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# The Effectiveness of Mechanical Power on An Auxiliary Rotor in The Design of Counter Rotating Wind Turbine (CRWT)

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***Abstract*—The counter-rotating wind turbine (CRWT) represents a novel development in horizontal-axis wind turbine technology. This innovative design incorporates an additional rotor that rotates in unison with the main rotor along the same axis. Without the supplementary rotor, the turbine's configuration is analogous to that of a horizontal-axis wind turbine (HAWT) with the main rotor functioning independently. The primary objective of this study is to undertake a comparative analysis of the effectiveness of mechanical energy generation, as measured by torque, between the CRWT and HAWT designs. The configuration of the wind turbine is situated within a wind tunnel, characterized by a rectangular cross-section. The testing of wind turbines has been conducted at wind velocity of 2 m/s, 3 m/s, and 4.5 m/s. The total mechanical power measured was 0.14 W, 0.21 W, and 0.28 W at wind velocity of 2 m/s, 3 m/s, and 4.5 m/s, respectively. The final results of the study have analyzed the effectiveness of power enhancement through power coefficients.**

***Keywords—Wind turbine, horizontal axis, double rotor, counter rotation***

## I. INTRODUCTION

The potential for wind turbine energy generation is contingent on the prevailing wind conditions, with the atmospheric pressure at each geographic location influencing the turbine's performance. The variation in pressure between distinct locations can facilitate air movement, characterized by a specific displacement velocity, contingent on the disparity in atmospheric pressure. The mapping of wind energy potential becomes of particular importance between two atmospheric pressure points, especially in Indonesia. The variation in wind velocity is contingent upon the selected velocity scale. The scales in question are categorized as low, medium and high level respectively [1].

The distribution of wind velocity in Indonesia is very diverse. It is expected that under initiation conditions, wind energy with a specific wind velocity is capable of rotating a stationary wind turbine rotor. The movement of air particles in the surrounding environment results in the blade being subjected to forces of lift and drag. The movement of the rotor is initiated when the wind energy is equivalent to or exceeds the moment of inertia of the rotor material itself. This is accompanied by energy losses due to friction, both at the pedestal and the generator [2].

The intermittent fluctuations in velocity throughout the year have the potential to generate a variable source of mechanical energy. This is attributable to the utilization of the rotor moment of inertia rate, which is contingent on the diameter size and material strength. Consequently, it is anticipated that wind energy with a low wind velocity scale will be capable of converting and generating mechanical energy [3][4].

The objective of this study is to undertake a comparative analysis of the effectiveness of mechanical power that can be generated from wind energy sources by adding rotor to the SRWT model. With the additional rotor, the CRWT design is capable of flexibly adapting to highly unequal wind velocity fluctuation rates.

## II. METHODS

The experiment was conducted by designing a wind turbine to be incorporated into a rudimentary wind farm. The design of both rotors incorporates three blades. The dimensions of the main (rear) rotor are 400 mm, and the auxiliary rotor is 230 mm [5]. In the HAWT model, the rotor used is the rear rotor, measuring 400 mm. By way of contrast, the CRWT model employs the rear rotor, with the front rotor measuring 400 mm and 240 mm, respectively. The axial distance between the front and rear rotors is equivalent to 0.61 of the rear rotor diameters [6][7][8]. Both rotors implement the NACA 0012 profile, with balsa wood constituting the material of construction [9].

Table 1. Specifications of SRWT model and CRWT model

| Specification | Front rotor | Rear Rotor |
|---|---|---|
| **Blade number** | 3 | 3 |
| **Rotor diameter** | 230 mm | 400 mm |
| **Rotor position** | Upwind | Upwind |
| **Airfoil type** | NACA 0012 | NACA 0012 |
| **Blade material** | Balsa wood | Balsa wood |
| **Rotation** | Clockwise | Counter clockwise |

