The effect of impeller cut on the performance of middle specific speed centrifugal pump

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Abstract. For researching the influence of impeller cut ways and methods on the external characteristics of centrifugal pump, the flow in IS125-100-216 pump was simulated by using FLUENT software after impeller cut, and the external characteristics were also predicted. The predicted external characteristics show that the head reducing value after cutting impeller is significantly greater than that after cutting blade in the same cut value. When the cut angle is in the range of 0° to 10°, the efficiency in the forward skew cut is higher than that in the straight cut and the backward skew cut. The shaft power in the impeller cut is obviously lower than that in blade cut. When the cut angle is in the range of -10° to 10°, the shaft power in the skew cut is lower than that in the straight cut. The results of the inner flow analysis indicate that in the same cut value the forward skew cut significantly weakens the vortex phenomenon in the straight cut with the increase of the cut angle. No matter the straight cut or the skew cut is conducted, the effect of blade cut is better than that of impeller cut in the same cut value.

Keywords: Centrifugal pump; impeller cut; blade cut.

1. Introduction
The outer diameter of impeller affecting pump performance is one of the main structural parameters [1-3]. In engineering practice, the method of impeller cut is usually used to adjust the performance of centrifugal pump. The selection of impeller cut value and effect of using in IEJ impeller pump was introduced by domestic scholars Xu and Dong [4]. The actual performance of centrifugal pump was changed by reducing the diameter of the impeller. The purpose to reduce noise and steady motor current is reached. The hydraulic performance of centrifugal pump was improved through designing the impeller by Tan [5]. Effect of impeller cut on centrifugal pump efficiency was researched by foreign scholars Mario Saver [6]. When impeller diameter was decreased, efficiency declined obviously. Energy saving effect was achieved and the rate of flow was increased using impeller cut by Stan Shields [7].
At present, the research on impeller cut mainly focuses on the condition of impeller tangent cut. However, impeller cut angle and blade cut only on pump performance are considered less [8]. The research object is IS125-100-216 centrifugal pump. Impeller and blade cut methods are investigated by numerical simulation. The effect of angle and amount cut on the internal flow of centrifugal pump are analyzed, and external characteristics are predicted. The effect of cut angle and amount and special speed on external pump characteristics are discussed.

2. The Geometric Model and Boundary Conditions

2.1. The Geometric Model

The research object is IS125-100-216 centrifugal pump. The performance and structural parameters are shown in table 1. The three-dimension model of the impeller and the volute by PRO/E 5.0 through two cut methods. There is a certain extension of the impeller entrance and the volute export to decrease the boundary conditions’ influence on the internal flow field, as shown in figure 1. The method of grid dividing of pump by blocking. The total number of generated grid cells is 1337113. The number of the generated grid cells of the impeller and the volute is 542353 and 647925, respectively. It is generally thought that the isometric slope and the equidimensional slope of a qualified grid should not exceed 0.85 value requirements. The isometric slope and the equidimensional slope of the grid in the model of the paper are no more than 0.8, such grid value can meet the requirements. The external characteristic prediction method and the boundary conditions are considered according to reference [9].

| Model          | ns | \( H / (\text{m}) \) | \( Q / (\text{m}^3/\text{h}) \) | \( \eta / (\%) \) | \( N / (\text{r/min}) \) | \( Z \) | \( b_2 / (\text{mm}) \) | \( D_1 / (\text{mm}) \) | \( D_3 / (\text{mm}) \) | \( D_2 / (\text{mm}) \) |
|----------------|----|---------------------|----------------------|-----------------|-------------------|-----|----------------|-----------------|----------------|----------------|
| IS125-100-216  | 128 | 52.35               | 200                  | 82.4            | 2900              | 6   | 26.5           | 125             | 216             | 216             |

Figure 1. 3D model of centrifugal pump

Figure 2. Schematic diagram of cut ways
3. Cut mode and method of impeller

Impeller cut method is divided into tangent, straight and skew cut, as shown in Figure 2. D2 is the diameter of impeller in uncut, and D2′ is diameter of impeller after cutting, cut value is (D2 - D2′)/2, b2 is the outlet width of impeller. Cut angle θ is defined between tangent and skew or straight cut. The cut angle range is: -arctan(D2 - D2′)/b2 < θ < arctan(D2 - D2′)/b2.

4. Influence of Impeller Cut Methods and Methods on External Characteristics

The external characteristics by two cut methods are shown in Figure 3. The amount of head reduction by impeller cut is greater than that by blade cut. The difference of head between these two methods are largest and the relative error is 10% when the cut value is 8%. The cut efficiency by straight cut is higher than tangent and skew cut when the cut angles in the scope of 0°~10°, whether impeller cut or blade cut. The shaft power by impeller cut is significantly less than that by blade cut shaft when in the same cut value. The shaft power of skew and straight cut is lower than that of the tangent cut when cut angles in the scope of -10°~10°. Therefore, the shaft power is reduced effectively by skew and straight cut.

5. The Effect of Impeller Cut Method and Method on Internal Flow Field

5.1. The impeller cut mode affects the internal flow field

Figure 4 is the relative velocity vector in the cross section of the impellers with different cut angles at the 4% impeller cut. The results show that the impeller passage near the suction side can produce a small vortex by tangent cut 4% when the same cut value, when cut angle is 10°of skew cut, the area of vortex become larger. When cut angle is 10°of straight cut, no vortex is produced. Therefore, the area of vortex by skew cut is obviously greater than tangent cut, and the vortex by straight cut is significantly improved compared with the tangent cut and skew cut, when the cut value is same.
5.2. Effect of impeller cut method on internal flow field

5.2.1 The effect of two cut methods on the internal flow field is obtained. Figure 5 shows the relative velocity vector distribution in the impeller passage by the two cut methods. The results show that vortex is generated in the impeller passage by impeller cut which reduce the performance of the pump. Compared with impeller cut, the vortex phenomenon basically disappeared, and the operation performance of the pump was significantly improved by only blade cut.

5.2.2 The Influence of Two Cut Methods on The Internal Flow Field Is Discussed. The relative velocity vector in the impeller passage by two cut methods is shown in Figure 6 (a) and (b) when it is straight cut under the same cut value. The results indicated that the impeller passage will produce a small vortex near the suction side by impeller cut. The vortex phenomenon is not obvious by blade cut, when in the same cut value and angle. In a similar way, the passage will produce a small vortex near
the suction side by impeller cut. The vortex phenomenon is not obvious by blade cut, when in the same cut value and angle. It can be seen that blade cut is better than impeller cut, whether tangent or straight and skew cut under the same cut value.

6. Conclusion

(1) The internal flow of 125-100-216 centrifugal pump by different impeller cut methods and methods was simulated by FLUENT Software, and the external characteristics of centrifugal pump was predicted. The results show that the reduction of head by impeller cut is obviously greater than that by blade cut in the same cut value. The efficiency by straight cut is higher than that by tangent and skew cut when the cut angles are in the scope of 0°~10°. The shaft power by impeller cut is significantly less than that of blade cut. The shaft powers by straight and skew cut are lower than that by tangent cut when cut angles are in the scope of -10°~10°.

(2) The vortex phenomenon is obviously reduced by straight cut than that by tangent cut with the increase of the cut angle.

(3) The internal flow field by impeller and blade cut methods show that vortex is generated in the impeller passage by impeller cut. However, the vortex phenomenon almost disappears by blade cut. Blade cut is better than impeller cut in the same cut value, whether tangent or straight and skew cut.

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