MULTIPLE ACTUATOR SQUARE MODEL FOR A VERTICAL AXIS WIND TURBINE

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SHORT TERM SCIENTIFIC MISSIONS REPORT

PURPOSE OF THE STSM

Nowadays the wind energy has experimented a significant progress in the energy production. This fact was made possible develop the wind engineering with emphasis in predictive methods. The predictive methods allow obtain approximate information without experimental results.

The conventional wind energy extractor are the horizontal axis wind turbines (HAWT) and throughout the years has developed important methods to predict the wake of the HAWT, one of them is the Actuator Disk model implemented by Svenning in open source. On the other hand, the prediction of wake of vertical axis wind turbines (VAWT) is most complicated by the interaction between wake's blades. Paraschivoiu developed a simple method to predict the coefficient power of a VAWT using the Actuator Disk (AD) model. This predictive method is based in to divide the VAWT in upwind and downwind and to apply a series of Actuator Disk in the path way of the blades. This method is called double multiple stream tube (DMST).

The main objective is to apply the DMST model at a VAWT and then to develop a new prediction model based in Actuator Disk model for VAWT in OpenFOAM, called Multiple Actuator Square model (MAS model).

DESCRIPTION OF THE WORK CARRIES OUT DURING THE STMS

The Center of Computational Engineering and Integrated Design (CEID) of Lappeenranta University of Technology is working with AD for horizontal axis wind turbines.

The first work was a bibliographic search about the application of AD in VAWT and studies the DMST model to predict the coefficient power of the vertical turbine easily. The second step was to modify the AD code provided by the CEID center to change the shape of AD and the forces applied. The shape changes from a disk shape to a rectangular shape like a blade. Finally, the new predicted method to VAWT was check it with an experimental and CFD results of a published paper.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

APPLICATION OF DMST

The results prediction of VAWT with complex solvers, such as, Ansys Fluent, entails high computational cost and long times. The simplified DMST model allows obtain the results immediately with good results, as it can be observed in Figure 1, because this model is applicable with a spreadsheet.

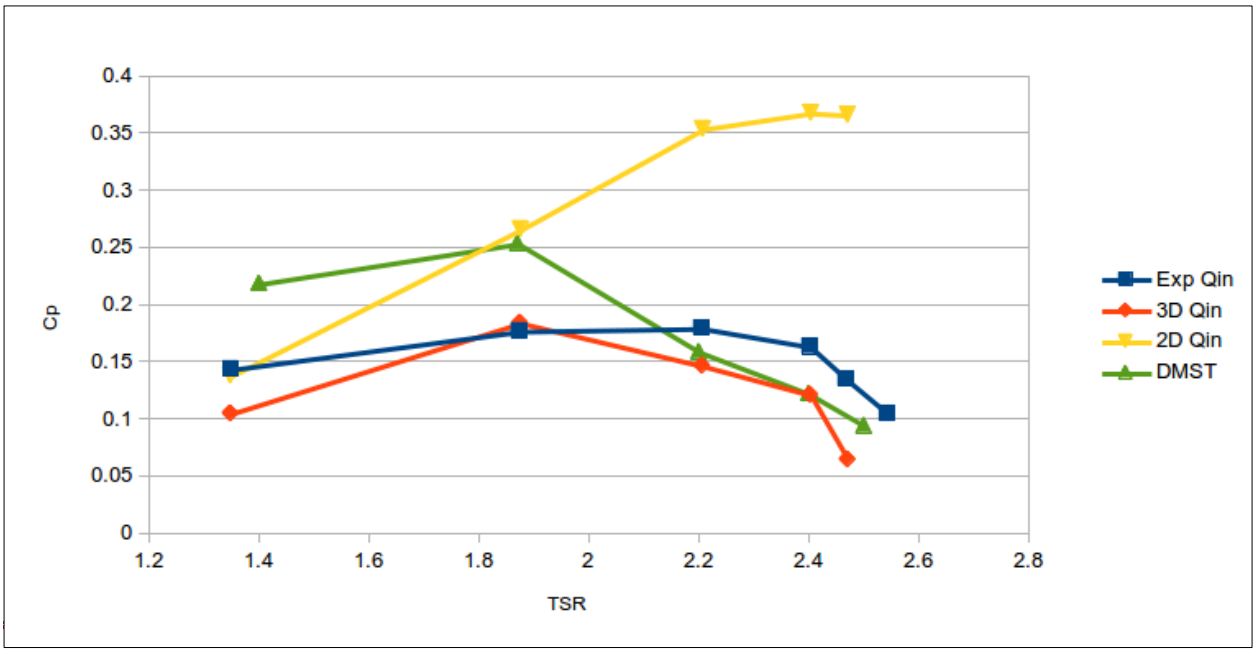
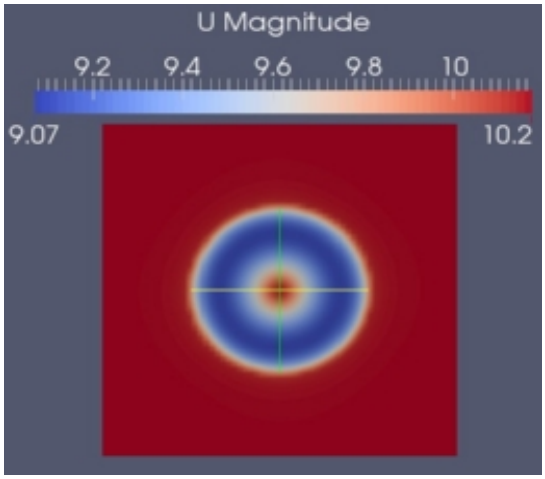


