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NUMERICAL CALCULATION OF STARTUP PROCESS OF A CENTRIFUGAL PUMP

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ABASTRACT

The centrifugal pump power-on process is unavoidable. To explore the internal flow characteristics during the boot process, In this paper, given the flow rate change, A numerical calculation of the three-dimensional flow of a small centrifugal pump was carried out. Through numerical calculations, it is found that it is fully feasible to reveal the internal flow transient characteristics of the start-up process by numerical simulation, which provides a reference for engineering applications.

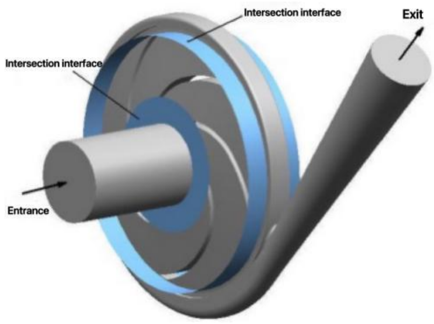
KEYWORDS: Centrifugal Pump, Numerical Calculations, Quasi-three-dimensional.

1. INTRODUCTION

During a wide variety of transient operations[1~6], the speed, flow rate, and inlet and outlet pressures of centrifugal pumps change rapidly with time.Therefore, if the internal flow field of a single pump is simulated, when specifying the boundary conditions, it is necessary to know the speed-time curve and the flow-time-curve, or the speed-time curve and the inlet and outlet pressure-time-curve, and the variation of flow and pressure is closely related to the pipeline System characteristics are closely related.Therefore, to accurately simulate the internal flow field, the above relationship needs to be determined experimentally. If a closed-loop piping system containing a pump is simulated, at least the speed-time curve must be known, and again to obtain an accurate flow field, the relationship must still be obtained experimentally. The impeller area is rotated as a whole. During various transient operations, the impeller region is rotated as a whole if there is a change in speed, which can be achieved by user-defined functions based on the dynamic grid method. The impeller rotating region and the worm gear stationary region are rotated relative to each other during the calculation, and the two regions are connected by a slip surface. For the non-constant calculation in the transient process, the overlapping surfaces are calculated once per time step, and for each slip surface, the flux is obtained in proportion to the area of the overlapping surfaces, to achieve the flux balance in the two regions. The following takes the centrifugal pump start-up process as an example to verify the feasibility of the above numerical simulation method.

2. Calculate the model

The model pump has a design flow rate of 6, a design head of 8, and a design speed of 1450. during rapid start-up, the speed-time curve depends on the starting characteristics of the power source, and the curve relationship approximately satisfies the exponential relationship. $n = n_{\max}(1-e^{-t/t_0})$, where, $n_{\max} = 1450\mathrm{rpm}$, $t_0 = 0.15$s. It has been shown in the literature that the flow rate variation approximately satisfies the cubic curve form. In combination with the literature, an artificially given form is used here, and the steady flow rate is set to 6 $\mathrm{m^3/h}$, as shown in Fig. The velocity inlet boundary condition is used at the inlet and the free outflow condition is used at the outlet. The computational domain is divided into three parts, which are the inlet section, the impeller rotation region and the worm gear stationary region. The impeller rotation area rotates as a whole. The RNG $k-\varepsilon$ turbulence model is used for the turbulence model, the transient term is discretized in first-order implicit format, the coupling of pressure and velocity is realized by the SIMPLE algorithm, and the convective term is discretized in first-order windward format, and the diffusive term is discretized in central difference format. The time step is taken as 0.0001s, and the time to reach the stable speed from standstill is about 1s. The maximum number of iterations in each time step is taken to be 20,000 (in practice, convergence is achieved in a few tens of iterations in each time step) to ensure absolute convergence in each time step. The convergence residual is 0.001. The calculation medium is clear water, the density is $\rho = 1000\mathrm{kg/m^3}$, the dynamic viscosity is $\mu = 1.0\times10^{-3}\,\mathrm{Pa\cdot s}$, considering the effect of gravity, and the total number of meshes in the calculation domain is 508792. Figures 1 and 2 show the mixing surface and mesh schematics.



