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轴流泵小流量工况条件下叶顶泄漏空化特性

Characteristics of tip leakage vortex cavitation in axial flow pump at small flow rate condition

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中文摘要:

为了研究轴流泵小流量工况下叶顶泄漏涡的空化问题，该文以TJ04-ZL-02轴流泵水力模型为研究对象，基于修正的空化模型和SST k-ω湍流模型，分析了叶顶间隙泄漏涡的空化特性。数值计算结果表明，叶顶间隙内泄漏流在工作面拐角处产生分离涡空化，其与叶顶泄漏涡空化共同构成轴流泵的初生空化；在同一空化数下，不同叶片弦长系数的截面空化情况不同，随着弦长系数的增加，叶顶泄漏涡的空化区域和空泡体积分数逐渐增大。随着空化数减小，叶顶泄漏涡的卷吸区也出现空泡团，并与涡带连成一片形成空泡云。在小流量工况下，叶顶区工作面和背面压差较大，间隙轴向速度均出现矢量负值。高速摄影试验结果表明，在小流量工况下，随着空化数的降低，空化现象率先出现间隙内部，接着空化程度不断增加，泄漏涡导致的空泡急剧增加，形成的空泡云在叶片尾部区域发生爆破。当空化数为σ=0.187～0.232时，空泡布满了叶片背面，且叶顶区的空泡在轴向厚度增大，且在叶片后缘出现了明显的空泡脱落现象。

英文摘要:

Abstract: The strong tip leakage vortex (TLV) in an axial flow pump at small flow rate condition will generate a cavitation vortex that would cause flow instability. In order to investigate tip leakage vortex(TLV) cavitation in axial flow pump in small flow rate, TJ04-ZL-02 hydraulic axial flow pump model was investigated based on the modified cavitation model and SST k-ω turbulence model. Numerical results showed that the separation vortex cavitation within the tip gap occurs around the blade pressure side corner, which was made up of a cavitation inception together with a tip leakage vortex cavitation. The gap region cavitation changes with the different blade chord ratio sections when the cavitation number is constant. With the increasing of the blade chord ratio, TLV cavitation region and bubble volume fraction increase gradually. With the decreasing of cavitation number, bubbles occur in the TLV entrainment region that emerged with the TLV cavitation vortex, and merged into bubble clouds. At small flow rate condition, owing to the large pressure difference between pressure side and suction side at the tip, the axial velocity of flow in the gap is negative, and the absolute value of axial velocity increases gradually from the pressure side to the suction side. High-speed photography experimental results show that as the cavitation number decreases gradually, leakage vortex cavitation initiates in the tip clearance at small flow rate condition, and then cavitation deteriorates severely and the bubble cloud breaks up in the trailing region of the blade, and gathers in the tip region and immensely occupies the blade passage region. While the cavitation number σ reaches 0.187~0.232, the suction side of blade is covered by bubbles, and bubbles separation and blasting occur due to the volume fraction increasing of the bubble cloud. The results from this study provide theoretical and experimental references to TLV cavitation in an axial pump.

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