Figure 1. Power curve of VAWT

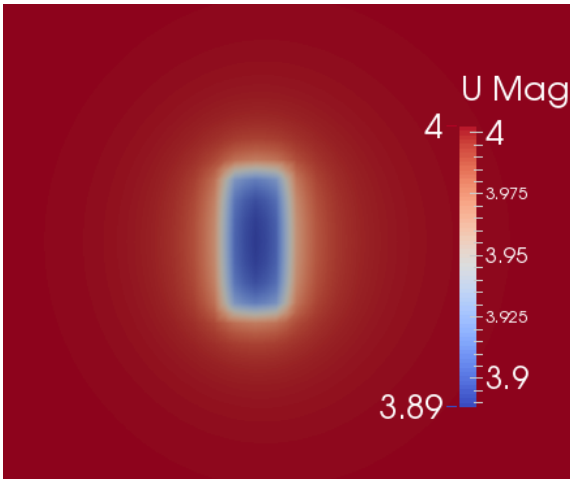
The Figure 1 shows the results obtained with the DMST model (green line) are similar that the 3D simulation of the R. Howell et al. (2010) paper (orange line) for TSR greater than 2.2, but for TSR lower than 2.2 the prediction of power coefficient is worst because of this model has problems with low Reynolds.

MULTIPLE ACTUATOR SQUARE

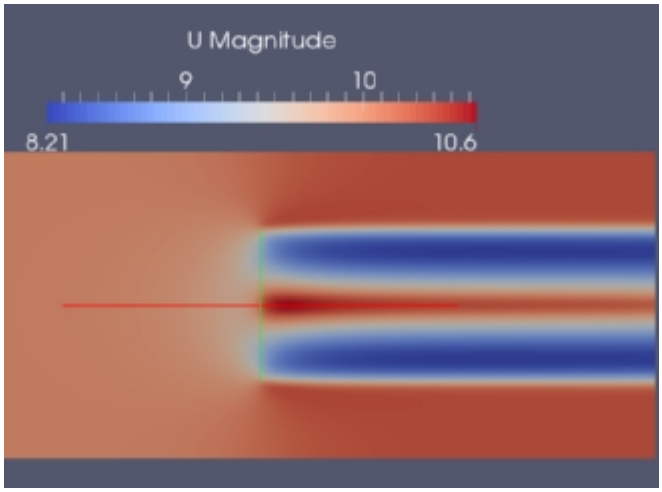
The modification of the OpenFOAM code of an Actuator Disk can be observed in the following figures, where it is compared with the Actuator Square developed in this job.