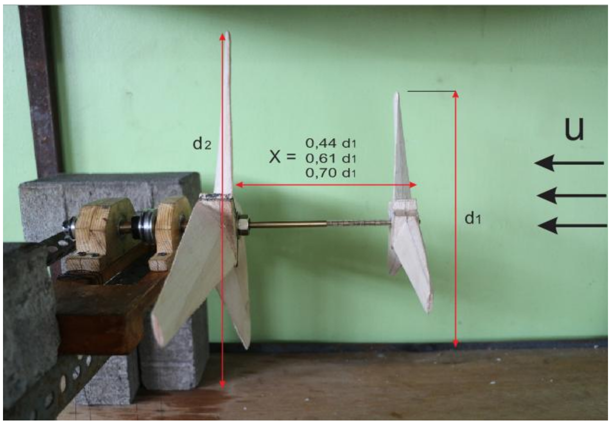


Fig. 1. Experimental scheme for the CRWT and HAWT



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The test was conducted with three replicates of data collection, thereby ensuring the measured shaft rotation was the mean torque of the entire dataset. In the process of data collection, certain pieces of equipment are required, including a digital anemometer, a digital tachometer, and load measuring scales. The anemometer serves as a tool for measuring wind velocity in the proximity of the rotor. The digital tachometer, on the other hand, is utilized to ascertain the rotational velocity of the pulley. Finally, a mass scale is employed to ascertain the dosage of a homogeneous mass load.

The equations employed for the analysis of wind turbines encompass the shaft mechanical power equation, wind energy potential, and wind turbine performance coefficient.

The total power of the CRWT model is the sum of the power of the main rotor (rear) and the auxiliary rotor (front). By contrast, the total power of the HAWT model is the power generated only by the main rotor (rear). The principle of power summation corresponds to the following equation.

$$P_{total} = P_{front} + P_{rear} \qquad (1)$$

The quantity of mechanical power transmitted through the shaft is contingent upon the rated torque and the angular velocity, which is measured in revolutions per minute. The following equation provides a quantitative representation of this relationship:

$$P_{shaft} = T\,\omega = T\,\frac{2\,\pi\,n}{60} \qquad (2)$$

Wind power can be defined as the potential kinetic energy carried by the wind velocity before it passes through the rotor surface area. The generation of wind power is contingent upon two principal factors: fluid density ($\rho$) and average wind velocity ( $v_o$ ).

$$W = \frac{1}{2}\,\rho\,A_t\,v_o^3 \qquad (3)$$

The power coefficient is defined as the ratio between the mechanical power generated and the wind power prior to the field area passing through the turbine. The equation is delineated in equation 4.

$$Cp = \frac{T\,\omega}{0{,}5\,\rho\,A_t v_o^3} \qquad (4)$$

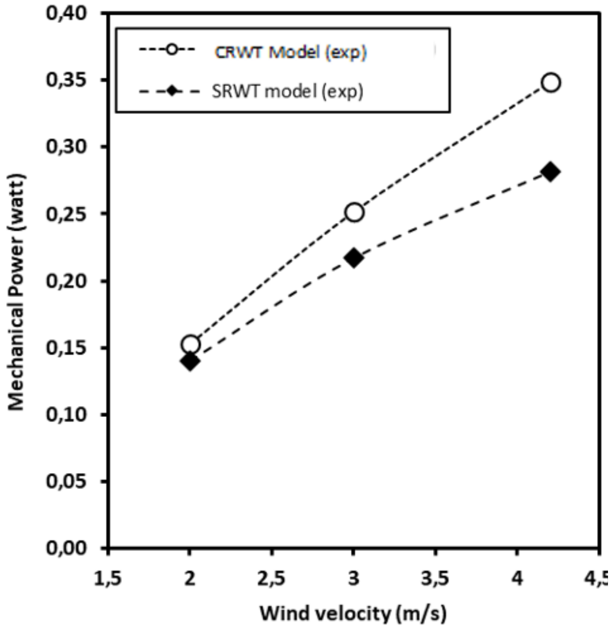


Fig. 2.The distribution of mechanical power in relation to variations in wind velocity

