# ABSTRAK

Studi tentang turbin angin *counter-rotating* sumbu horisontal tipe propeler tiga *blade* atau lebih dikenal dengan nama *counter-rotating wind turbine* (CRWT) telah menunjukkan suatu perkembangan yang baik. Fenomena aliran di sekitar rotor yang sangat kompleks akibat rotor belakang yang berada pada daerah gelombang aliran (*wake)* dari rotor depan dengan konfigurasi rotor yang berbeda semakin sulit untuk dapat diprediksi dengan tepat performa aerodinamikanya. Tujuan penelitian adalah untuk melakukan kajian aerodinamika terhadap performa dan fenomena aliran pada rotor turbin angin *counter-rotating* melalui variasi parameter rasio diameter, rasio jarak, dan *tip speed ratio.* Kajian aerodinamika rotor turbin angin ini meliputi performa rotor (koefisien daya) terhadap *tip speed ratio* dan fenomena stall, pertumbuhan vorteks serta interferensi aliran di sekitar rotor (*near wake*) baik rotor depan maupun rotor belakang CRWT. Untuk mengetahui pengaruh modifikasi *blade* standar turbin angin *counter-rotating*, yakni dengan penambahan *winglet* pada tip dan *vortex generator* terhadap performa rotor turbin dan karakteristik aliran di sekitar CRWT dengan konfigurasi rotor yang ada. Metode penelitian yang digunakan adalah metode numerik dan metode eksperimen. Metode numerik dengan simulasi CFD (*computational fluid dynamics)* aliran 3-D (tiga dimensi) menggunakan model turbulen *k–e* melalui program Fluent. Pembuatan geometri *blade* dan *meshing* untuk domain komputasi digunakan *software* Gambit. Parameter penelitian, yakni karakteristik aerodinamika rotor turbin akan dikaji secara komprehensif melalui variasi rasio diameter, rasio jarak rotor, dan tip speed ratio, sehingga dapat menampilkan karakteristik turbin yang lebih representatif.

Hasil simulasi CFD tentang performa turbin angin counter-rotating (CRWT) melalui variasi rasio diameter rotor secara keseluruhan lebih baik dari rotor tunggal (SRWT). Performa rotor depan (*front rotor)* turbin CRWT mengalami peningkatan jika rasio diameter rotor dinaikkan, tapi sebaliknya performa rotor belakang (*rear rotor)* menurun dengan dinaikkannya rasio diameter rotor. Performa maksimum (*peak performance*), CRWT dengan rasio diameter, $D_1/D_2$=0,5 diperoleh nilai koefisien daya maksimum tertinggi sebesar 1,193 lebih baik dari pada SRWT pada TSR=5. Performa turbin angin *counter-rotating* berdasarkan variasi rasio jarak aksial rotor pada rasio diameter, yaitu $D_1/D_2$=0,5 menunjukkan peningkatan tertinggi koefisien daya total 2,196 dan koefisien daya maksimum 1,47 terhadap SRWT pada rasio jarak $L/D_1$=0,5. Pertumbuhan vorteks akibat interaksi rotor depan dan rotor belakang pada CRWT dengan rasio diameter rotor $D_1/D_2 < 1,0$ yang menguat ke arah tip rotor belakang. Hal ini mempercepat pemulihan kecepatan yang cenderung menurunkan performa rotor belakangnya. Sedangkan untuk rasio diameter $D_1/D_2 \geq 1,0$ terjadi pertumbuhan vorteks yang cenderung menguat ke arah tip *blade* dengan separasi yang meningkat di *suction surface* yang dimulai dari daerah hub *blade* rotor belakang.

Kata kunci: Turbin angin, Rotor ganda, *Counter-rotating,* Aerodinamika*, Blade*

# *ABSTRACT*

*The study of counter-rotating three-blade type propeller horizontal axis wind turbine or better known as the counter-rotating wind turbine (CRWT) has shown a good development. The flow phenomenon around a very complex rotor due to the rear rotor located in the wake region of the front rotor with different rotor configurations is increasingly difficult to be predicted with precise aerodynamic performance. The aim of the study was to conduct aerodynamic studies of the performance and flow phenomena of the counter-rotating wind turbine rotors with various rotor configurations through various parameters of the diameter ratio, distance ratio, and tip speed ratio. The study of the aerodynamics of wind turbine rotors includes the performance of the rotor (power coefficient) on tip speed ratio and stall phenomenon, vortex growth, and flow interference around the rotor (near wake) in both the front rotor and rear rotor, so it can display the flow phenomenon around CRWT. In order to determine the effect of standard counter-rotating wind turbine blade modification, an addition of winglets on the tip and vortex generator was conducted to the performance of the turbine rotor and flow characteristics around the CRWT. The research method used was a numerical method and experimental method. Numerical method with 3-D (three-dimensional) CFD (computational fluid dynamics) simulation used the k-e turbulent model through the Fluent Program. Making blade geometry and meshing for the computational domain was conducted by using Gambit software. The research parameters, namely the aerodynamic characteristics of the turbine rotors was reviewed comprehensively through the variations of the diameter ratio, rotor distance ratio, and tip speed ratio, so as to display more representative turbine characteristics.*

*The CFD simulation results on the performance of counter-rotating wind turbines (CRWT) through variations in the ratio of the overall rotor diameter are better than the single rotor (SRWT). The front rotor performance of the CRWT turbine increases when the ratio of the rotor diameter is increased. On the contrary, the rear rotor performance decreases along with the increase in the rotor diameter ratio. Maximum performance (peak performance), CRWT with diameter ratio, $D_1/D_2=0.5$ obtained the highest maximum power coefficient value of 1.193 which is better than SRWT at TSR=5. Counter-rotating wind turbine performance based on variations in the ratio of axial rotor distance at diameter ratio, namely $D_1/D_2=0.5$ indicates the highest increase in total power coefficient of 2.196 and maximum power coefficient of 1.47 for SRWT at the distance ratio $L/D_1=0.5$. Vortex growth due to interaction of the front rotor and rear rotor in the CRWT with a ratio of rotor diameter $D_1/D_2 < 1.0$ which was reinforced towards the rear rotor tip. This speeds up the speed recovery which tends to reduce the rear rotor performance. Meanwhile, for $D_1/D_2 \geq 1.0$ diameter ratio vortex growth tends to strengthen towards the blade tip with increased separation in the suction surface starting from the rear rotor blade hub area.*

*Keywords: Wind Turbine, Double Rotor, Counter-rotating, Aerodynamics, Blade*