Influence of Turbulence Model for Wind Turbine Simulation in Low Reynolds Number

Masami Suzuki, Department of Mechanical Systems Engineering, University of the Ryukyus, Okinawa, Japan

Long Abstract

Introduction

Computational fluid dynamics (CFD) modeling and experiments have both advantages and disadvantages. If doing both can be complementary, we can expect more effective understanding of the phenomenon. Although CFD has more advantages than experiments for the prediction where experiments are difficult to carry out, e.g. free stream conditions, it is generally difficult to obtain reliable results when compared with experiment. However, it is possible to obtain useful CFD results based on verification by the experimental results. Moreover, experiments do not necessarily provide correct results for any arbitrary condition due to limitations to experimental equipment, measurement errors and problems with measurement systems. Utilizing CFD can complement very fundamental experimental results. It is useful to utilize CFD as an efficient tool for the turbo-machinery and can complement uncertain experimental results. However the CFD simulation takes a long calculation time for a design in generally. It is need to reduce the calculation time for many design conditions. In this paper, it is attempted to solve the more accurate characteristics of a wind turbine for a short time, using the coarse grid. The wind tunnel test for the wind turbine is low Reynolds number. Therefore the accurate prediction with CFD is very difficult why the turbulent model is used by the transition area on the blade. The investigation of prediction results with and without turbulence model are performed.

1. Numerical Methods

The CFD code [1] is an in-house incompressible finite volume Navier-Stokes solver which is developed by the author. The solver is based on structured grids and the use of curve-linear boundary fitted coordinates. The SIMPLE algorithm is used for pressure-velocity coupling. The convection term is calculated using the QUICK scheme and the other terms in space are calculated using the 2nd order difference schemes. It is well known that sophisticated turbulence models do not always produce better results than the very simple models. Therefore the proven and computationally efficient Launder-Sharma low-Reynolds-number k-ε turbulence model, are used in this report. BEM [2] is a very simple method, and serves as the important tool of a wind turbine design. However, BEM is formulized by roughly assumption and approximation as compared with CFD which solves a flow directly in detail; it is not fully expressing the physical phenomenon. But it is convenient to grasp the simple and rough wind turbine characteristics, and is the tool having high utility value. The lift and drag coefficients of BEM are calculated by the 2-dimensional CFD.

2. Computational Results

The analysis results by the 3-dimensional CFD simulation and the blade element momentum theory (BEM) are compared, and they are investigated minutely about the factor contributed to the wind turbine characteristics. Figure 1 shows the upper half grid around the 2 blades turbine. Figure 2 shows the power coefficient and the thrust coefficient for CFD, BEM and the experiment results. The CFD and the BEM results are agreement with the experiment results. Figure 3 shows the limiting streamlines and the tip vortex around the blade which are calculated by CFD.

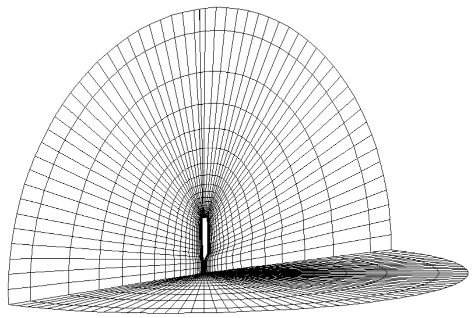

Figure 1. 3-D computational O-O grids of the 2 blades wind turbine.

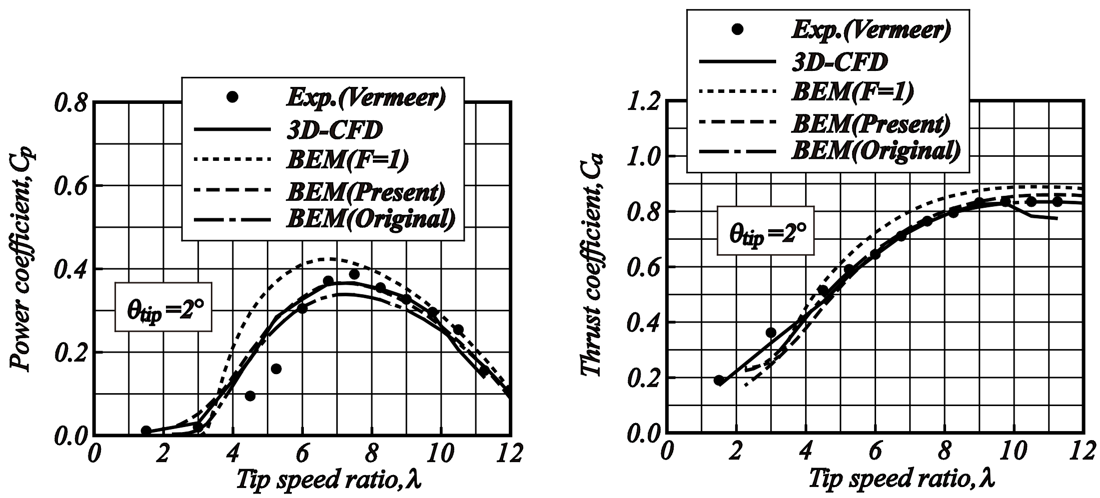

Figure 2. Power and Thrust Coefficient for CFD, BEM and the experiment results.

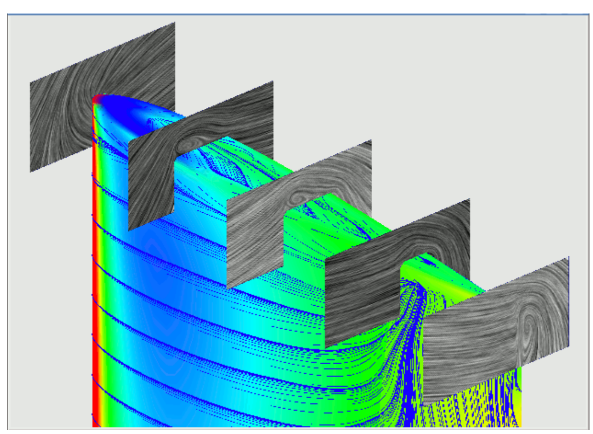

Figure 3. Limiting streamlines and tip vortex around a blade.

References

[1] M. Suzuki, Evaluation of Experimental Results for Wind Turbine Characteristics by CFD, Proceedings of the 9th International Symposium on Experimental and Computational Aero-thermodynamics of Internal Flows (ISAIF9), Gyeongju, Korea, CDROM, Paper No.1D-2, 2009.

[2] J.F. Manwell, J.G. McGowan and A.L. Rogres, Wind Energy Explained, Theory, Design and Application, Second Edition..