Numerical Investigations of Cavitation Performance of the Bionic Hydrofoil with Discontinuous Leading-edge Protuberances

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Abstract

The humpback whale's unique and sensitive hunting ability in the ocean is due to the leading-edge protuberances of its flippers, which is also a viable passive control method for flow separation and cavitation. In this paper, the linear leading-edge of NACA 63_4-021 foil was modified, and a bionic hydrofoil with discontinuous sinusoidal leading-edge was constructed. The wavelength and amplitude were λ=0.25C and A=0.025C, respectively, and the distance between adjacent protuberances was 0.25λ. The cavitation performances of the basic hydrofoil and the bionic hydrofoil with a cavitation number of 0.8 were numerically studied using the large eddy simulation method. The instantaneous flow characteristics of the hydrofoils were reported, including the lift and drag coefficients, pressure fluctuations, and the cavitation evolution. It was found that the flow of the discontinuous sinusoidal leading-edge hydrofoil shows obvious periodic patterns in the span direction, which changes the cavitation characteristics of the hydrofoil. The streamwise vortices induced by the protuberances restricted the incipient cavitation to the trough region and inhibited the cavitation near the peak section. Compared with the basic hydrofoil, the cavitation volume of the bionic hydrofoil was reduced by 35.94% at the 15° angle of attack, the stability of cavitation flow was stronger, and the standard deviation of pressure coefficient near the leading-edge of the suction surface was reduced by up to 50%. This study verified the feasibility of the discontinuous protuberance structure to inhibit the hydrofoil cavitation, which can provide theoretical guidance for the blade design of hydraulic machineries.

Keywords: cavitation control; bionic hydrofoil; leading-edge protuberances; Large eddy simulation; pressure fluctuation