MSAM 2021

August 16-19, 2021

Online Conference

MS1681

Optimization Design of Multistage Pump Impeller Based on Response Surface Methodology

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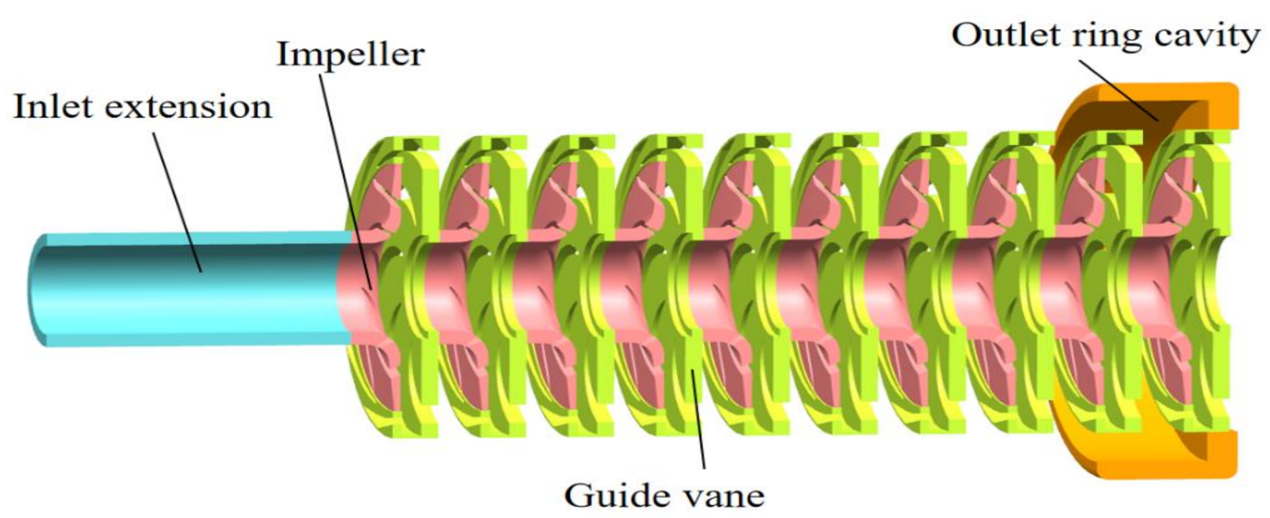
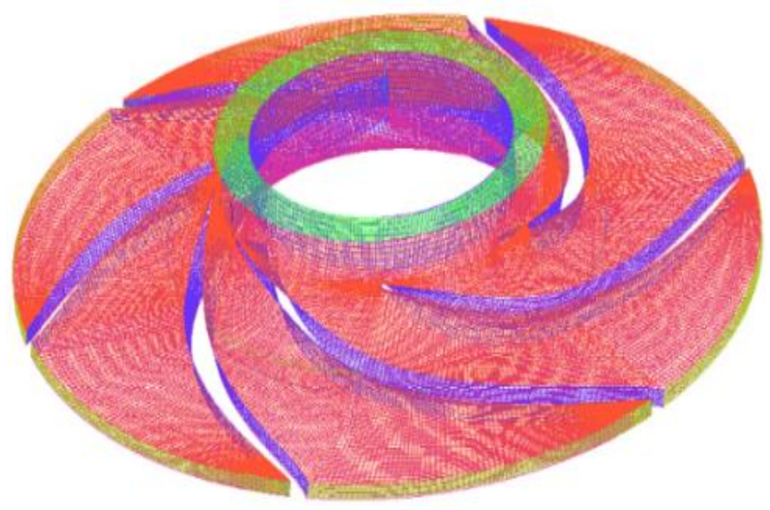
Introduction

Multi-stage centrifugal pump is a high-lift centrifugal pump with two or more impellers, which is widely used in chemical, electric power, fire protection and other fields. Compared with the single-stage centrifugal pump, the internal flow field is more complicated, including the flow changes caused by the periodic change of the relative position between the internal rotor and the stator and the pressure field boundary conditions.

