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Study of the flow around a cylinder from the subcritical to supercritical regimes

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Abstract. The objective of the present simulations is to evaluate the applicability of the standard k-ε turbulence model in engineering practice in the subcritical to supercritical flow regimes. Two-dimensional numerical simulations of flow around a circular cylinder at Re=1×10^5, 5×10^5 and 1×10^6 , had been performed using Unsteady Reynolds-Averaged Navier Stokes (URANS) equations with the standard k-ε turbulence model. Solution verification had been studied by evaluating grid and time step size convergence. For each Reynolds number, several meshes with different grid and time step size resolutions were chosen to calculate the hydrodynamic quantities such as the time-averaged drag coefficient, root-mean square value of lift coefficient, Strouhal number, the coefficient of pressure on the downstream point of the cylinder, the separation angle. By comparing the values of these quantities of adjacent grid or time step size resolutions, convergence study has been performed. Solution validation is obtained by comparing the converged results with published numerical and experimental data. The deviations of the values of present simulated quantities from those corresponding experimental data become smaller as Reynolds numbers increases from 1×10^5 to 1×10^6. This may show that the standard k-ε model with enhanced wall treatment appears to be applicable for higher Reynolds number turbulence flow.

Keywords: solution verification; validation; cylinder; k-ε; higher Reynolds number

1. Introduction

Flow around a circular cylinder is of great interest for its applications in engineering problems such as vortex-induced vibration on risers and pipelines, inertia and damping forces of columns of platforms or other cylindrical structures. Most of engineering problems are often subject to very high Reynolds numbers, which makes them hard and expensive to carry out experiments. Thus Computational Fluid Dynamics (CFD) becomes a possible tool to substitute the experimental measurement to predict the hydrodynamic quantities of flows around a circular cylinder. However, due to uncertainties in CFD turbulence model, solution verification and validation of the numerical turbulence models need to be carried out before they can be used for engineering applications (Simonsen 2003, Oberkampf and Trucano 2008, Eca and Vaz 2012).

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(5) The standard k-ε model predicts the high-Reynolds-number flow problems with more accurate results, compared with 2D LES model. At Re= 1×10^6, the values of C_{Daver}, St and C_{Pb} and θ calculated by the standard k-ε model are close to those by 3D LES model. However, the former are two-dimensional cases, which saves much calculation time and expense.

Finally, it is truth-worthy to mention that the standard k-ε model with enhanced wall treatment is sufficiently applicable for simulating relatively high Reynolds number (Re near 1×10^6) offshore flow for both its relatively accurate predictions with relatively high calculation speed and its accessibility in most commercial CFD software.

References

Achenbach, E. (1968), "Distribution of local pressure and skin friction around a circular cylinder in cross-flow up to Re=5×10^6", *J. Fluid Mech.*, **34**(4), 625-639.

Catalano, P., Wang, M., Iaccarino, G. and Moin, P. (2003), "Numerical simulation of the flow around a circular cylinder at high Reynolds numbers", *Int. J. Heat Fluid Fl.*, **24**(4), 463-469.

Cheung, J.C.K. and Melbourne, W.H. (1983), "Turbulence effects on some aerodynamic parameters of a circular cylinder at supercritical numbers", *J. Wind Eng. Ind. Aerod.*, **14**(1), 399-410.

Eça, L. and Vaz, G. (2012), "Workshop on verification and validation of CFD for offshore flows", *Proceedings of the ASME 2012 31st International Conference on Ocean*, *Offshore and Arctic Engineering*, Rio de Janeiro, Brazil, July.

FLUENT User's Guide (2006), Version6.3, FLUENT Inc, USA.

Franke, R., Rodi, W. and Schönung, B. (1989), "Analysis of experimental vortex-shedding data with respect to turbulence modelling", *Proceedings of the 7th Symposium on Turbulent Shear Flows*, Stanford, USA.

Fung, Y.C. (1960), "Fluctuating lift and drag acting on a cylinder in a flow at supercritical Reynolds numbers", *J. Aeronaut. Sci.*, **27**, 801-814.

Launder, B.E. and Spalding, D.B. (1972), *Mathematical models of turbulence*, Academic Press, London.

Mittal, R. and Balachandar, S. (1995), "Effect of three dimensionality on the lift and drag of nominally two dimensional cylinders", *Phys. Fluids*, **7**(8), 1841-1865.

Oberkampf, W.L. and Trucano, T.G. (2008), "Verification and validation benchmarks", *Nuclear Eng. Des.*, **238**(3), 716-743.

Ong, M.C., Utnes, T., Holmedal, L.E., Myrhaug, D. and Pettersen, B. (2009), "Numerical simulation of flow around a smooth circular cylinder at very high Reynolds numbers", *Marine Struct.*, **22**(2), 142-153.

Schewe, G. (1983), "On the force fluctuations acting on a circular cylinder in crossflow from subcritical up to transcritical Reynolds numbers", *J. Fluid Mech.*, **133**, 265-285.

Simonsen, C.D. and Stern, F. (2003), "Verification and validation of RANS maneuvering simulation of Esso Osaka: effects of drift and rudder angle on forces and moments", *Comput. Fluids*, **32**(10), 1325-1356.

Singh, S.P. and Mittal, S. (2005), "Flow past a cylinder: shear layer instability and drag crisis", *Int. J. Numer. Meth. Fl.*, **47**(1), 75-98.

Sumer, B.M. (2006), *Hydrodynamics around cylindrical structures*, World Scientific.