The 5th IAHR Asian Working Group Symposium on Hydraulic Machinery and Systems (IAHR-Asia 2025), 4-7 August 2025, Jeju, Korea

IAHR-Asia 2025

Flow control of microstructure modification for centrifugal pump and mixed-flow pump

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Abstract. As significant energy conversion equipment, vaned pumps have been applied in various scenarios in clean energy, advanced power and maritime engineering. Due to the complex transient multiphase turbulent flow fields, i.e., high rotation speed, high curvature, strong unsteadiness, and multiple interactions, there always appear complex flow structures inside vaned pumps, e.g., blade passage vortex, secondary flow, impact flow, jet-wake, and rotating stall. To deal with the hydraulic instability during the operation of vaned pumps, the microstructure modification is introduced to vaned pumps so as to develop flow control methods, which can improve the comprehensive performance of vaned pumps. Inspired by fish scales to realize drag reduction, the bionic structure design method based on fish scales is proposed according to flow field regulation through microstructures. The experimental results show that, after introducing fish scales bionic structures, the amplitude of pressure fluctuation under blade passing frequency can be reduced by 20.98%, 5.85%, 19.20%, and 25.77% under the flow rate of 0.6Qd, 0.8Qd, 1.0Qd and 1.2Qd, respectively. By combined optimization of structure modification and flow field regulation, the control method for tip leakage vortex flow is proposed to eliminate additional flow losses and flow instabilities, which constructs T-shaped blade tip to suppress tip leakage vortex. The experimental results show that, the efficiency of a mixed-flow pumps can be improved by an average of 1.87% under 0.23Qd -1.0Qd after introducing T-shaped blade tip. The area of main leakage vortex is reduced by an average of 47.15% along the chord direction. The intensity of pressure fluctuations is reduced by 11.11% in average. Inspired by the unique characteristics of desert organisms that are resistant to wind and sand erosion, the anti-erosion flow control method is proposed to overcome the erosion on the surface of particles cutting at small angles. A hump bionic structure is built based on microstructure and passive control, and an axisymmetric composite bionic coupling element structure with continuous curvature transition is designed. The experiments suggest that, the blade surface erosion is reduced by 8.58% by introducing hump bionic structure in a centrifugal pump, and the continuous erosion is reduced to discrete erosion.