CFD ANALYSIS OF TURBULENCE EFFECTS IN-BETWEEN THE DUAL ROTOR WIND TURBINE HUBS

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Abstract- *A wind turbine is a device that converts kinetic energy from the wind, also called wind energy, into mechanical energy in a process known as wind power. In the past two decades, research have been carried out on Counter Rotating Wind Turbine (CRWT) system and reported that the power extracted is relatively more for a given swept area than that of a SRWT. The counter-rotating wind turbines (CRWT) are a wind turbine model developed from a single rotating wind turbine (SRWT) model with a horizontal axis. CRWTs have two rotors rotating in opposite directions on the same axis. In CRWT the secondary rotor experience the turbulent effect from the front rotor. In such case, the secondary rotor undergoes poor rotation or fails to rotate sometimes. In order to make rotate the secondary rotor properly, it is necessary reduce the turbulence effect in between the dual rotor wind turbine hubs. This research paper investigates on the turbulence effect in between the dual rotor wind turbine. In this study the flow around CRWTs is simulated using computational fluid dynamic (CFD) with ANSYS Fluent.*

Key Words: *CRWT (Counter Rotating Wind Turbine), Turbulence effect, CFD.*

1. INTRODUCTION

Wind turbine (also called referred as wind energy converter) is a device that converts the wind's kinetic energy into electrical energy. When a system expels or accelerates mass in one direction, the accelerated mass causes a proportional but opposite force on that system. The spinning blade of a single rotor wind turbine causes a significant amount of rotational air flow. The energy of this rotational air flow is wasted in a single- rotor propeller design. To use this wasted air flow, the placement of a second rotor behind the first takes advantage of the disturbed airflow, and can gain more energy from a given swept area as compared with a single rotor.

1.1 COUNTER ROTATING WIND TURBINE

A Counter -rotating wind turbine (CRWT) can be described as a system consisting of two rotors separated by an appropriate distance. One of the rotors is rotating in counter-clockwise direction and the other in clockwise direction. The primary rotor is placed in upwind location, while the secondary rotor is placed in downwind location. The secondary rotor is advisable to rotate in the same direction as the wake in order to extract the available energy in the wake efficiently. CRWT accounts to less moment in the turbine towers due to torque equivalence of both rotors.

2. METHODS AND MODELLING

In this study wherein the two rotors are identical and the blades inclination angle are of opposite directions, as a result, the rotors will have the opposite motion to each other.

For an Ideal Wind Turbine Blade design

1. The blade diameter is determined.
2. Airfoil type is selected for the wind turbine blade.
3. The blade is divided into sections.
4. The chord length of each section is calculated.

2.1 BLADE DIAMETER

Assumed design power is 600 W.

$$P = \frac{1}{2} \times \rho \times A \times V^3 \times C_P \times \eta$$

$$600 = \frac{1}{2} \times 1.225 \times \pi \times R^2 \times 12^3 \times 0.54 \times 0.9$$

R^2 =0.6093 m

R = 0.61m = 610 mm.

D = 1220 mm.

Where P is the power, ρ is the air density, A is the swept area, V is the wind velocity, C_P is the coefficient of power and η is the turbine efficiency.

2.2 AIRFOIL TYPE

The airfoil type selected for the wind turbine is NACA 4412 and the maximum coefficient of lift obtained is 1.2973 at the angle of attack 8˚.

2.3 CHORD LENGTH

The blade radius 0.61 m is divided into 10 sections. The chord length of each section is calculated by using the formula

$$C = \frac{8\pi R}{BC_L}(1 - COS\emptyset)$$

Where C is the chord length, R is the radius, B is the number of blades, C_L is the coefficient of lift and Ø is the angle for the blade.

Table 1 – Chord length for each section.

S.NO	RADIUS in mm	CHORD LENGTH in mm
1	61	3.8336
2	122	7.6672
3	183	10.9825
4	244	15.3344
5	305	19.1680
6	366	23.0016
7	427	26.8352
8	488	30.6688
9	549	34.5024
10	610	38.3360

2.4 MODELLING

Using the coordinates of NACA 4412 airfoil the dual rotor wind turbine is modelled for the chord lengths using the CATIA software.

