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Time resolved particle image velocimetry experimental study of the near wake characteristics of a horizontal axis wind turbine

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Background and Research purposes

Background:
In recent years, large numbers of wind farms have been installed worldwide. Wind turbines are often placed close together in small clusters or in large wind farms, so wind turbine wakes have a great influence on the power output in the wind farm.

Research purposes:
To reveal the wind turbine near wake characteristics;

To build up a experimental benchmark for validation of relevant computational fluid dynamics (CFD) models.



Fig.1 Wind turbine wakes in the wind farms [1]

[1] Zuo-wu LI, De-xin HE, 2013. Review of fluid dynamics researches in wind energy engineering.

Experimental setup

Time resolved particle image velocimetry is applied to measure wind turbine flow properties at different tip speed ratios in present study, and the experimental setup and the size of wind tunnel are showed in the Fig.2 and Fig.3.

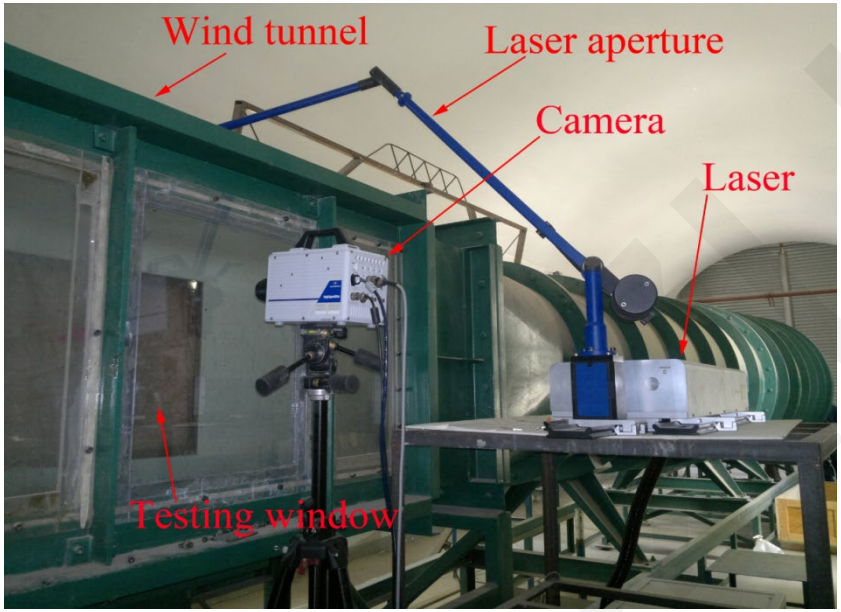


Fig.2 Experimental setup

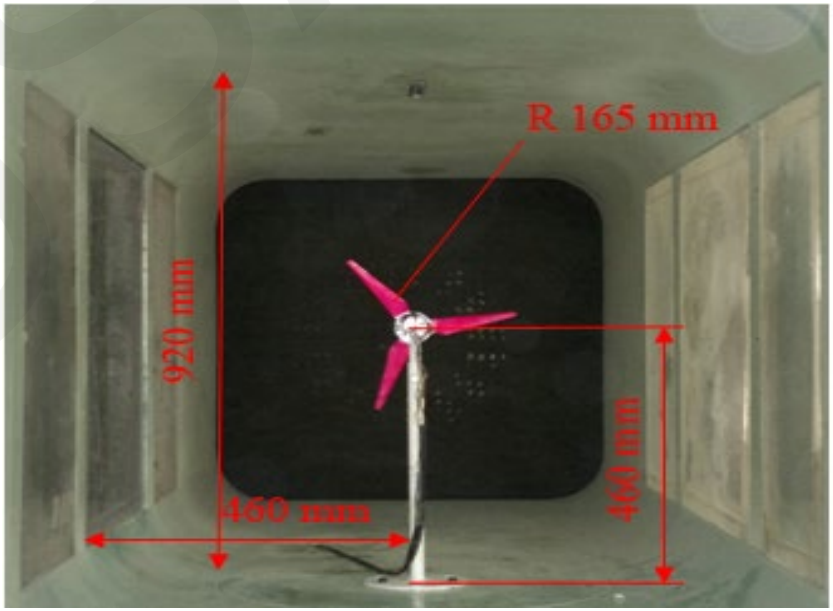


Fig.3 Diagram of the wind tunnel size

Qualitative flow characteristics

