is possibly linked to the spread of the disease. As the linked eddy scales from small to large are numerous, it is hard to estimate the trajectory of a single contaminant particle in the eddies. Statistically, we can estimate the probability of a particle's location.

II. OBJECTIVES

In this research, we predict a diffusion length scale related to the micro-atmospheric diffusion scale valid up to several hundred meters. The diffusion lengths of the mud released from the tires or silt on the road represent one of the diffusion lengths of the present problem. Since the diffusion of the moving bluff body is more effective, the wake is larger on both regular roads and highways. We confined the CFD problem to predict the wake of the bluff body.

III. METHOD

The wake of a bus was studied computationally and experimentally. The bus is moving in the computation, but for the experiment the bus and the ground are at rest. The LES option of the V-Sphere code from the V-CAD system developed by RIKEN [2] is used for the prediction. The experiments with a steel model of the bus were performed with a smoke line released from the roof at a Reynolds number of about one million. Any smoke stream released from the top of the bluff body was recorded with a high-speed camera. The image data was processed and the Reynolds stress along a streamline on the centerline and the rate of diffusion were evaluated along the streamline.

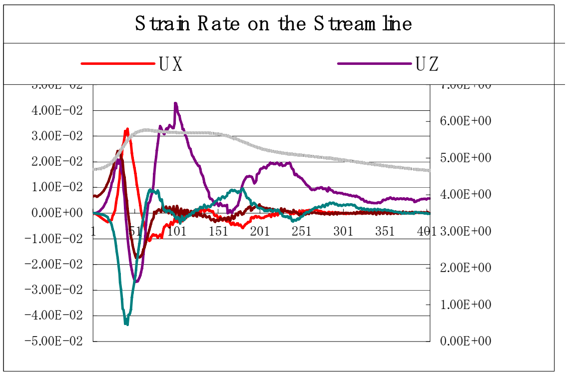

Fig. 1 Mean Strain Rates

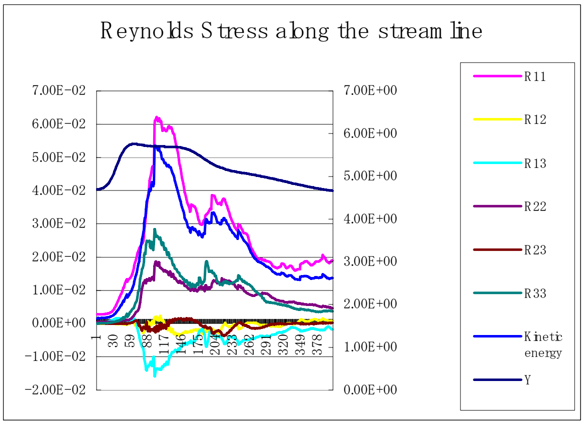

Fig. 2 Reynolds stress

Y. Obikane is in Sophia University, Mechanical Engineering Department, 7-1 Kioi-cho, Chiyoda-ku ,Tokyo, 102-8554, Japan(Professor invited ENSAM, Dynfluid, ParisTech, Paris, Fr.)Email : y-obikan@sophia.ac.jp
T. Nemoto , K. Ogura are in Tamagawa University, Mech. Sys. 6-1-1 Tamagawa-gakuen,Machida-shi,Tokyo194-8610,Tokyo,Japan Email : kogura@eng.tamagawa.ac.jp
Masako Iwata, Kenji Ono were in *RIKEN, V-CAD, Sys Res. Program, 2-1 hirosawa,wako-shi, Saitama,Japan, 351-0198*Email : miwata@riken.jp ,
Email : kono@riken.jp

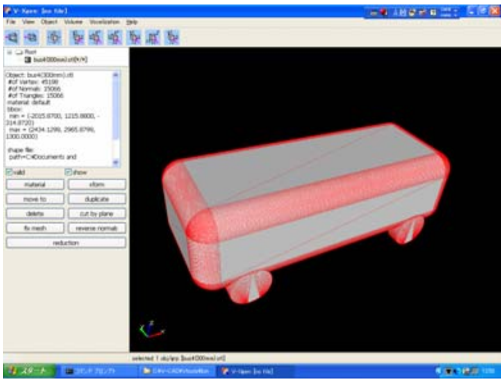

Fig.3 Bus configuration

Fig.4 Wake in Smoke tunnel (Experiment)

IV. Results

1) The results show that du/dz are well correlated to the kinetic energy of turbulence. This implies that the classic model will work well in the present case, except near the leading edge of the body. LES may be more powerful in the strong distortion region than in the RNS. The sustainable turbulence energy observed in the far wake is supposed to dissipate the contaminants over a longer period. The turbulence level of the wake was about 1.4e-2 in a no-dimensional scale and the diffusivity with the Von-Karman's model was about 0.96 of the mean velocity in the present computation (Figures 1 and 2).

2) Experimental results show three large patches of smoke fluctuations along the centerline that can often be seen in a wake of the body. The ratio of the wake almost agrees with the computational results (Figures 3–5).