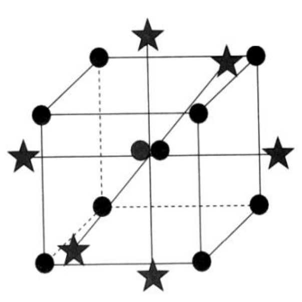
At the same time, due to the high-speed operation of the rotor, the force of the shafting rotor system is complex and often accompanied by vibration, which may cause shock damage to the equipment and seriously affect the safe and stable operation of the multi-stage centrifugal pump. In this paper, the GRD-100 chemical multistage centrifugal pump is the research object, the impeller is optimized hydraulically, and the dynamics of the shaft rotor components are studied.



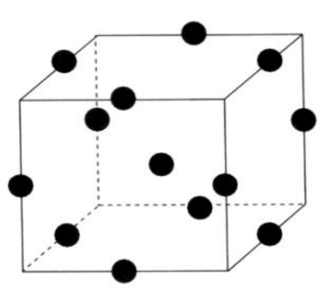


Contents

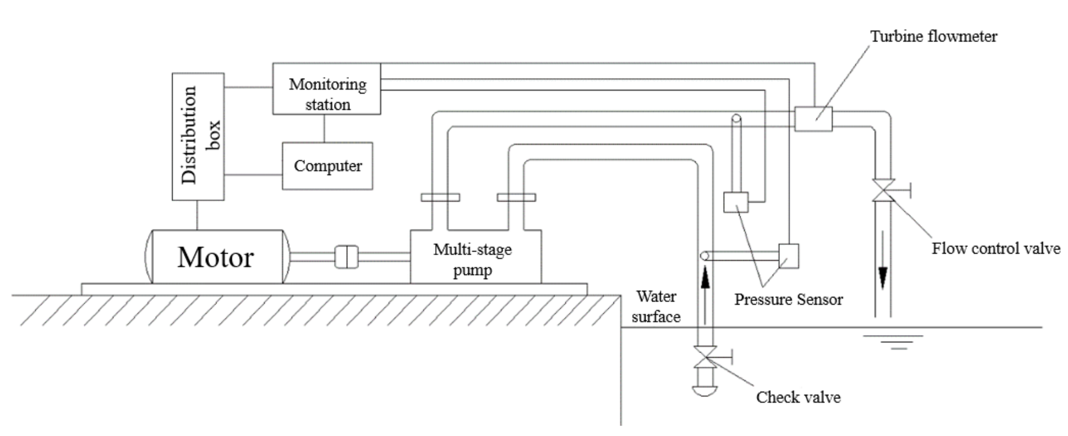
(a) Based on the Central Composite Design-response surface optimization analysis method, the number of impeller blades, the diameter of the impeller, the blade wrap angle, and the width of the blade outlet are optimized.