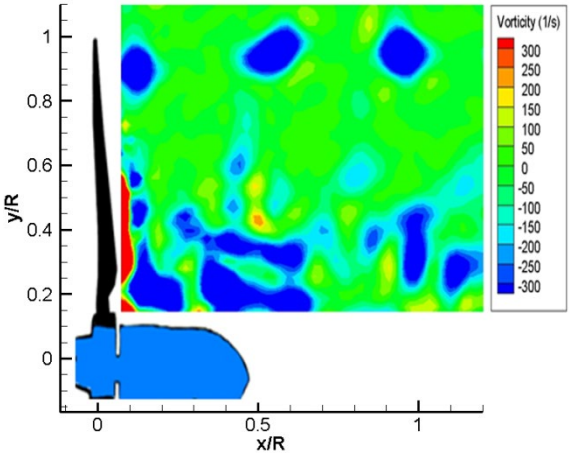


Fig.4 Instantaneous vortex structures

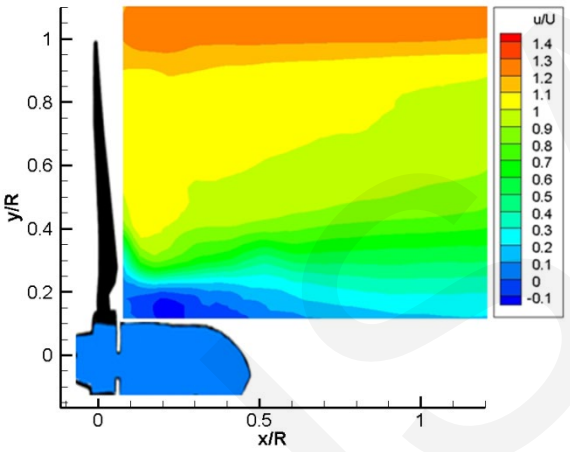


Fig.5 Axial average velocity

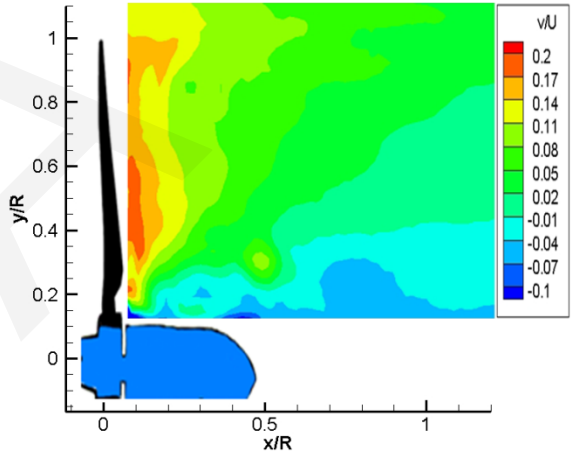


Fig.6 Radial average velocity

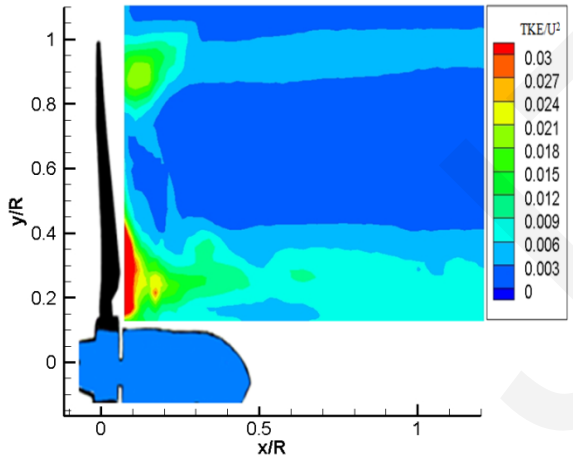


Fig.7 Turbulent kinetic energy

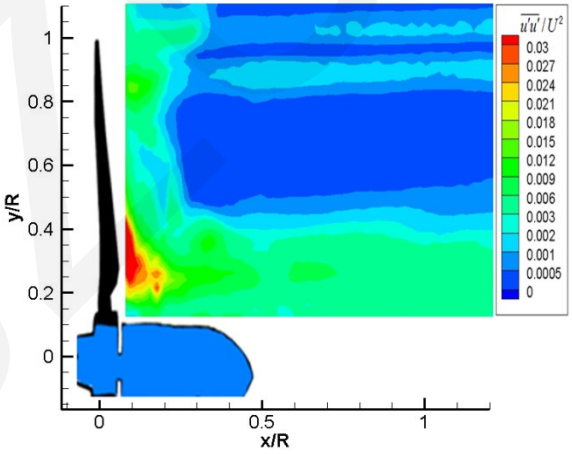
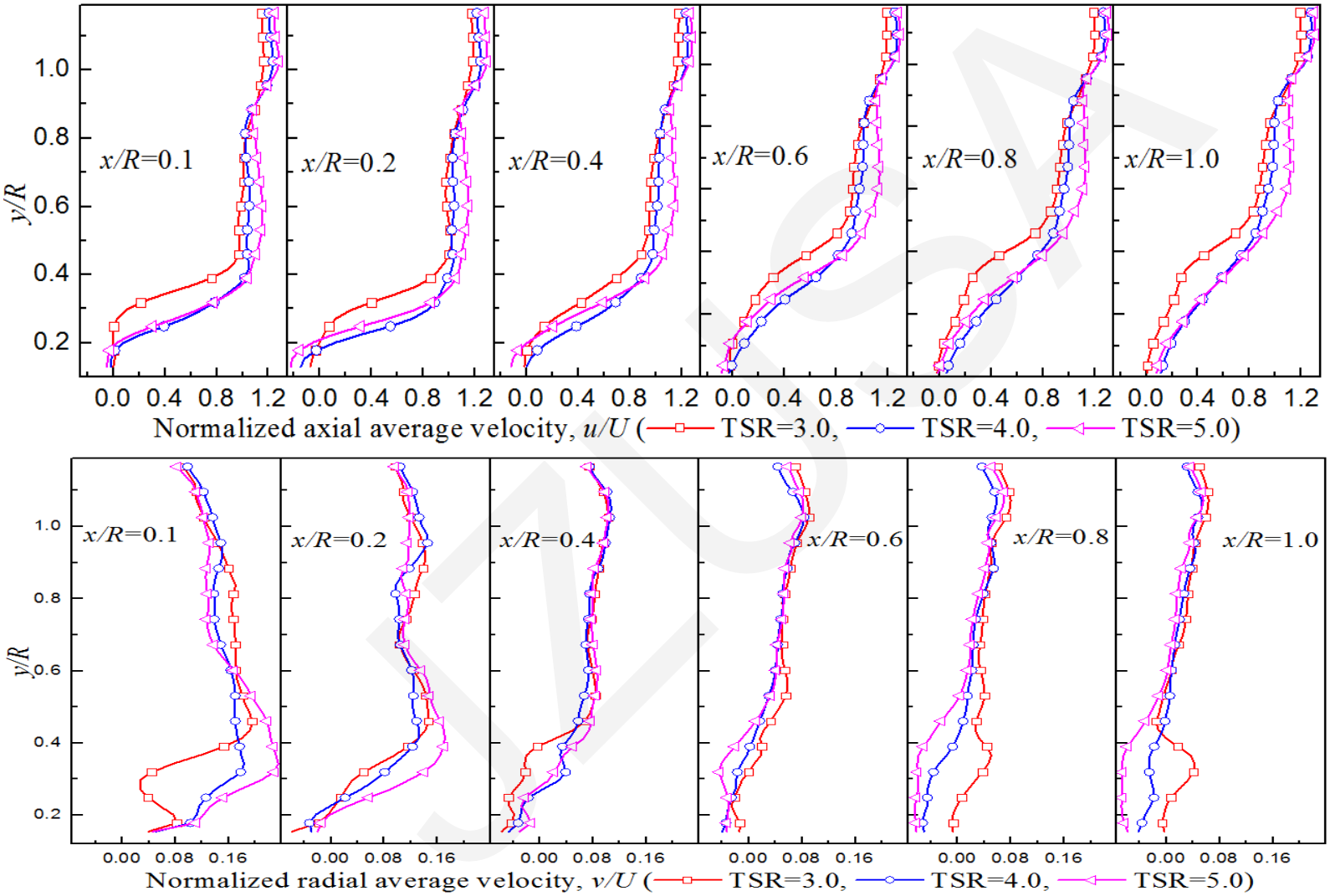
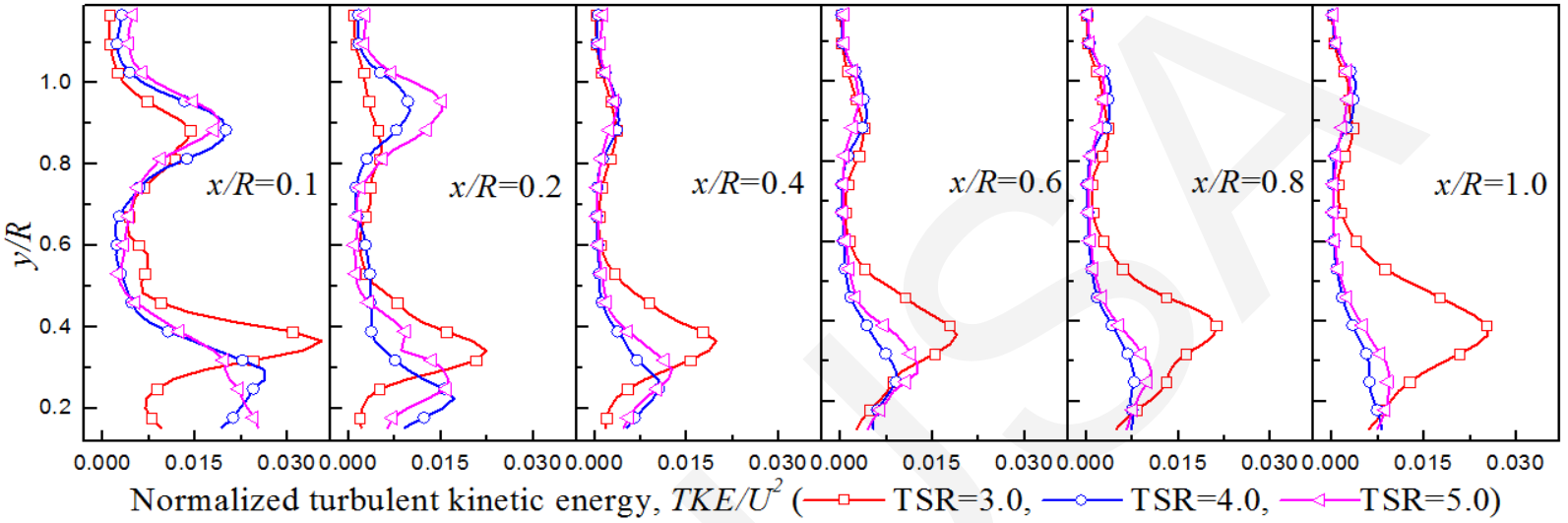


