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Design and experiment of the centrifugal pump impellers with twisted inlet vice blades *

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Abstract: In order to introduce gap drainage technology into practice, the design concept and expression format of spatial geometry are proposed for gap drainage impeller with twisted vice blades. First, the profile of vice blade at leading edge and relative position of main blade need to be parameterized. In addition, the influence of these parameters on the performance of a centrifugal pump should be studied. After the above-mentioned work is done, a centrifugal pump with good performance can be designed. On the basis of previous research results, the geometric parameters of twisted blades are determined and the centrifugal pump impellers are designed and manufactured. Through performance tests and cavitation tests, it is verified that the twisted vice blades on centrifugal pumps are effective and practical.

Key words: Centrifugal pump, gap drainage technique, twisted blade, parameterization, performance, experiment

Gap drainage technology is a design scheme for centrifugal pump impellers proposed by the author. With the addition of a vice blade which is overlapped with main blade and hold a certain gap in the vicinity of the leading edge of main blade, the flow in the centrifugal pump is effectively controlled and therefore the performance is improved.

Since gap drainage impeller has been put forward, the author and his collaborators have carried out a series of research[1-7]. In terms of the design of gap drainage impeller, the optimized design process of vice blades are explored, as a preliminary. For the research into mechanism, a scalable detached simulation (SDES)[4] model was proposed and developed based on the detached eddy simulation (DES)[8] method.

By numerical analysis based on SDES model and flow visualization experiments[4], it was considered that the leading edge deviating from original position reduced the blade exclusion and the vice blades overlapping partly with main blades increased the inlet flow channel area. This made flow velocity field distribution more uniform to reduce the energy loss, as can be seen in Fig.1.

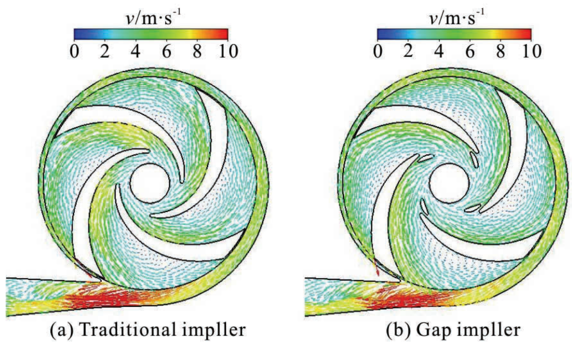

Fig.1 (Color online) Water velocity distributions[4]

In addition, the separated flow would be suppressed at the leading edge as a result of guide flow function of the vice blades of gap drainage impellers, and high pressure fluid on the pressure surface passes through the gap into the suction surface which compensates pressure to low pressure zones to some extent. At the same time, the fluid ejected from the gap produces a disturbance to the cavitation region, which accelerates the cavity shedding and suppresses

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the formation of large cavitation area to improve the cavitation performance, as are illustrated in Fig.2.

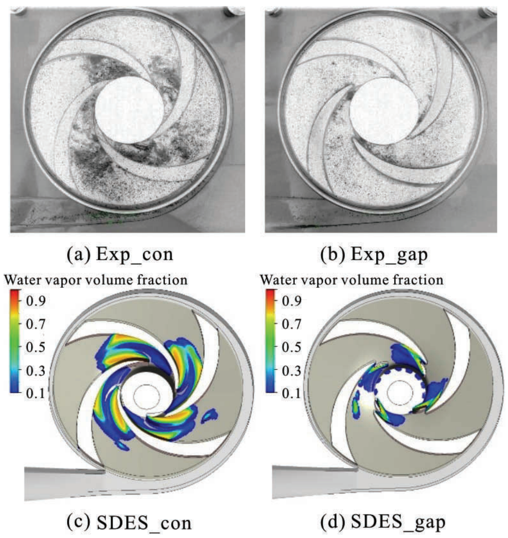

Fig.2 (Color online) Water vapour volume[4]

Based on theoretical analysis, numerical simulation and PIV flow field tests, the mechanism how gap drainage impellers improve hydraulic performance and cavitation performance of low specific speed centrifugal pumps has been deeply studied. Furthermore, the measurement of pressure pulsation and vibration was carried out at inlet, outlet and volute zone of centrifugal pumps with gap impellers under cavitation and non-cavitation conditions. It was found that gap drainage blades also improve the dynamic characteristics of centrifugal pumps in a certain range of conditions.