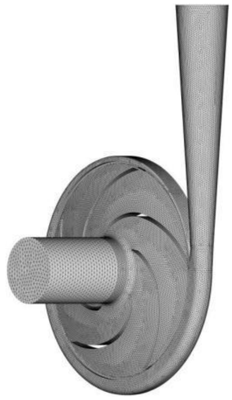


Figure 1: Mixed polygons **Figure 2: Grid diagram.**

3. Analysis of results

Figure 3 shows the time course of the pressure changes at the inlet and outlet of the centrifugal pump during startup. At the inlet, the pressure fluctuation changes very little during start-up. At the outlet, the pressure rises rapidly with the rapid increase in speed and fluctuates significantly. Figure 4 shows the time course of the change in the external characteristic curve during the start-up process.Where the speed and flow curves are externally specified boundary and initial conditions, the head curve is the time course obtained by numerical calculation. It can be seen that as the speed increases, the value of head fluctuation also increases. The maximum fluctuation value is about 1.5m, which is seen to be very large about the design head. Figure 5 shows the time course of the hydraulic power and hydraulic efficiency calculated during the start-up process. Similar to the trend of the head curve, the hydraulic power and hydraulic efficiency are also a continuous fluctuation process. The increase in flow and head during start-up leads to an increase in hydraulic power, Hydraulic efficiency shows the same trend, It is completely different from the assumption of constant efficiency in the quasi-steady state assumption, so the transient effect in the transient process is very obvious.

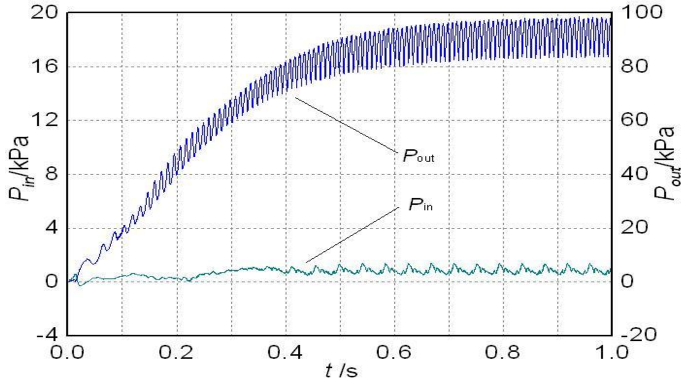


Fig. 3: Inlet and outlet pressure change curve.

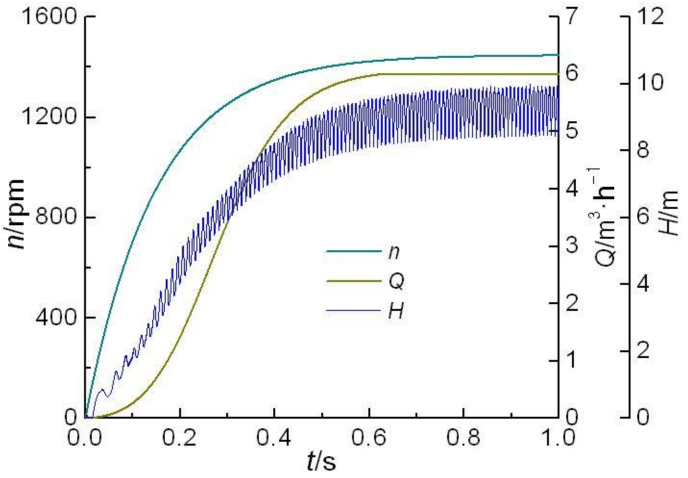


Fig. 4: External characteristic curve during startup.

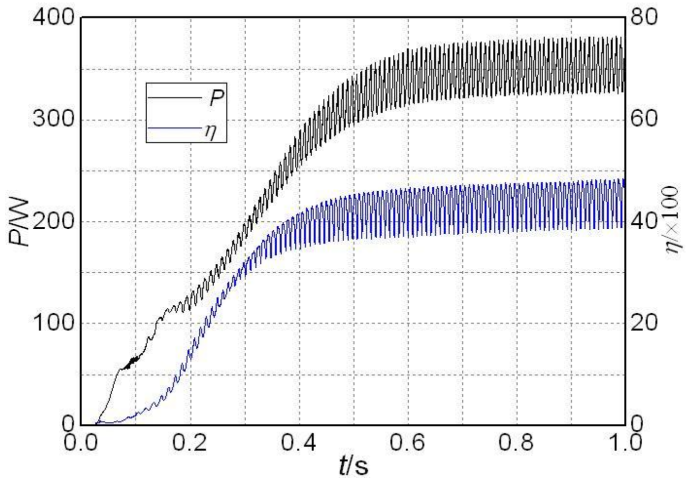


Fig. 5: Changes of hydraulic power and hydraulic efficiency during startup.