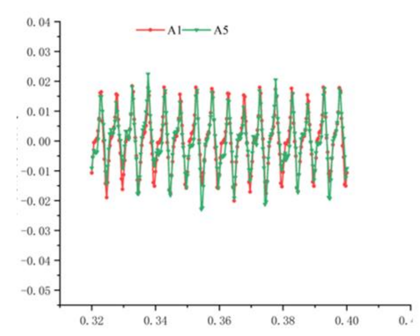
Center composite design

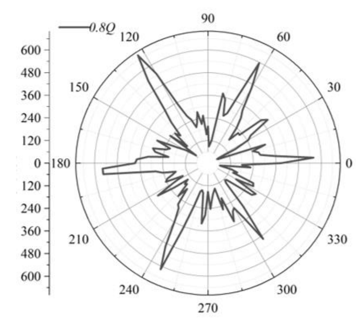


Box-Behnken design

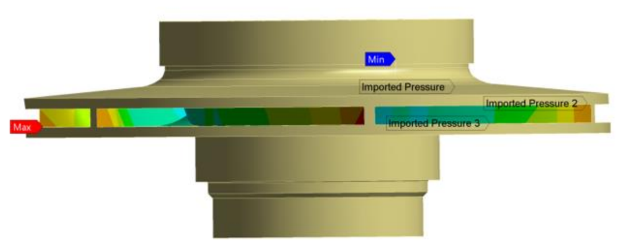


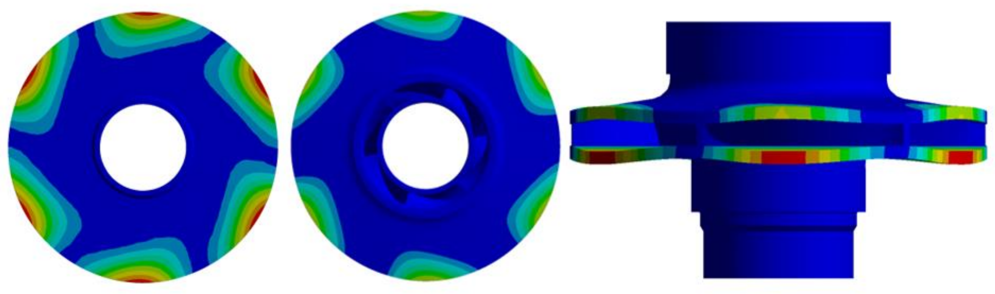
(b) The internal unsteady flow of the impellers and guide vanes of different stages of the multi-stage pump under different flow conditions is simulated and calculated. The pressure pulsation analysis and radial force analysis are carried out.



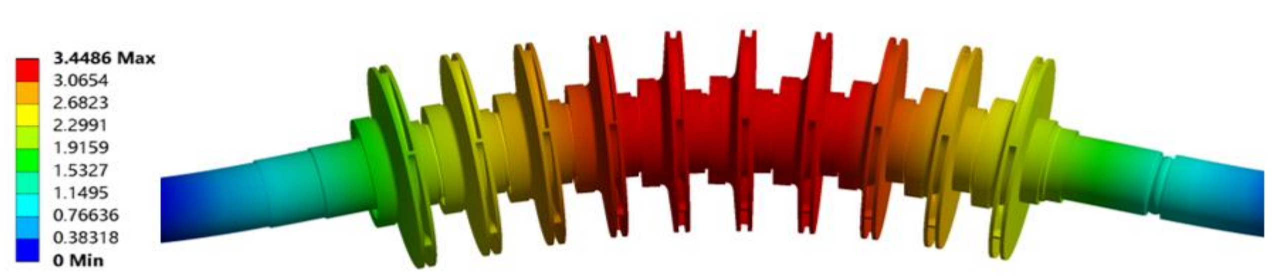


(c) The impeller deformation is concentrated at the exit position of each flow channel.





(d) The "dry" and "wet" modal analysis of the multi-stage centrifugal pump shaft system rotor system are carried out.



Conclusions

In this paper, the central composite design of response surface methodology is applied to optimize the geometry parameters of multistage pump impeller, and the experiment was conducted.

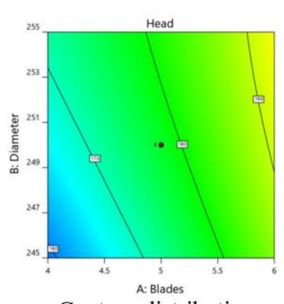
(a) The 30 groups of test schemes are obtained based on the software of Design Expert, and the numerical calculation of each scheme is conducted.

$$Ey = f(z_1, z_2, z_3, z_4) = b_0 + b_1 z_1 + \cdots + b_4 z_4 + b_{11} z_1^2 + \cdots + b_{44} z_{44}^2 + b_{12} z_1 z_2 + \cdots + b_{34} z_3 z_4$$

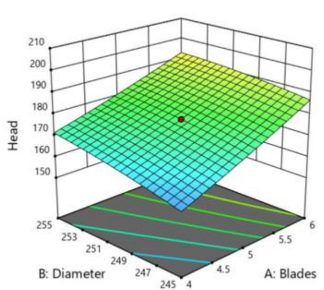
$$y = f(x_1、x_2 \cdots)$$

$$y = a_1 + a_2 \sum_1^n x_i + a_3 \sum_1^n x_i^2 + a_4 \sum_1^n x_i x_j$$

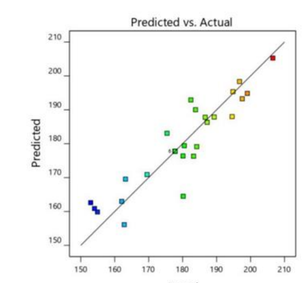
(b) The response surface regression model of the single-stage impeller head of multistage pump was established after removing the insignificant factors.



Contour distribution



Response surface distribution



Distribution of predicted and actual values

(c) According to the analysis of response surface distribution, it can be seen that the significant sequence of the influence of response variables on the head is blade number > impeller diameter> blade outlet width> blade wrap angle.