Currently, gap drainage technology is mainly used for cylindrical blades. In order to introduce gap drainage technology into practice widely, the twisted vice blade should be studied based on the above physical mechanism. The profile of the vice blade at leading edge and relative position of main blade need to be parameterized, and the influence of these parameters on the performance of a centrifugal pump should be explored. The essence of spatial geometric expression for a traditional centrifugal impeller is to calculate geometric parameters according to performance parameters, draw main streamlines to determine the working surface of blade, and then obtain the whole blade by thickening surface based on a certain law.

Compared with a traditional impeller, a gap impeller has a short blade at the leading edge, which partially overlap and hold a gap with main blade. The vice blade usually can be designed and modified on the basis of the traditional impeller. The gap impellers have the same structure parameters as traditional impellers, which means that they are identical in meridional cross-section. The basic process of drawing the gap drainage blade can be described in Figs.3(a), 3(b).

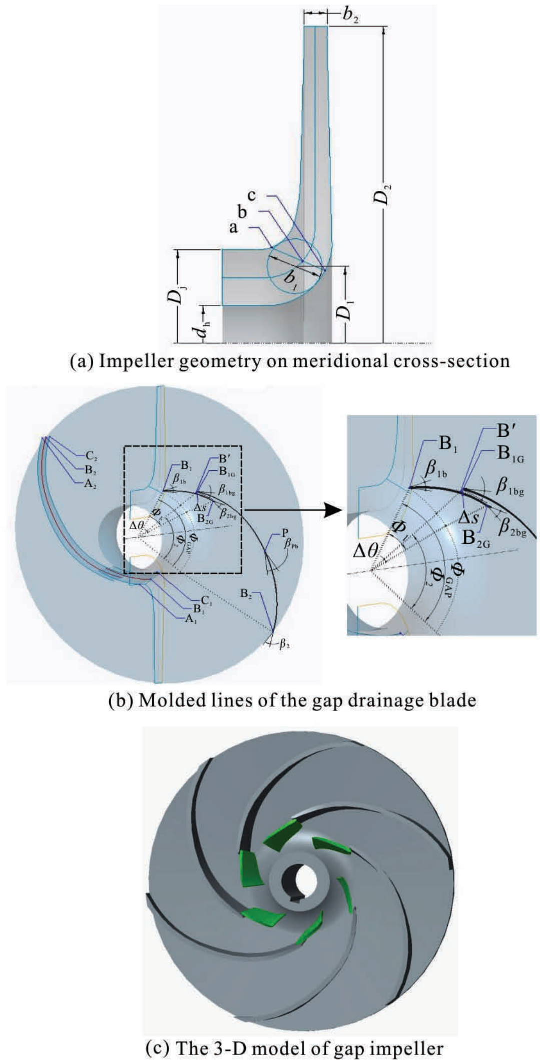

Fig.3 (Color online) Geometric drawing process of the gap drainage impeller

(1) The total wrap angle Φ_0 is determined by number of blades Z and specific speed n_s. The initial inlet location points (A_1, B_1, C_1) of the blade, as well as the outlet location points (A_2, B_2, C_2) are obtained according to the hydraulic design method of a traditional centrifugal impeller.

(2) According to the design method of the traditional impeller, three streamlines on meridional cross-section which is starting from A_1, B_1 and C_1 are drawn, and flow surfaces A, B and C are formed by rotating around the rotation axis.

(3) Inlet angle $(\beta_{1a}, \beta_{1b}, \beta_{1c})$ and outlet angle $(\beta_{2a}, \beta_{2b}, \beta_{2c})$ are calculated and selected properly. According to a given change rule of blade angle, three smooth streamlines are fitted on the spatial flow surface.