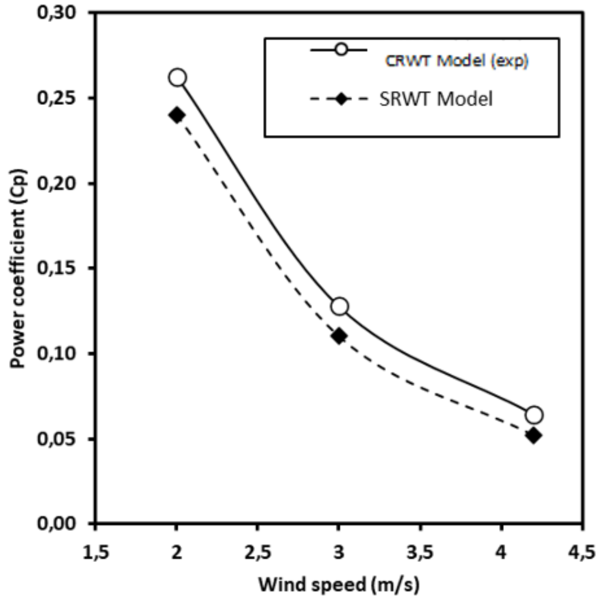


Fig 3. The distribution of power coefficient against variations in wind velocity

## III. Results and Discussion

The comparative study analysis of the SRWT and CRWT model wind turbines consists of total power and power coefficient analyses.

### *A. Total Power*

Total power is the sum of the power generated by the main rotor and the auxiliary rotor. The total power generated by the SRWT model is 0.140 watts, 0.217 watts and 0.281 watts for wind velocity of 2.0 m/s, 3.0 m/s and 4.5 m/s respectively, see Fig. 2. The potential wind energy that can be converted is not fully converted into mechanical power. The airflow in the SRWT and CRWT models is not the same. The airflow in the SRWT model passes through the main rotor with a more laminar flow tendency. In contrast, in the CRWT model the airflow tends to flow on the main rotor after passing through the auxiliary rotor. Therefore, the airflow of the CRWT model tends to be irregular [10][11]. The power generated by the CRWT model tends to be higher than that of the SRWT model. This is because the addition of a smaller rotor allows the auxiliary rotor to operate at a more optimal velocity in low wind conditions.

At low wind velocity, the auxiliary rotor, which has a smaller diameter than the main rotor, can rotate with the rotor's moment of inertia. The moment of inertia is strongly influenced by the density of the homogeneous blade material and the shape factor of the rotor cross-section. At the start, wind energy has to fight against energy resistance in the form



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of moment of inertia, bearing friction and pulley (Prony brake). If the required wind energy is equal to or greater than the sum of all energy losses [12][13]. Then the rotor is easier to operate. By providing an additional rotor with a smaller diameter, the moment of inertia and energy losses due to friction are minimized [14].

### B. Power Coefficient

The power coefficient is defined as the ratio of the power generated by the wind turbine to the power of the wind energy source. For the CRWT model, the power coefficient is 0.26, 0.13 and 0.17 at wind velocity of 2 m/s, 3 m/s and 4.5 m/s, respectively. For the SRWT model, the power coefficient is 0.22, 0.10 and 0.05 at wind velocity of 2 m/s, 3 m/s and 4.5 m/s, respectively. The theoretical maximum of wind energy that can be converted is not possible to be fully converted into mechanical power. The coefficient power value has been observed to be substantial at low wind velocity. Conversely, the power coefficient curve tends to decrease in size at high wind velocity. This finding suggests that the wind energy converted into lift force and drag force on the blade surface is more optimal [15][16]. It has been established that the forces of lift and drag tend to reach a maximum and do not increase in proportional to wind velocity optimum.

## IV. Conclusion

Based on the analysis of the power generated between the SRWT and CRWT wind turbine models, it can be concluded that the CRWT model turbine is capable of generating greater mechanical power than the SRWT model wind turbine. This is supported by the presence of an additional rotor that can provide additional power that is more optimal for the CRWT model. The addition of rotors to the CRWT model allows the CRWT design to be more adaptable to highly variable velocity changes.

In particular, the power coefficient is greater at low wind velocity. This means that the wind potential successfully converted into mechanical power is greater at low wind velocity. The power coefficient decreases as the wind velocity increases. This indicates that the converted wind mechanical energy potential is only a fraction of the maximum wind mechanical energy potential. As the rotor dimensions increase, the potential lift and drag forces along the blade cross-section increase. Therefore, the addition of a smaller diameter rotor is more effective in generating power at low wind velocity. Conversely, rotors with larger diameter dimensions can generate more optimal power at higher wind velocities.

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