CFD analysis on a turbulence generator of medium consistency pump

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Abstract. Medium concentration paper suspension is a water-air-fibre three phase suspension. It has complicated physical features. When concentration exceeds 7%, it stops flowing and acts like a solid. A generator suspension is installed before the impeller to disturb the flocs and networks to make it start to flow. In this paper, CFD method is adopted to study the effects of the turbulence generator. As there is not a mature model to describe the characteristic of pulp suspension, Newtonian fluid is used to get the general property of the turbulence generator. In the CFD simulation, apparent viscosity of the pulp suspension is used to characterize the mixture. Firstly, numerical method is applied to get the turbulence generator properties in different rotational speed and different viscosity. From another point of view, air contained in the suspension is separate initially by means of centrifugal force. As it is difficult to describe a practical model of pulp suspension, it is simplified to be a water-air two-phase mixture. Several air contents are simulated to study the air distribution in the turbulence generator. The results show that there are three main effects of turbulence generator. Firstly, it has an entrainment effect of the suspension to make it into the pump. Secondly, it stirs the pulp suspension to bring it into flowing. Last, air is centralized in the shaft centre and pre-separated in the turbulence generator. So, the turbulence generator can pre-treat the pulp suspension to make the MC pump transport suspension successfully.

1. Introduction
Medium consistency technology (MC technology) is developed in 1970’s. As transporting equipment, medium consistency pump (MC pump) is important in MC unit operation. Pulp suspension in medium concentration is a water-fibre-air multiphase non-Newtonian fluid [1-3]. When concentration exceeds...
7%, pulp suspension stops flowing and acts like a solid. It is found that when sufficient shear stress is applied in the suspension, it begins to flow again [4]. This is the fundamental basis of MC technology. On the other hand, air content in pulp suspension cannot be ignored either. The abundant amount of air in the suspension gathers in the pump inlet and causes air lock. As a result, pump cannot operate successfully. So, in order to solve these problems, special structures are designed. Firstly, a turbulence generator is installed before the impeller to stir the suspension. It consists of three twisted blades. Secondly, separate air remove system is settled to remove the air in the suspension. In this paper, a turbulence generator with 3 twisted blades is analyzed with CFD method. Different viscosities are adopted to study the influence of material physical property. Eulerian two phase model is used to get the air distribution in the turbulence generator. At last, the influence of the turbulence generator to the pump performance is analyzed.

2. Structure of the turbulence generator

So far, there are several different structures of the turbulence generator in integrate structure MC pump. They are shown as figure 1 [5, 6]. The common characteristic of all these products are the twisted blades inserted into the suspension. Before the pulp suspension getting into the pump impeller, the turbulence generator exerts great shear forces to the suspension to make it flow. At the same time, air contained in the suspension begins to gather to the center because of centrifugal force. Also, the turbulence generator has an effect to the suction of the pulp suspension. The turbulence generator could be separate or connected with the impeller. In figure 1(d), it is an extension of the impeller blade.

![Figure 1. structure of turbulence generator](image)

3. Numerical method

3.1 Numerical model and mesh information

The studied turbulence generator is shown in figure 2. The turbulence generator consists of 3 twisted blades. It is coaxially installed before the impeller. The model is meshed in ICEM. Tetra/mixed mesh type is used. The total element is 424099.
3.2 Numerical method
Fluent 6.3 is used to perform the simulations. Newtonian fluid with different apparent viscosity is adopted to describe the suspension property. Air-water two phase is simulated with Eulerian model. In Eulerian multiphase flow, the description of multiphase flow as interpenetrating continua incorporates the concept of phase volute fractions. The law of conservation of mass and momentum are satisfied by each phase individually and momentum and continuity equation is solved for each phase. Boundary conditions are set as follows: 1. Inlet: velocity inlet. 2. Outlet: pressure outlet. 3. The rotational zone is treated with MRF model. 4. The material is set as Newtonian material.