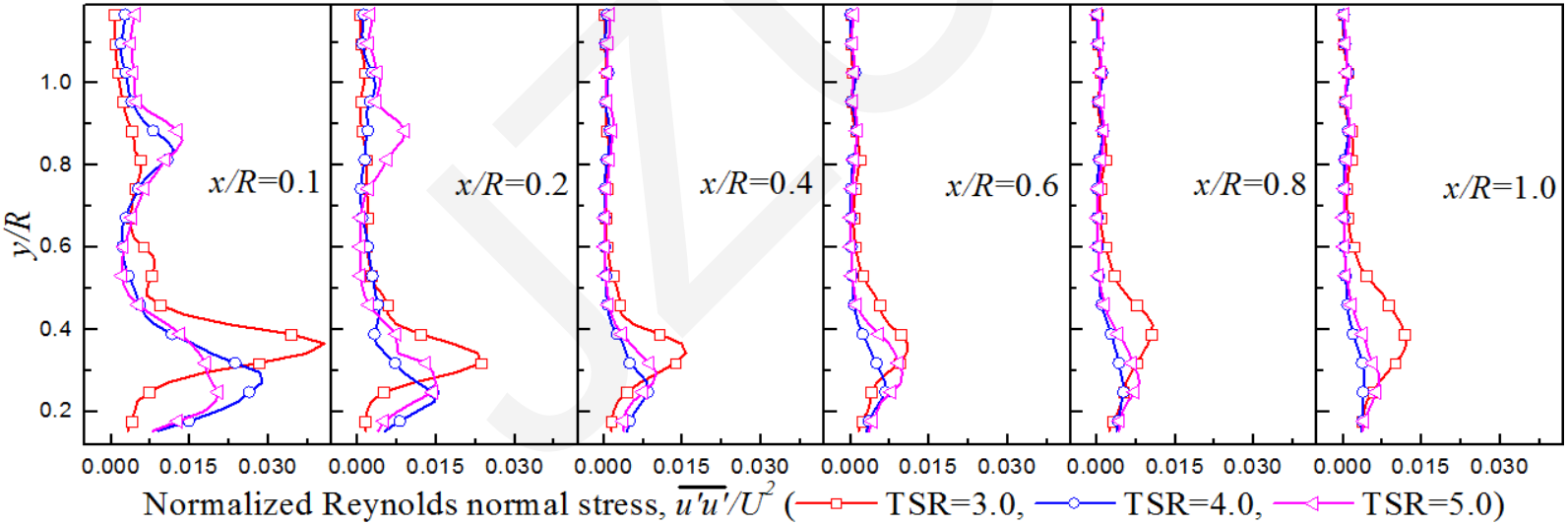
Fig.8 Reynolds stress

Quantitative flow characteristics

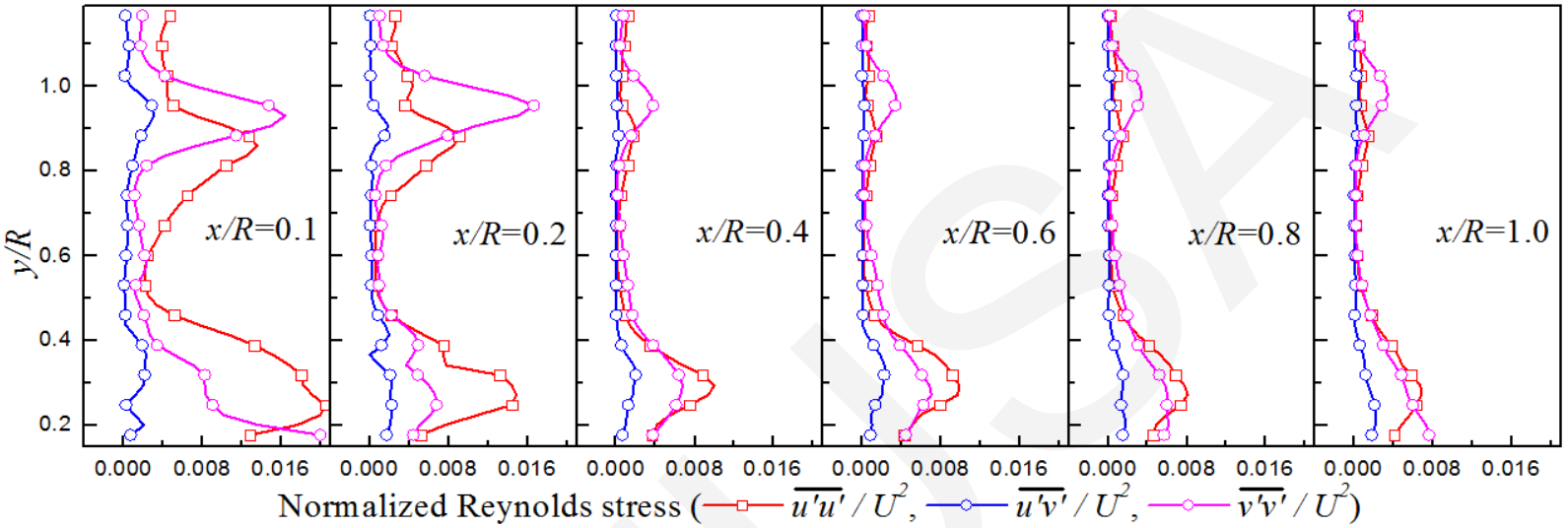


Quantitative flow characteristics





Quantitative flow characteristics



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Conclusions

1. the wind turbine near the wake flow field can be divided into three regions in the radial direction: velocity increased region, velocity remain unchanged region and velocity deficit region, and the axial average velocities at different TSRs in the wake reach the inflow velocity almost at the same radial location;

2. the radial average velocity has an increased tendency along the radial direction in the later half radial length wake region, while it decreases above the blade tip region;

3. the turbulent kinetic energy would appear to have two peaks at approximately the y/R=0.3 and y/R=0.9 regions, turbulence kinetic energy would meet its minimum value in the half blade radius height region along the radial direction;

4. Reynolds shear stress is lesser than the Reynolds normal stresses, axial Reynolds normal stress is larger than Reynolds shear stress and radial Reynolds normal stress in the blade root region, while radial Reynolds normal stress is larger than Reynolds shear stress and axial Reynolds normal stress in the blade tip region.