The effect of different particle diameters on waste submersible motor-pump’s two-phase flows

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Abstract. Dispersed turbulence model in Euler model was employed to analyze liquid-solid two-phase flow for a WQ87-28-15 waste submersible motor-pump. The comparisons between the results indicated that the pressure of outlet, the absolute velocity of fluid and the turbulent intensity of vent are in direct proportion to the diameter when the diameter is smaller than 4mm; otherwise, they will go up. The head declined until the diameter of the particle reached 1mm, and efficiency fell while the particle diameter was increasing, but it was fixed and even rose when the diameter was between 1mm to 20mm; It inferred that it has a right area of the diameter when the waste submersible motor-pump operated, and the maximum diameter of particles can be gained.

1. Introduction
Waste submersible motor-pumps, which are widely used in power, petrochemical, light industry, medicine, mining, environmental protection, sewage treatment, aquaculture, dredging and other industries and fields, are suitable for transport all kinds of sewage and mixed liquid containing solid particles or fibers, such as industrial waste, waste slurry, urban construction sewage. With the rapid economic development and the needs of the industrial and agricultural production, as well as the growing importance of environmental protection, the studies of non-clogging and the maximum diameter of solid particles become wider, which has become a subject of concern of the research and application of the pump industry.

Commonly used methods for solid-liquid two-phase flow simulation are the Euler-Euler method and Euler-Lagrange method. The Euler-Euler method regards the particles and the liquid as continuous fluids co-existence and mutual penetration. The Euler-Lagrange method regards the liquid as a continuous fluid and the solid particles a discrete phase. The Euler-Euler method was used in the present study. [1-5]
2. Calculation parameters and Meshing

The basic parameters are shown below: flow rate of 87 m$^3$/h, head of 28m, rotating speed of 1450 r/min, the impeller diameter of 108mm, outlet width of 36mm and the discharge diameter of 100 mm. It is assumed that the solid particle is sand and the volume concentration is 2%. The computational domain uses tetrahedral unstructured grids, totally 833,767 elements.

3. Models and Boundary Conditions

Mass conservation equation, momentum conservation equation, three-dimensional incompressible pressure Reynolds N-S equations and RNG turbulence model equations have been chosen. Considering the commonly used two-phase flow model, Euler-Euler model is used to study the flow field. The dispersion turbulence model is used when using the Euler model to calculate due to the solid phase volume fraction below 2%. Volume fraction is introduced to the basic equation of phase. The volume fraction represents the volume of the space occupied by each phase. Each phase must satisfy the law of momentum and mass conservation. Conservation equation can be obtained by local instantaneous conserved overall average or mixed law of each phase. The velocity inlet, outflow and no slip boundary conditions are used. [6-8]

4. Results and analysis

Due to space limitations, only eight kinds of different particle sizes are used in two-phase flow analysis, which are 0.1, 0.5, 1, 4, 8, 10, 20 and 30 mm.

4.1. Internal flow field analysis

The pressure distributions for 8 different kind particles under the calculated conditions are shown in figure 1 and figure 2. The pressure changing range is not too large due to the concentration of the particles not too high.

When the particle diameter is between 0.1mm and 4mm, pressure of the impeller outlet increases as the diameter increases, which is helpful to improve the performance of the pump. Zhao Binjuan et al. summarized previous experiments and demonstrated the following results: the pressure loss is inversely proportional to the particle diameter in conveying the mixture fluid containing small diameter particles [9]. But it can be seen in figures that when the diameter is more than 4mm and gradually increased, the pressure of the impeller outlet gradually decreases. The main reason is probably because the larger the particle diameter is, the larger inertia force particle has, making particle following the fluid performance poor. That is, when the particle diameter is greater than a certain value, losses within the impeller increases and the pump performance drops.
Comparing solid phase velocity distribution and liquid phase velocity distribution in figure 3 and figure 4, it can be seen that the absolute velocity of the solid phase in the two-phase flow is less than the liquid phase and the speed difference between them is greater as closing to the impeller outlet. With the increase of the diameter, the absolute velocity of the liquid phase first increases and then decreases, having a maximum value when the particle size of 4mm. At the same time, the absolute velocity of the solid phase is inversely proportional to the particle diameter, decreasing rapidly.
Relative velocities shown in figure 5 and figure 6 reflect that solid phase is faster than the liquid phase. Both the relative velocities in the two phases increase with the increasing sand particle diameters and the solid phase velocity increases faster than the liquid phase. That is, with the increase in the diameter of solid particles, the difference between the velocities of the solid-liquid two-phase fluid becomes larger and the location of the equal velocity in liquid and solid phase is getting closer to the impeller suction.

The figure 5 shows the relative velocity of the liquid phase in the vicinity of the pressure surface is significantly lower than the relative velocity near the suction surface, which has a good correlation with the variation of pressure on the blade surface. With the increase of diameter, the velocity difference between the liquid and solid phase increases, the velocity at the exit of the pressure surface also increases and the solid phase velocity indicates particles are away from the suction surface when the particle diameter exceeds 4mm, which are consistent with the actual situation.
Figure 5. Relative velocity of the liquid phase under the influence of different particle sizes.

Figure 6. Relative velocity of the solid phase under the influence of different particle sizes.

Figure 7. The turbulence intensity distribution under the influence of different particle sizes.

Figure 7 shows the turbulence intensity at the impeller outlet increases when the particle size increases. But as the particle size continues to increase, the turbulence intensity at the outlet even declines rather than increasing. The reason may be that the larger particles in the impeller channel are deposited by gravity so that the turbulent flow began to weaken.
4.2. **External characteristic curve analysis**

![Graph](image)

**Figure 8.** Head curve under different particle sizes.

**Figure 9.** Efficiency curve under different particle sizes.

As can be seen from figure 8, the pump head gradually decreases with the increase in particle size. During the process of particle diameter increases from 0.06mm to 1mm, head sharply declines and thereafter as the diameter of the sand continues to increase, the change of the head tends to flatten. Within the scope of the study calculated, head also increased slightly as the particle diameter increased to maximum.

The pump efficiency gradually decreases as particle size increases, while the efficiency has stabilized rather than continuing to decline with the particle size continues to increase from 0.8mm to 4mm, shown in figure 9. When the particle size continues to increase to more than 20mm, the efficiency of the pump declines relatively obvious.

5. **Conclusions**

I ) For the pump used in the present study, pressure at impeller outlet, the absolute velocity of liquid phase and turbulence intensity at the impeller outlet is proportional to the particle diameter when the particle diameter less than 4mm, and on the opposite trend while exceeding this value.  

II) With the increase of the particle diameter, the head and efficiency decreased, but the head tends to be flat later when the diameter increases to 1mm, and the efficiency drops less obvious when the particle diameter within the range of 1mm to 20mm.

III) The most suitable particle diameter for such models of waste submersible motor-pump ranges from 1mm to 20mm, and 20mm is the maximum throughput particle diameter.

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