4. Results and discussion
4.1. Turbulence generator performances
When handling water, the turbulence generator performance is shown in figure 3. The rotational speed is set 2668.5 rpm. From the results shown in figure 3, it can be found that with increase of flow rate, the total head is decreasing. But which is different with an ordinary pump is that the head firstly decreases fast, then there is a stable variation with flow rate and finally it decreases almost linearly. The similar phenomenon is appeared in large flow rate centrifugal pumps, which are usually a mixed or axial type. The head-efficiency curve is firstly increasing then decreasing with flow rate.

![Figure 3. H-Q curve](image3.png)

![Figure 4. Performance variation with viscosity](image4.png)

Setting the flow rate as constant as 56m$^3$/h, rotational speed as 2668.5 rpm, and changing the viscosity of the material, the performance is shown in figure 4. From the results shown in figure 4, it is obvious that head decreases with increase of viscosity. When the viscosity is changing from 0.001 to 0.1 kg/m-s, the head decreases sharply. While the viscosity continuous to increase, the head decreases...
smoothly. When the viscosity is above 2 kg/m-s, because of the great friction loss in the internal flow field, the head begins to be negative, which means all of the energy dissipates through heat. For medium concentration suspension, the viscosity is always tending to be very large, so there is corresponding large energy consumption.

Figure 5 is the turbulence generator performance variation with speed. The material is water. As it is obvious shown in figure 5, with the increase of speed, the head and energy are increasing. It can exert enough shear force to the pulp suspension in high rotational speed. And also, although it is not simulated in this paper, the air separation effect is better in high rotational speed. Since the diameter of the turbulence generator is large, the rotational speed is enough when it exceeds 600rpm. The main effect of the turbulence generator is to remove the air. Some experiments have been done in a test rig. During the experiment, when the speed is low (n= 1800rpm), the pump performance declines because of the remained air. When the speed increases, the pump performance is getting better.

4.2. Air distribution and internal flow field
Water-air two phase fluid is simulated in the inducer. Air distribution is presented in different air contents. Rotational speed is 2668.5 rpm and flow rate is 56m³/h. From the results shown in figure 6, it can be found that with the centrifugal force of the turbulence generator, the air gathers into the centerline. But in the outlet, it is obvious that in the pressure side of the turbulence generator, the air content is very low.
This could be explained by the pressure distribution in the turbulence generator shown in figure 7(a). In the outlet of the turbulence generator, the total pressure in pressure side is larger than the suction side. Velocity and streamline shown in figure 7 presented the basic flow pattern in the turbulence generator. Fluids are tending to gather at the pressure side.

Figure 6. Air distribution in different air volume fraction

Figure 7. Internal flow field (Cv=0.15)

4.3. Influence to pump performance
Simulate the flow field of a pump with and without the turbulence generator and compare the internal flow field. From the results, it is shown that the turbulence generator has minor effect to the pump head and efficiency. Within the turbulence generator, the pump head and efficiency will drop a little. Difference in the internal flow field is distinguished. When the turbulence generator is installed before the impeller inlet, as is shown in figure 8, there will be a great positive pre-whirl before the fluid getting into the impeller. The streamline is shown in figure 9. A large inlet circumferential velocity is produced. From the theatrical equation for calculating the pump head, it is known that a positive circumferential would result in a head reduction.

**Figure 8.** Install location  
**Figure 9.** Inlet streamline with a turbulence generator

5. Conclusions
In this paper, a turbulence generator is modeled and simulated to get the performance. Several conclusions can be obtained: A turbulence generator pre-treats the pulp suspension before it comes into the impeller. The turbulence generator can disturb the pulp suspension, separate the air and suck the pulp suspension to the impeller. With increase of viscosity, the turbulence generator head decreases. Air separation effect is shown more obviously with increase of air content and rotational speed. With the turbulence generator installed before the impeller, the pump head and efficiency will drop a little because of the pre-whirl. But the influence to pump performance is not so distinguish. The difference mainly exists in the internal flow field.

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