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Investigation on wake by various turbulent models in 2MW rotor turbine using a 2-D and a 3-D CFD modeling

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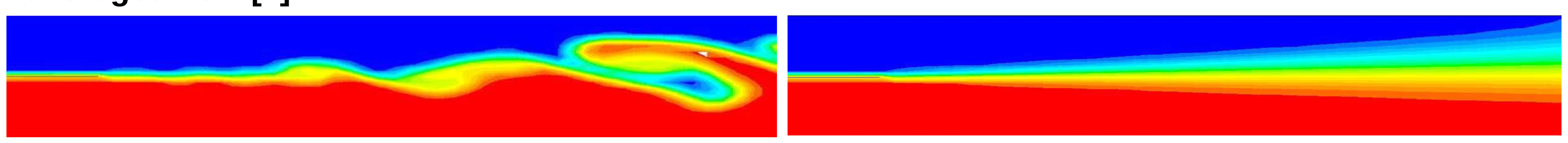
Introduction

- In recent years, there has been a growing interact in the wind power because of renewable energy and CO2 emission. The wind power is eco-friendly energy by zero emission.
- In this study, 2-D and 3-D CFD modeling on wake with turbulent models were conducted in 2MW rotor turbine using a Reynolds Averaged Navier-Stokes Simulation (RANS) model and a large eddy simulation (LES) model, respectively, In the RANS model, k-e model was applied to the CFD simulation as turbulent model.
- Characteristics on turbulent models of RANS and LES were presented in Fig. 1. The LES model solves a filtered Navier-Stokes equation and some turbulence is directly resolved, while RANS solves time-averaged Navier-Stokes equation and All turbulent motion is modeled with time-averaged flow [1].

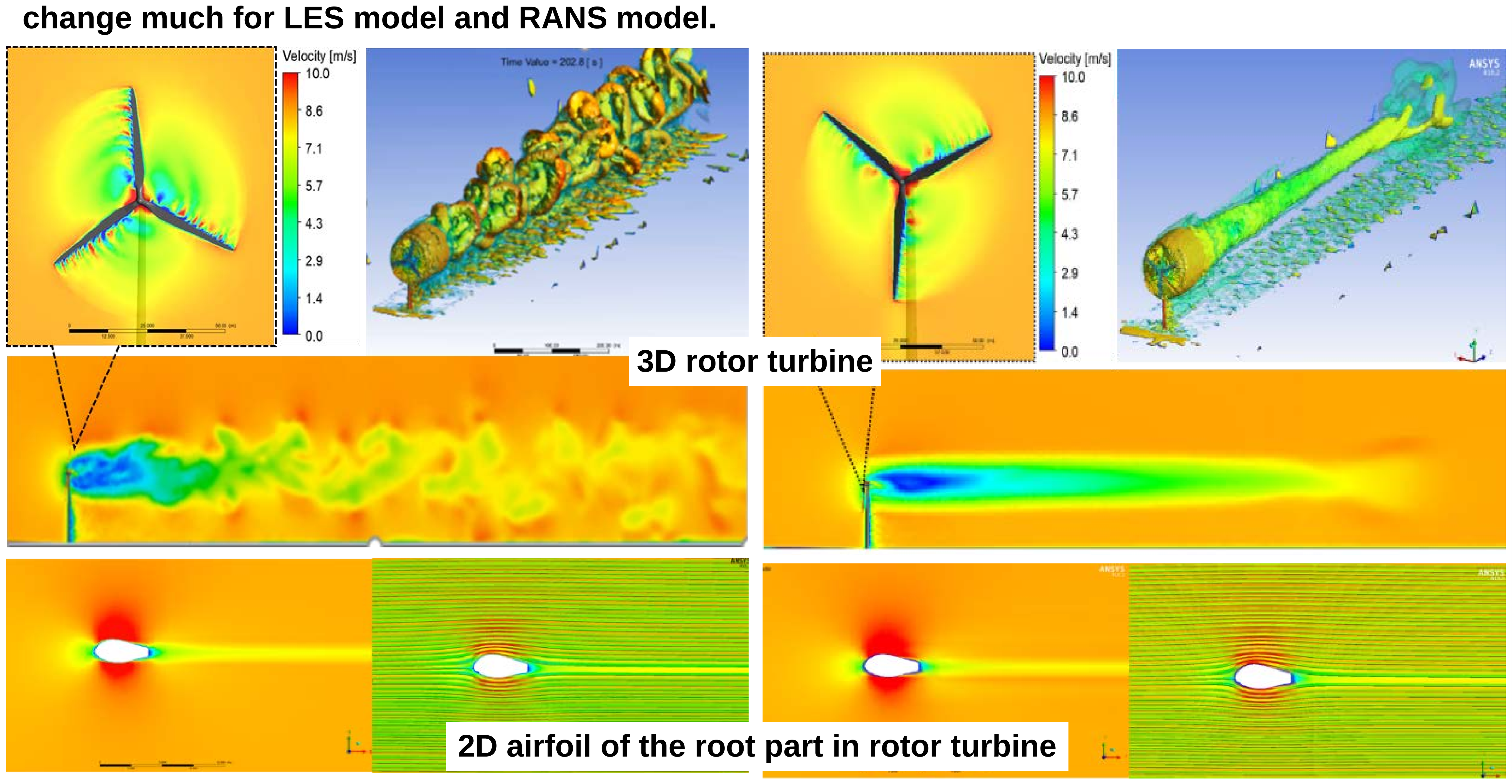


(a) LES model (b) RANS model

Fig. 1. Major turbulent models in CFD simulation (ANSYS Fluent).