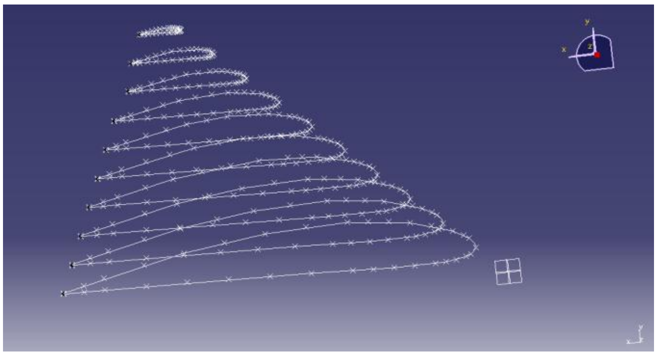

Fig -1: Aerofoil view

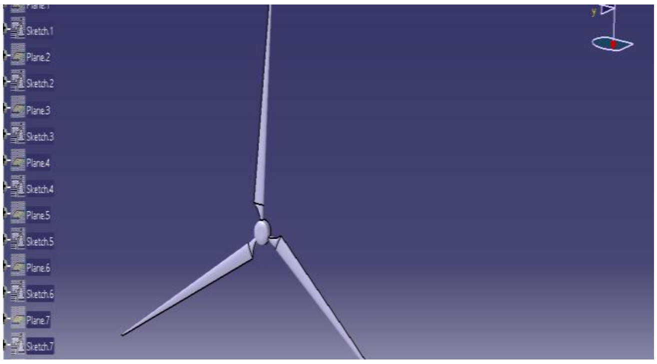

Fig -2: Single rotor design

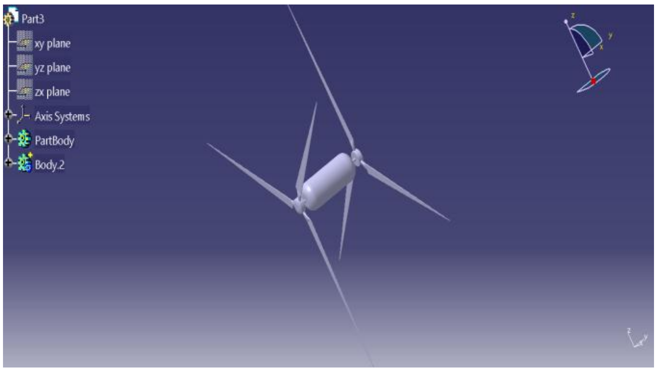

Fig -3: Dual rotor design

3. CFD ANALYSIS

Using the software ANSYS- Fluent the numerical simulation is carried out on the dual rotor wind turbine to analyse the aerodynamic performance. The turbulence model k-ω SST is used for the solver setting.

The numerical simulation is carried out with the initial wind speed of three different velocities 3 m/s, 5 m/s and 7 m/s.