3) The Reynolds stress was computed in symmetrical patterns; however, the mean flow was slightly asymmetrical in the present computation (i.e., we can see a short Karman vortex street). The results were consistent in the wind tunnel (i.e., the flow attained a steady state faster than the Reynolds stress) (Figures 6–8). Since the Reynolds stress patterns were almost symmetrical, the turbulent state may be nearly at equilibrium, so the diffusion coefficient can be evaluated (Figures 9 and 10).

If the wake domain is small, the solution diverges at the end of the wake.

4) The typical run-time on a CPU (405 x 104 x 74) was for a few weeks, depending on the Reynolds number.

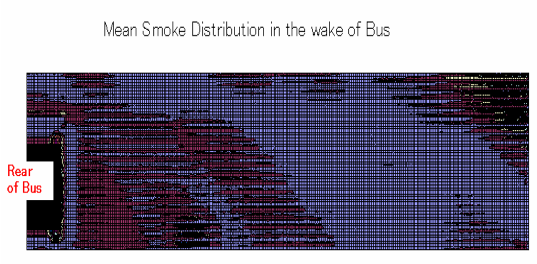

Fig.5 Smoke Density Moment in the wake

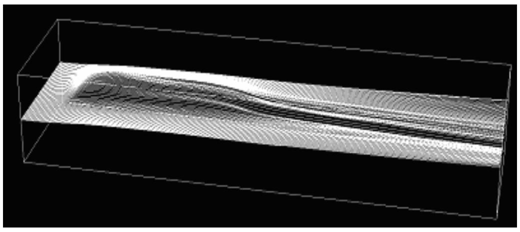

Fig.6 Streamlines around the Bluff body

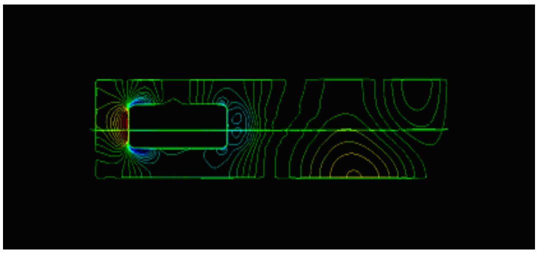

Fig. 7 Mean Pressure (Kerman Vortex)

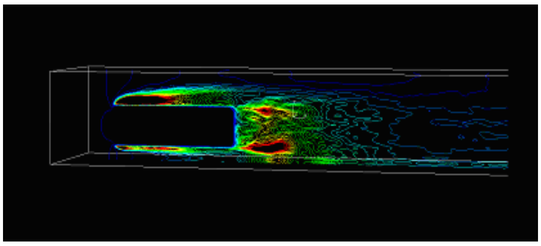

Fig.8 Reynolds Stress 11

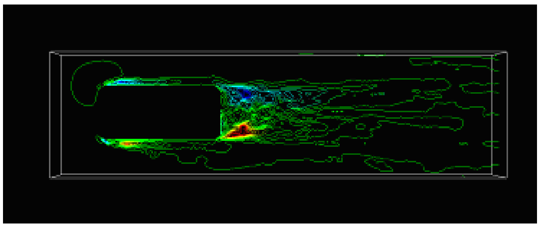

Fig.9 Reynolds Stress 12

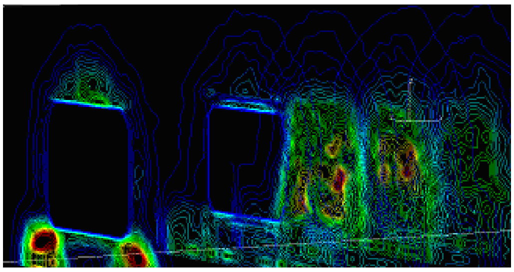

Fig.10 Reynolds Stress 11

V.CONCLUSION

The third order MUSCL scheme generated stable solutions. The large CPU time implies that the computation of the flow field should separate from the simulation of the passive scalar, such as the smoke and heat. The asymmetrical solutions observed in the present computation may require more CPU time. The diffusion coefficient was estimated with the computed non-dimensional Reynolds stress to be about 0.96 of the mean velocity. The results can be applied to aero-acoustics problems.

ACKNOWLEDGMENT

The authors would like to thank to RIKEN to use RICC system for the feasibility study of the speed and maximum storages for V-Sphere for the present problem. The authors would like to thank Mr. Suzuki, Mr. Ikeda, Mr. Miyasaka, mechanical system department, Tamagawa University ,who helped to conduct the experiments, and also thank to Dr. Florent Margnat for the valuable discussion of the application to sound generation from the bus during Y. Obikane's staying at ENSAM, ParisTech, DynFluid, France as invited Professor.

REFERENCES

[1] Y.Obikane,*Numerical Computation of Turbulent Flow Around the Spinner of a Turbofan Engine* , in proceedings, the 13th International Symposium on Air Breathing Engine, 1984

[2] K.Ono and T.Tamaki, *Development of a framework for parallel simulators with various physics and its performance, IN proceeding, International conference on parallel computational fluid dynamics*, Antarya, Turkey, 2007,may, Parallel CFD *Introduction to Signal Detection and Estimation*. New York: Springer-Verlag, 1985, ch. 4.