Results & Discussions

- In this CFD analysis, the turbulence flows of wake for the 2D airfoil of the root part in rotor turbine and the 3D rotor turbine was solved via LES and RANS model.
- The results was shown in Fig. 3. In Fig. 3 (a) LES model, turbulence flow in wake was shaped as a similar real turbulence flow of wake, while in Fig. 3 (b) RANS model, the turbulence flow in wake was shaped as a simplified cylindrical surface.
- These results lead to differences of LES and RANS model. The LES model solves a filtered Navier-Stoks equation and some turbulence is directly resolved, while RANS solves time-averaged Navier-Stoks equation and All turbulent motion is modeled with time-averaged flow [1].
- In the case of 2D 2D airfoil of the root part in rotor turbine, the turbulence flows of wake did not change much for LES model and RANS model.

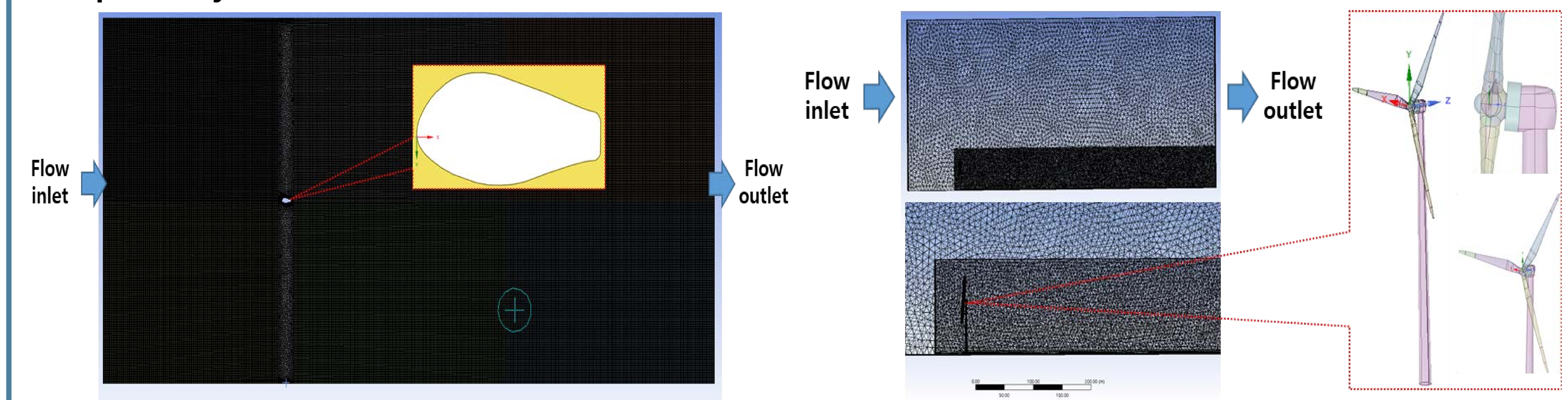


(a) LES model (b) RANS model

Fig. 3. CFD simulation results for LES model and RANS model.

Numerical Methods

- For CFD simulation, numerical schemes was shown in Fig. 2. 2D airfoil of a root part in rotor turbine was consisted as about 184,000 cell, while 3D rotor turbine was consisted as about 11,000,000 cell. In the case of 3D rotor turbine, diameters of rotor, hub, and tower are 70.46 m, 2.64m, and 81.4 m, respectively.



(a) 2-D airfoil model (b) 3-D rotor turbine model

Fig. 2. Numerical schemes of 2-D and 3-D models.

- Numerical models of turbulence were applied to LES and RANS simulation models, respectively. The wall-adapting local viscosity (WALE) model in the LES model and realized k-e model in the RANS were applied to capture the turbulence flow in wake. Inlet condition is 8.5 m/s for all geometry. In the RANS model, the realized k-e model can be described as follows [2]:

$$\frac{\partial}{\partial x_i}(\rho k u_i) = \frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right] + G_k + G_b - \rho\varepsilon - Y_M + S_k \quad \text{------ Equation 1}$$

$$\frac{\partial}{\partial x_i}(\rho\varepsilon u_i) = \frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_j}\right] + \rho C_1 S_\varepsilon - \rho C_2\frac{\varepsilon^2}{k+\sqrt{\nu\varepsilon}} + C_{1\varepsilon}\frac{\varepsilon}{k}C_{3\varepsilon}G_b + S_\varepsilon \quad \text{------ Equation 2}$$

- In these equations, G_k represents the generation of turbulence kinetic energy. G_b is the generation of turbulence kinetic energy. Y_M represents the contribution of the fluctuating dilatation in compressible turbulence. C_{1e}, C_{2e}, and C_{2e} are constants. s_k and s_e are the turbulent Prandtl numbers for k and e, respectively. S_k and S_e are user-defined source terms. The LES model can be expressed as [1]:

$$\overline{\emptyset(x,t)} = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\emptyset(r,\tau)G(x-r,t-\tau)d\tau dr \quad \text{------ Equation 3}$$

where, G is the filer convolution kernel. The filter kernel G has an associated cut-off length scale D and cut-off time scale t_c.

Conclusions

- This study disclosed turbulence flow of wake for the 2D airfoil of the root part in rotor turbine and the 3D rotor turbine using CFD simulations with LES model and RANS model.
- The LES model was in good agreement with actual turbulence flow in wind power plant.

Acknowledgement

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