CS 128 APPLICATION OF AN EDDY VISCOSITY MODEL TO FINITE ELEMENT ANALYSIS OF TURBULENT FLOW AROUND A CIRCULAR CYLINDER

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1. Introduction

Due to very high Reynold numbers in real flow conditions, simulation of turbulent flow is necessary in the field of wind engineering. Large eddy simulation(LES), which does not require so many grid points in simulation as direct numerical simulation, is widely used to predict turbulent flows in mechanical and aeronautical engineering[3]. However, application of LES to flows around bluff bodies is limited[4,5]. This paper tries to show some possibilities of an application of LES to wind engineering problems especially for flow around a circular cylinder. Finite element analysis is used as a numerical scheme in this study.

2. Eddy viscosity model

Large eddy simulation(LES) with Smagorinsky subgrid scale model[1] is used in this study. The filtered Navier-Stokes equations take the form

$$\frac{\partial \overline{u}_i}{\partial t} + \frac{\partial}{\partial x_i}\overline{u}_i\overline{u}_j = -\frac{1}{\rho}\frac{\partial P}{\partial x_i} + (\nu + \nu_T)\frac{\partial^2 \overline{u}_i}{\partial x_j \partial x_j} \quad , \quad \frac{\partial \overline{u}_i}{\partial x_i} = 0 \qquad (1,2)$$

where $\overline{u}_i$ is a mean component of velocity in i direction; P is mean pressure;ρ is the density of fluid; ν is the kinetic viscosity of fluid; and ν_T is an eddy viscosity which is calculated from

$$\nu_T = C^2 h^2 \left(2\, \overline{S}_{ij} \overline{S}_{ij} \right)^{1/2} , \quad \overline{S}_{ij} = \frac{1}{2}\left(\frac{\partial \overline{u}_i}{\partial x_j} + \frac{\partial \overline{u}_j}{\partial x_i} \right) \qquad (3,4)$$

where C (= 0.1) is a subgrid constant; h is the length scale which is set equal to the square root of each finite element area; $\overline{S}_{ij}$ is the strain rate tensor.

So as to account for a high peak of eddy viscosity which results from high velocity gradient at near wall region, usually various kinds of damping function are employed. In this paper, we investigated an effect of the Van Driest damping function[2] :

$$W(\zeta^+) = 1 - \exp\left[\left(-\zeta^+ (1 + \zeta/D) \right) / A^+ \right] \qquad (5)$$

where ζ is the distance to the nearest wall; D is the diameter of the circular cylinder; $\zeta^+ = \zeta u_\tau / \nu$; u_τ is the friction velocity on the wall; and $A^+ =$ 25. Then $W(\zeta^+)$ is modified to ν_T .

The governing equations are solved numerically using the streamline upwind/Petrov - Galerkin finite element method for space discretization and the predictor - corrector method for time integration.

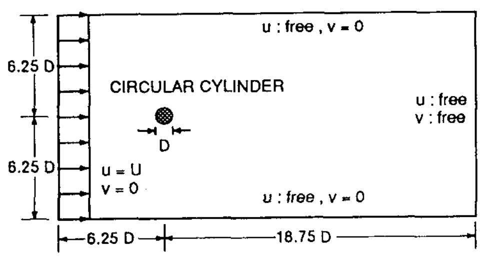

Fig. 1 Computational domain and boundary conditions

4. Results & Discussion

The computational domain which covers 25D in x direction and 12.5D in y direction and the boundary conditions are shown in Fig. 1. This domain is discretized into 2940 nodes and 2840 elements (Fig. 2). The numerical simulation is done by increasing the upstream velocity up to Re = 10^3,10^4,and 10^5 respectively. A flow pattern at Re = 10^4 is shown in Fig. 3. The introduced damping function cancels high peaks of eddy viscosity near the cylinder surface as shown in Fig. 4. It is found from distribution of eddy viscosity(Fig. 5) that high eddy viscosity is located in the wake region behind the cylinder. Figure 6 shows that, the drag coefficients from the simulation without the damping function(5) are higher than the experimental ones. However, after the wall-damping function has been employed, the drag coefficients reduce to have better values.

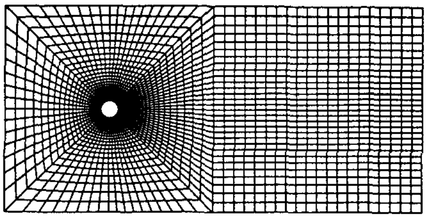

Fig. 2 Mesh configuration

5. *Conclusions*

Turbulent flows around a circular cylinder have been numerically studied using large eddy simulation. The finite element method for LES has shown a possibility in prediction of a turbulent flows. The wall-damping function can be used to improve computational results by suppressing prohibitively high peaks of the eddy viscosity near the wall.

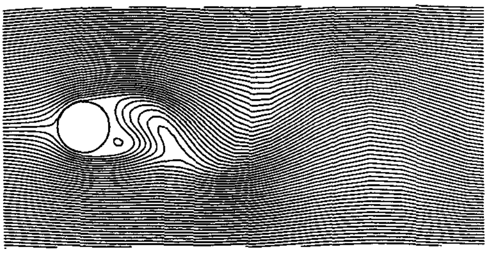

Fig. 3 Streamlines at Re=10^4

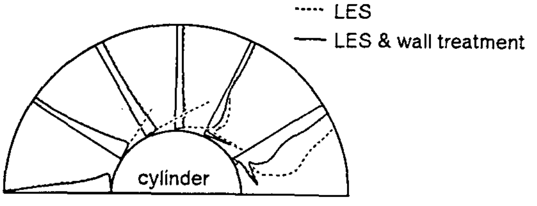

Fig. 4 Eddy viscosity profile along the cylinder surface at Re=10^4

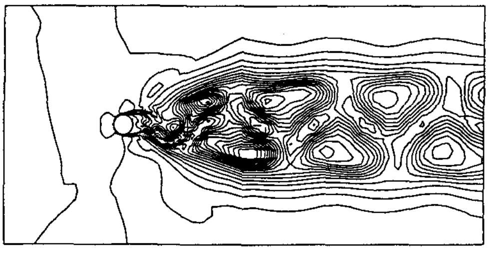

Fig. 5 Eddy viscosity at Re=10^4

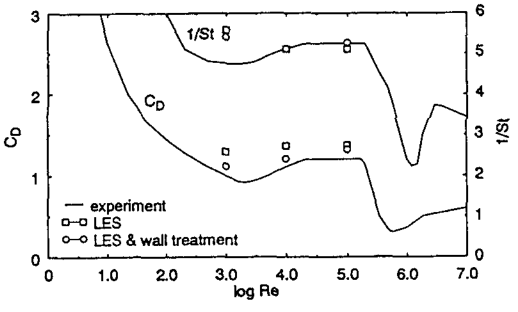

Fig. 6 Drag coefficient and reciprocal of Strouhal number[6]

6. *Reference*

[1] Smagorinsky, J. Mon. Weather Rev. , (1963), 91, pp. 99-164, [2] Van Driest, E. R. , J. Aero. Sci. , (1956), 23, pp. 1007-1011, [3] K. Horiuti, J. Comput. Phys., (1987), 71, pp. 343-370, [4] S. Murakami, J. Wind Eng. Ind. Aerodyn., 31 (1988) 283-303, [5] C. C. S. Song, J. Fluid Eng. , (1990),Vol.112,pp. 155-160, [6] Cantwell, B. and Coles, D.,J. Fluid Mech. , (1983),Vol.136, pp. 321-374