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CFD Simulation on Wind Turbine Blades with Leading Edge Erosion

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Deep understanding on the impacts of leading edge erosion on the performance and flow characteristics of wind turbines is significant for blade design and wind farms management. Pitting erosion and three levels of delamination are considered in present study. Results showed that the degrees of leading edge erosion have great influence on the flow separation, tangential force coefficient, normal force coefficient as well as the power output of wind turbine. Leading edge erosion has the greatest impact on the aerodynamics of wind turbine at 15 m/s, where the maximum loss in power output can reach up to 73.26%.

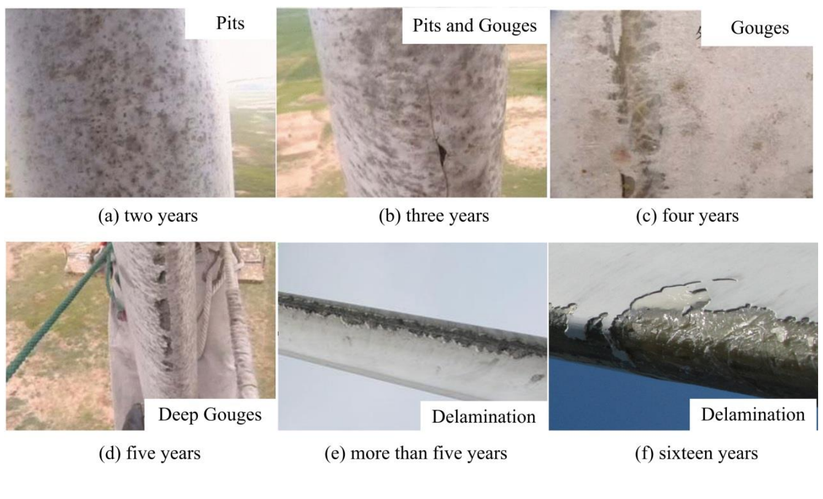

Figure 1 Photographs of the eroded wind turbine blade

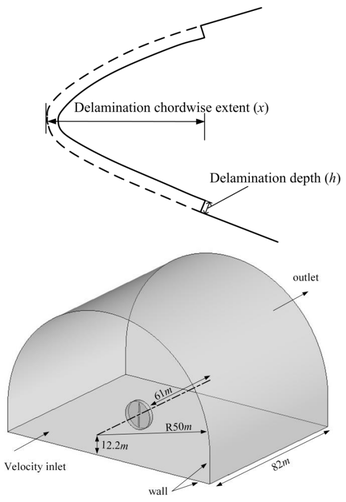

Figure 2 Geometrical model and computational field

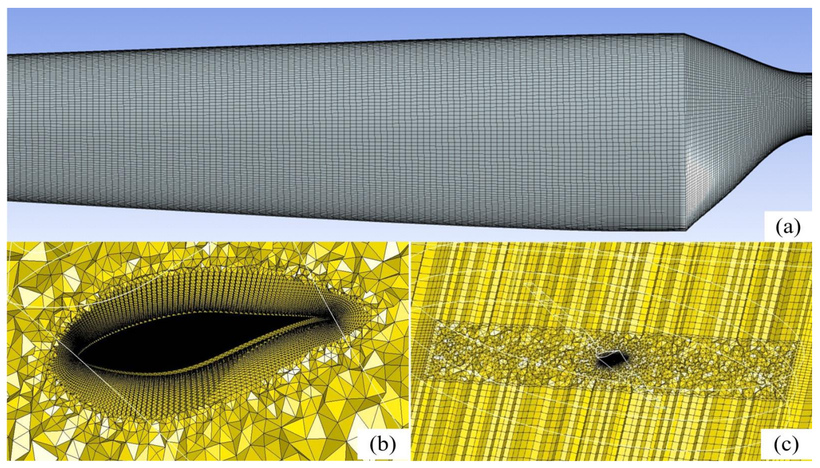

Figure 4 Local grids near the blade, in the boundary layer and rotating domain.