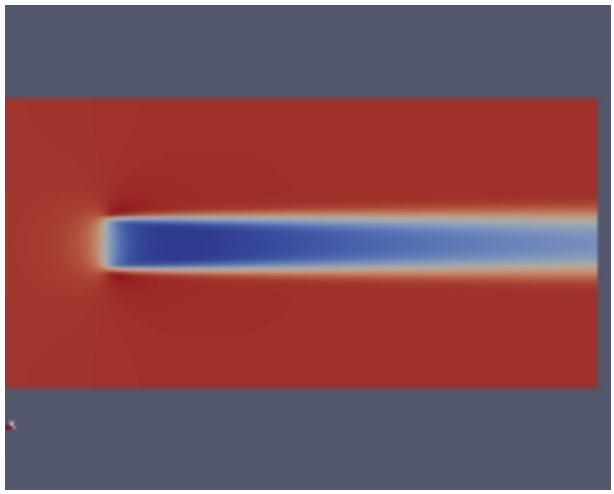
a) frontal view of Actuator disk.



b) frontal view of Actuator Square.



c) lateral view of Actuator disk.



d) lateral view of Actuator Square.

Figure 2. Analysis of velocity magnitude for a HAWT with AD model (left) and a single blade with AS model (right).

The original Actuator Disk, Figure 2a, represents a frontal view of a horizontal axis wind turbine and was modified to obtain the square shape of a single blade, as it can be seen in Figure 2b. The square shape allows study the high of the vertical axis wind turbine, see Figure 2d.

The results obtained with the DMST and the Actuator Square prediction model allows to use multiples Actuator Square, called MAS model, to predict the velocities in the wake of the VAWT with low computational times.

The difference of computational time to the same case between commercial solver, Ansys Fluent, and MAS model is around 5 weeks and around 21 hours respectively, with computers with 4 cores. An examples of velocity profiles are shown in Figure 3 and 4.

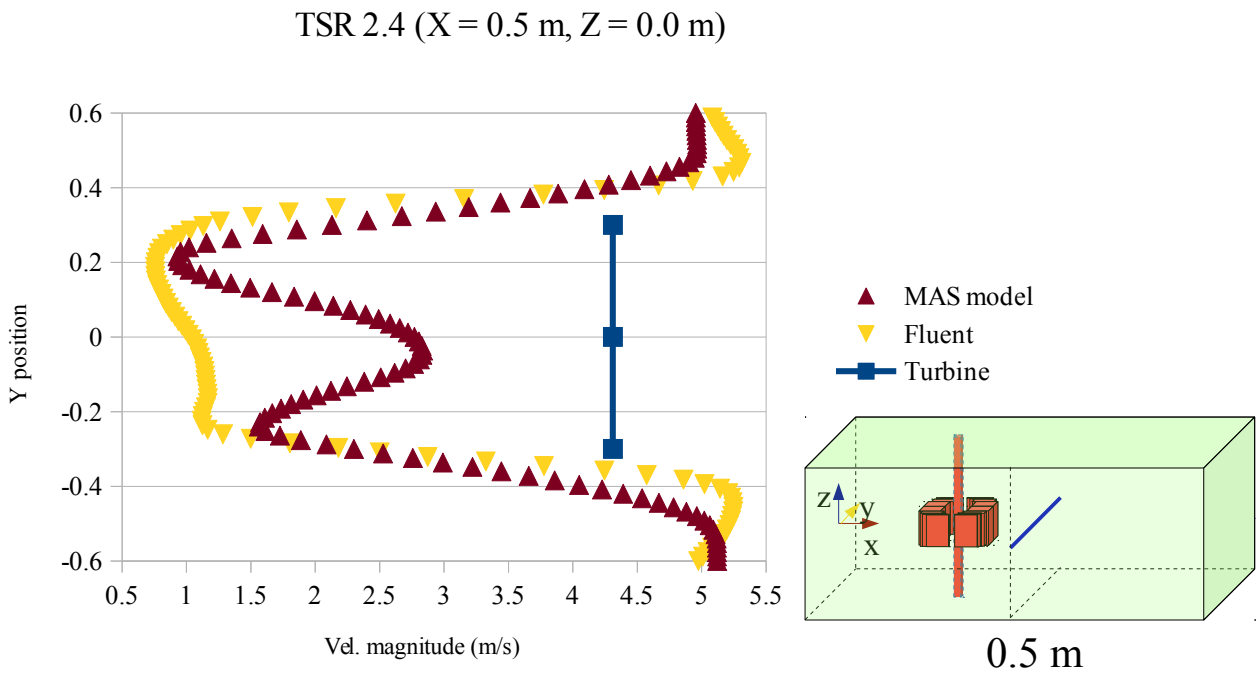


Figure 3. Velocity profile in Y direction at 0.5 m from the axis.