Figure 6 shows the time course of the total pressure change over the cross-section in the centrifugal pump during start-up. At 0.04s, the impeller stirs the water body to do work due to the relatively low speed, so the internal pressure field map is not obvious at this time. The pressure gradient then becomes more pronounced as the speed continues to rise. At any given moment, the pressure gradually evolves from low pressure at the inlet to high pressure at the impeller outlet. And the centre pressure decreases rapidly with increasing speed. After 0.6s, the pressure change in the impeller part is not obvious, and the change mainly occurs inside the worm gear. From the analysis of the evolution trend of the pressure field combined with the changing trend of the external characteristic curve of the head, it can be seen that the two have a good correspondence.

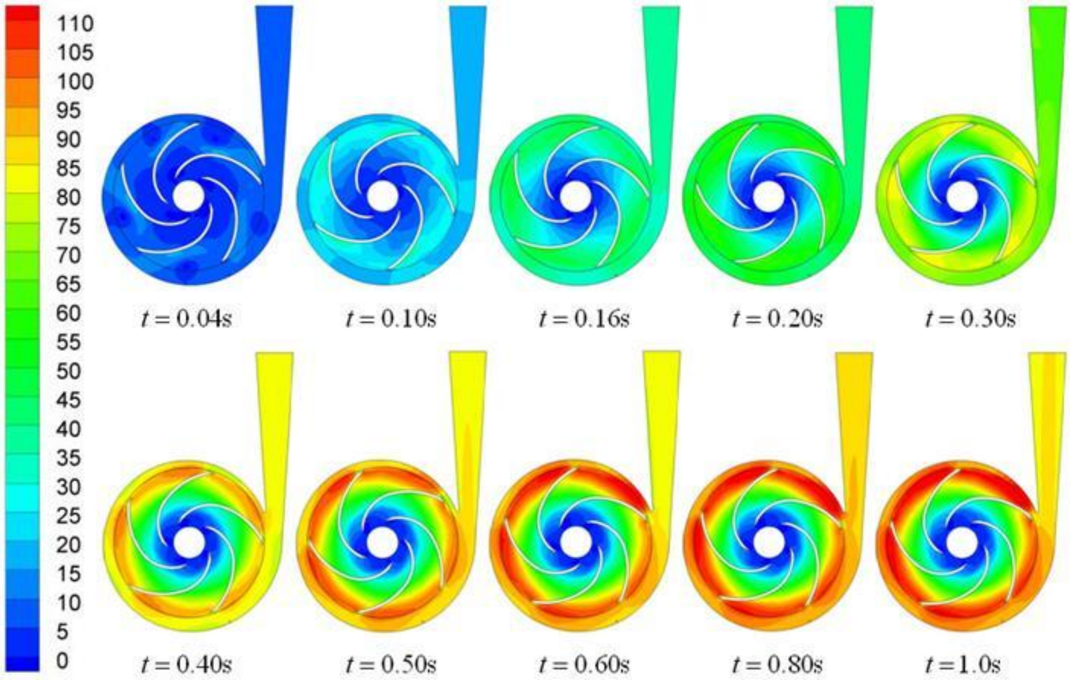


Fig. 6: Total pressure change time course during start-up (kPa).

4. CONCLUSION

A combination of slip-grid technique, dynamic grid technique, and user-defined functions was used to numerically predict the three-dimensional non-constant flow of a single pump during startup, and the numerical simulation method is feasible and reliable in terms of the results of the internal flow field and external characteristics. However, since the variation history of rotational speed and flow rate is artificially given, especially the flow rate condition is given with more uncertainty, which leads to the difference between the simulation results and the real situation, and the accurate and reliable non-constant flow field evolution results cannot be obtained. To obtain accurate flow and pressure curves need to resort to experimental results to numerically simulate the accurate evolutionary characteristics of the internal flow field.

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