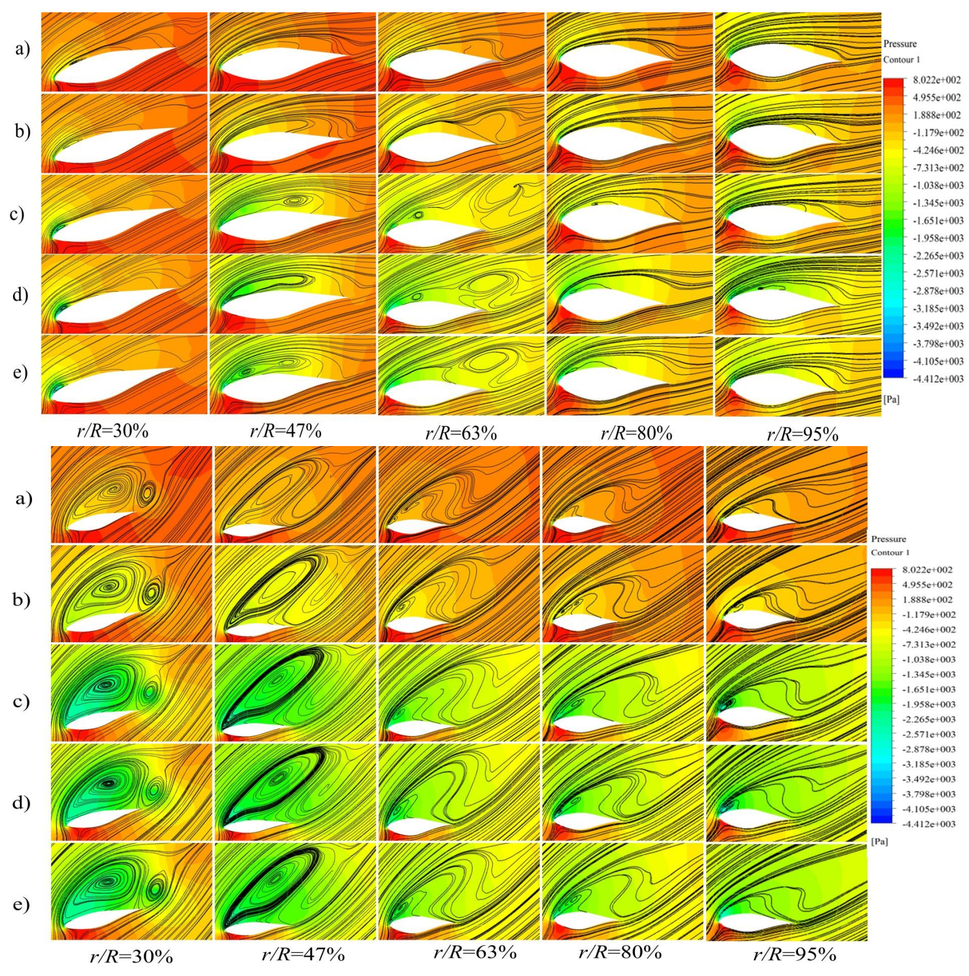

Figure 5 Flow structures around the blade section at the wind speed of 10m/s and 20m/s.

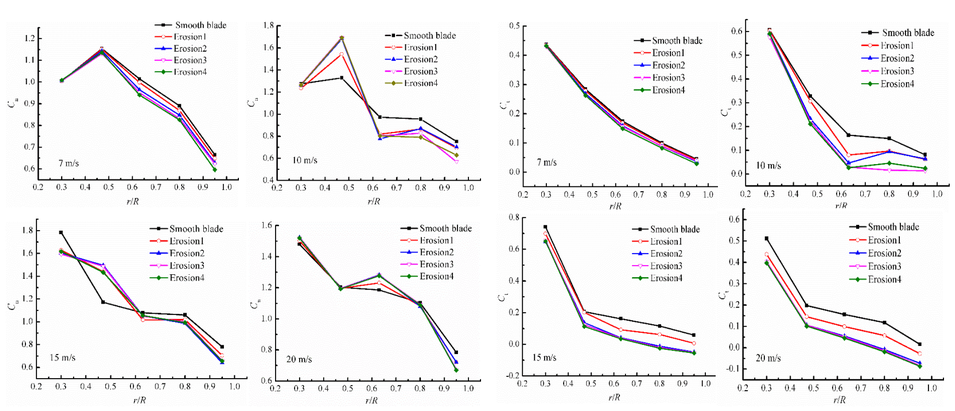

Figure 6 The C_t and C_n along the blade under various wind speed.

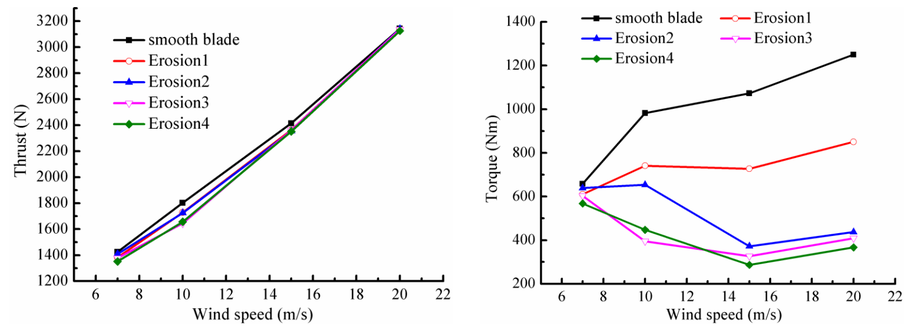

Figure 7 Thrust and torque vary with wind speeds for various eroded Phase VI rotors.

- Leading edge erosion has significant impact on surface streamlines and flow structures around the blade. As the degree of erosion increases, the flow separation becomes more obvious, and the separation region is larger with the separation point being closer to the leading edge. In addition, erosion also induces the generation of leading edge separation bubble on the upper surface of the inside of the blade, and the size of which increases with the degree of erosion.

- Leading edge erosions reduce of the normal force coefficient in the whole blade at low wind speeds when compared with smooth blade. The tangential force coefficient of the blade decrease with the aggravation of leading edge erosion. Meanwhile, the impacts of leading edge erosion especially delamination on the tangential force coefficient of the blade section gradually reduces with the increase in wind velocity.

- The torque and thrust of wind turbine decrease with the aggravation of leading edge erosion. At a fixed erosion depth, there exists a peak wind speed for the erosion effects on thrust and torque of wind turbine. That is, the reduction ratios of the wind turbine torque and thrust increase first and then decrease with the increase of wind speed. At 15m/s, the impact of leading edge erosion on power is the most significant, with the maximum and minimum wind turbine power loss being 73.26% and 32.21%, respectively. Furthermore, the differences among the three levels of leading edge delamination on the power loss of wind turbine decrease with the increase of wind speed.