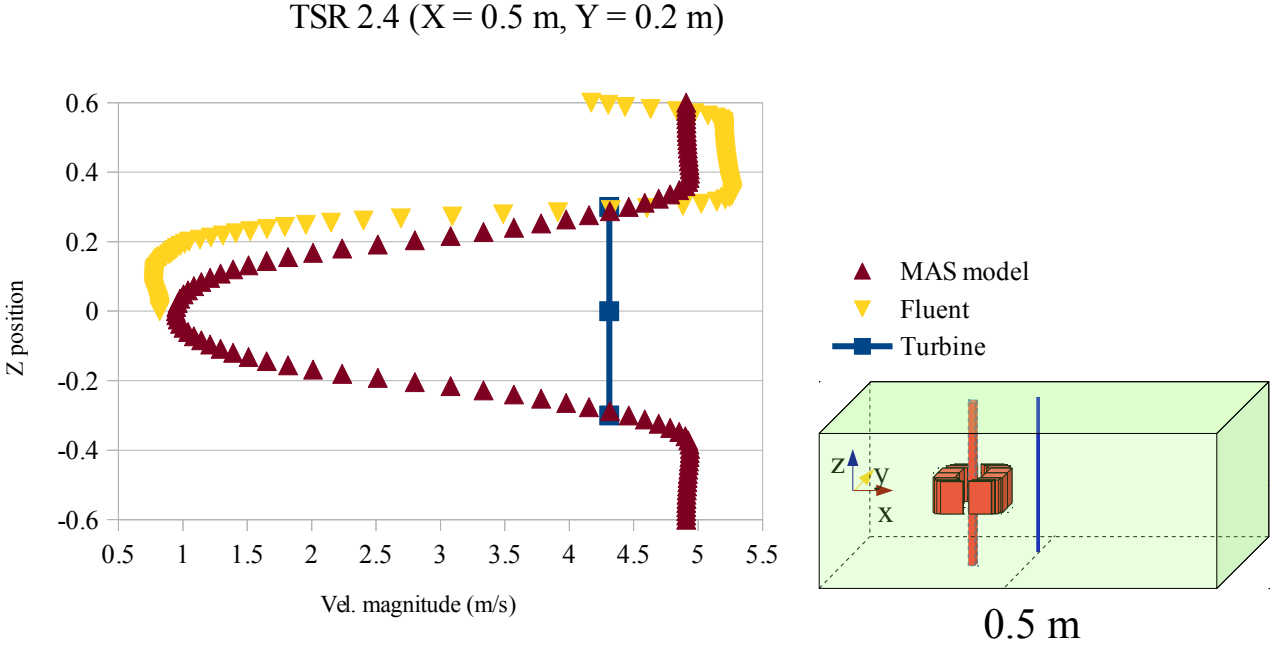


Figure 4. Velocity profile in Z direction at 0.5 m from the axis.

Figure 3 shows the velocity profile for Fluent and MAS model data in Y direction at a distance of 0.5m from the axis. It can be seen that the prediction of velocities in the wake with the simplified model are similar that the Fluent solver, except at centre of the turbine by the axis interaction. However in velocity profile in Z direction, Figure 4, the MAS model fit better with Fluent results.

It can be concluded that the MAS model is able to predict the wake of turbine with low computational times and with results relatively good results.

FORESEEN PUBLICATIONS RESULTING FROM THE STSM

The STSM will allow to do a paper thanks to the collaboration between both institutions, EcoMMFIT, Department of Mechanical Engineering, Rovira i Virgili University and CEID, Department of Mathematics and Physics, Lappeenranta University of Technology.

The future paper will be titled “Multiple actuator square for a vertical axis wind turbine” and the authors are Valentin Sanchez, Jordi Pallares, Anton Vernet and Jari Hämäläinen.

To whom it may concern

I certify that Valentin Sanchez Morales (Department of Mechanical Engineering, Universitat Rovira i Virgili, Tarragona, Spain) have executed successfully the short terms scientific missions (STSM) at Lappeenranta University of Technology (LUT) during 28 July - 27th October, 2014, and I have been his supervisor during his working in my research group on CFD for wind energy applications.

October 27, 2014 Lappeenranta, Finland.

With best regards,

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