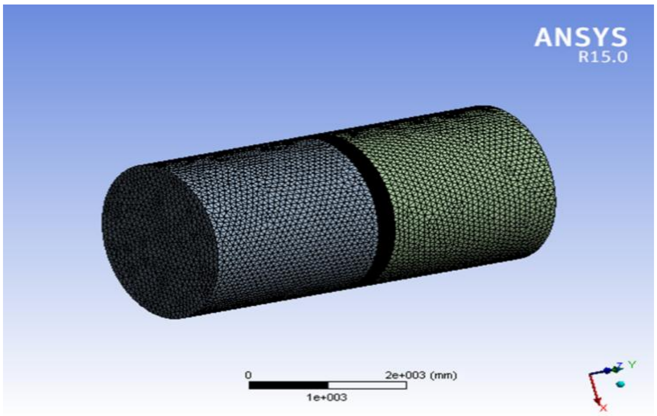

Fig -4: Mesh image of the domain

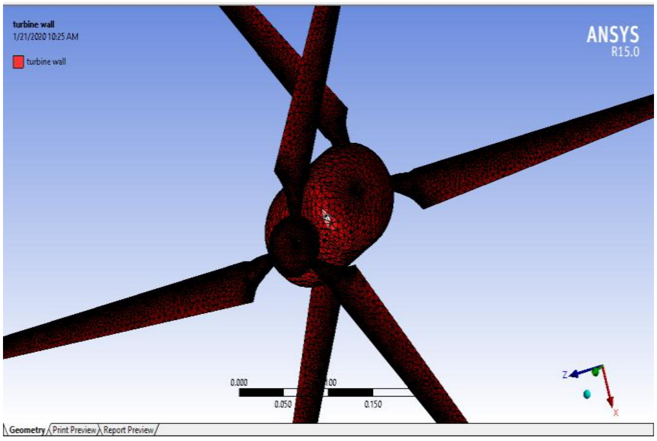

Fig -5: Mesh image of the dual rotor wind turbine

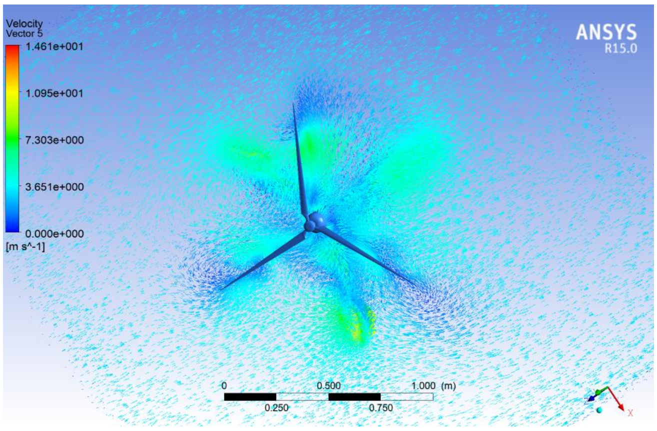

Fig -6: CFD result for 3 m/s wind speed

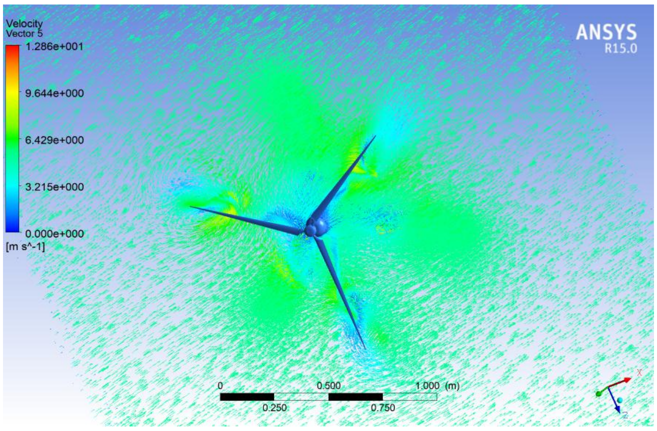

Fig -7: CFD result for 5 m/s wind speed

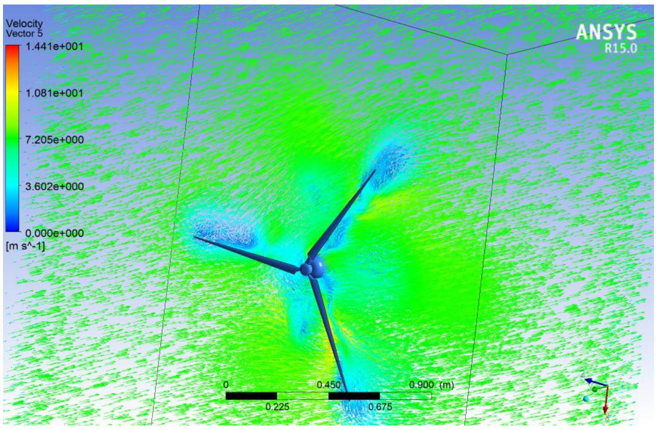

Fig -8: CFD result for 7 m/s wind speed

4. RESULT AND DISCUSSION

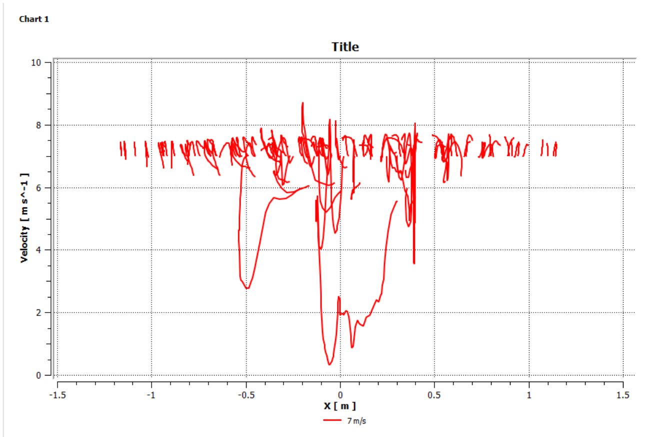

Chart -1: Velocity variation graph

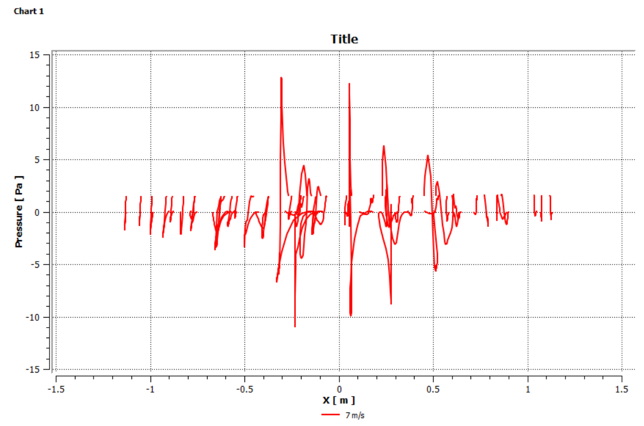

Chart -2: Pressure variation graph

Table 2- Wind speed analysis

Initial Velocity (Front Rotor)	Wind speed in-between the rotors	Final Velocity (Rear Rotor)
3 m/s	From the Fig 6 The Contour colour lies between 3.651 to 7.303	5.447 m/s
5 m/s	From the Fig 7 The Contour colour lies between 6.429 to 9.644	8.0365 m/s
7 m/s	From the Fig 8 The Contour colour lies between 7.205 to 10.61	8.9075 m/s

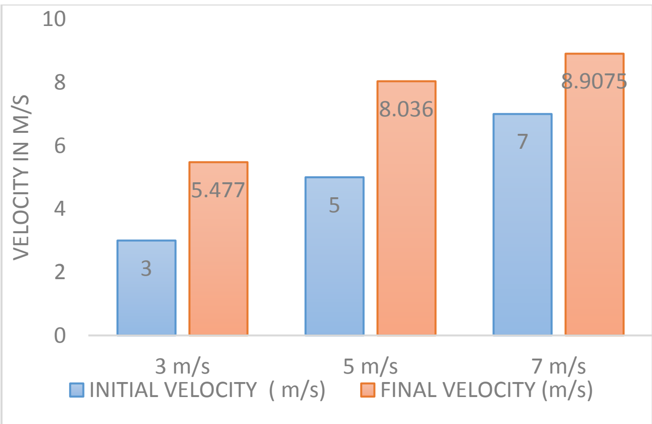

Chart 3: Velocity comparison graph

From the above CFD results and comparison charts it is clear that the velocity get varies from the initial velocity. The front rotor faces the wind speed with the initial velocities like 3 m/s, 5 m/s and 7 m/s. The spinning blade of a front rotor wind turbine causes a significant amount of rotational air flow. The combined rotational airflow from the front rotor and the actual wind speed gives the final wind speed 5.447 m/s, 8.036 and 8.9075 m/s behind the front rotor which helps to rotate the secondary rotor.

5. CONCLUSION

In this study the numerical simulation were carried out using the ANSYS- Fluent K-ω SST turbulence model for 3 m/s, 5 m/s and 7 m/s wind velocity on CRWT. The velocity get varies behind the front rotor and at the same time the front rotor causes the significant amount of rotational airflow. So the combined wind velocities behind the front rotor causes the rotation of the secondary rotor.

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