Research on the Shape of Biomimetic Airfoil Leading Edge Protuberance

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Abstract: Wind turbines, and other fluid machinery can experience stall during operation, leading to highly transient and heavy load fluctuations that jeopardize the structural integrity of the turbines and result in fatigue failure, significantly reducing performance. Inspired by the protuberance on the leading edge of a humpback whale's pectoral fin, 8 different configurations of protuberances were added to the leading edge of a NACA 0021 airfoil segment with a span of 0.24m as a passive control method to investigate their inhibitory effect on flow separation. The protuberance structures altered the pressure distribution on the airfoil's leading edge, particularly reducing the pressure at the trough after stall, allowing the fluid to reattach to the airfoil surface and delaying the onset of dynamic stall. The most significant improvement in alleviating airfoil stall was observed with the protuberance structure composed of a quarter-circle with a radius of 0.02m and a quarter-circle with a radius of 0.01m. At an angle of attack of 22° after the original airfoil stall, the lift coefficient increased by 6.7.7%. At the initial angle of attack of 4°, the lift coefficient increased by 60.4%, and then maintained a stable linear growth at various angles, with no stall occurring at 24° angle of attack. This study provides inspiration for the design of bionic airfoil protuberance on structures and has guiding value for practical applications.

Keywords: Leading-edge protuberance; Flow control; Lift coefficient; Numerical simulation

Declaration of competing interest:

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Conflicts of Interest:

This abstract has not been published or presented elsewhere in part or in entirety and is not under consideration by another journal.