

# Based on Fluent, the numerical simulation of the flow field on the filter disk surface of the rotary filter device

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## ABSTRACT

The rotary screen filter is the most typical basic structural element in rotating mechanical devices. It is being widely applied in various fields of industrial production. Using a spinning disc as the research subject, this study utilizes Computational Fluid Dynamics (CFD) techniques to establish a physical model of the filter disc. Various parameters and their corresponding boundary conditions are set, followed by a comprehensive and detailed three-dimensional numerical simulation of the high-speed rotating disc using the Fluent software platform. The objective is to investigate the effects of disc rotation speed and liquid inlet velocity on the surface flow field, as well as the influence of rotational speed on the attachment of particle impurities to the surface. Finally, the computational results will be visualized and thoroughly analyzed.

## KEYWORDS

Fluent; High speed rotation; Impurities particles; Numerical simulation

## 1. INTRODUCTION

The filter disc is the most typical basic structural element in rotary filtration mechanical devices, which is widely used in fields such as water conservancy and chemical industry. When the filter plate inside the device is fully filled with liquid and is driven by the rotating shaft to rotate at a high speed, it will exhibit fluid mechanics performance that is distinct from when the filter plate is in a static non-rotating or low-speed rotating state [1-4].

On the surface of the high-speed rotating filter disc, the flowing liquid forms a complex fluid flow field. The study analyzed the influence of rotation speed on the flow field over the surface of a high-speed rotating disc and the influence of rotation speed on the formation of filter layer by impurities on the surface of the filter disc. This is of significant importance for guiding the design to meet the requirements of high-speed rotating discs in various fields. The numerical simulation and analysis of the velocity flow field on the surface of a high-speed rotating disc were conducted using the computational fluid dynamics software Fluent platform.

## 2. SIMULATION ANALYSIS

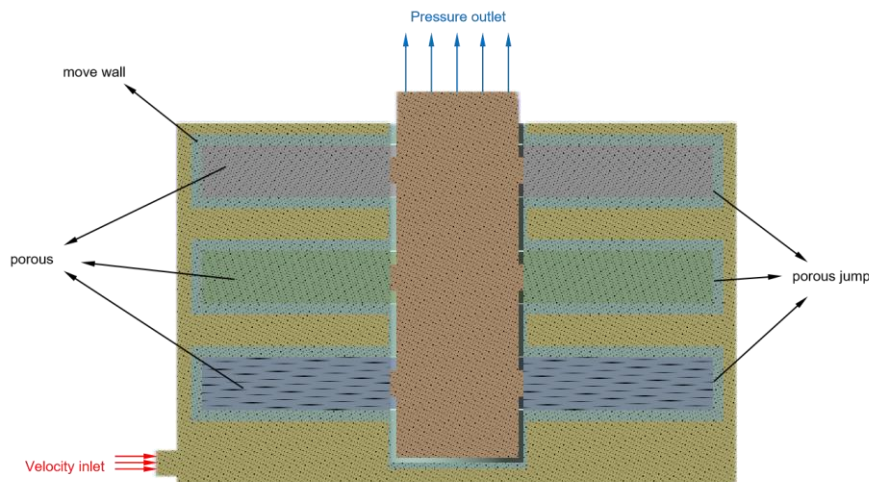
The main steps for simulating and analyzing a high-speed rotating disk based on the computational fluid dynamics software platform Fluent are [5].

1) Based on SpaceClaim preprocessing module, establish the geometry model and carry out meshing and boundary condition settings.

2)Based on the parameter setup of the Fluent post-processing module, calculations are performed and related calculations are made in order to achieve the visualization of the calculation results.

## 2.1. Model building

Based on the SpaceClaim pre-processing module of Fluent software, establish a three-dimensional simulation model for the disc filter device and perform corresponding mesh partition, as shown in Figure 1. At normal temperature and pressure, the liquid inlet is set parallel to the surface of the disc, and the disc surface is always filled with liquid. Separately examine the influences of rotational speed on the fluid mechanics performance of the high-speed rotating disc surface and the effects of rotational speed on the formation of the filter layer composed of impurities particles on the surface of the filter disc.



**Figure 1.** Rotary filter model and grid division

## 2.2. Boundary conditions and calculation methods

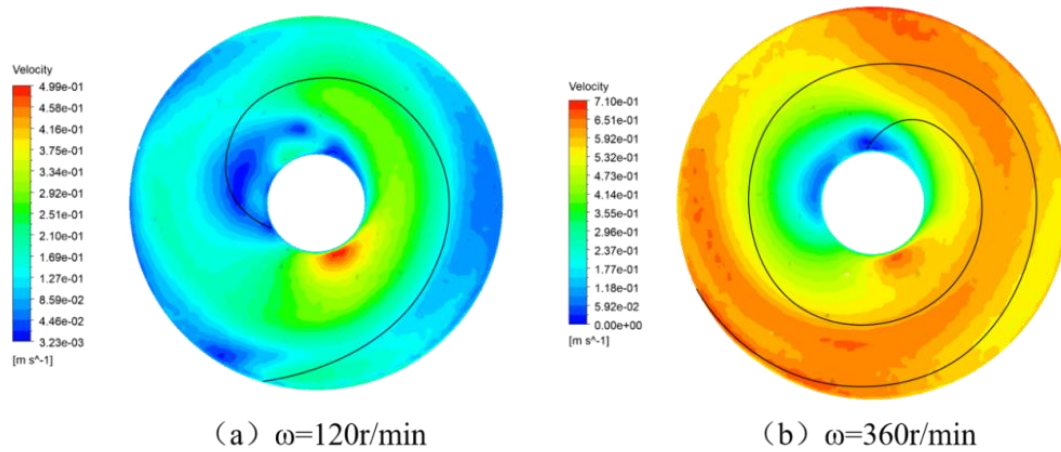
The setting of boundary conditions in Fluent software is crucial. In the simulation, the left side of the device is the liquid inlet, which is set as the velocity inlet boundary. The liquid outlet is connected to the hollow shaft, which is connected to the filter disc. Set it as the outflow boundary. Due to the transient motion of the high-speed rotating filter disk area, its mesh is set as a sliding mesh. In this way, during the calculation process, each pair of elemental regions will slide along the grid interface and rotate with a certain rotational speed. However, the grid in these two regions will not undergo any changes[6]. Adopt Fluent 2022R1 for simulating the velocity flow field on the surface of a high-speed rotating disc. When specifically calculating, a separate implicit solver is used to numerically solve the problem [7]. Because there is an obvious swirling flow field in the rapidly rotating disc. Therefore, the more superior performing "realizable"  $k-\epsilon$  turbulence model with swirl correction is chosen. Compared to the standard model, this model can more accurately represent the flow field characteristics of rotating and vortex flow fields [8].

## 3. RESULTS AND DISCUSSION

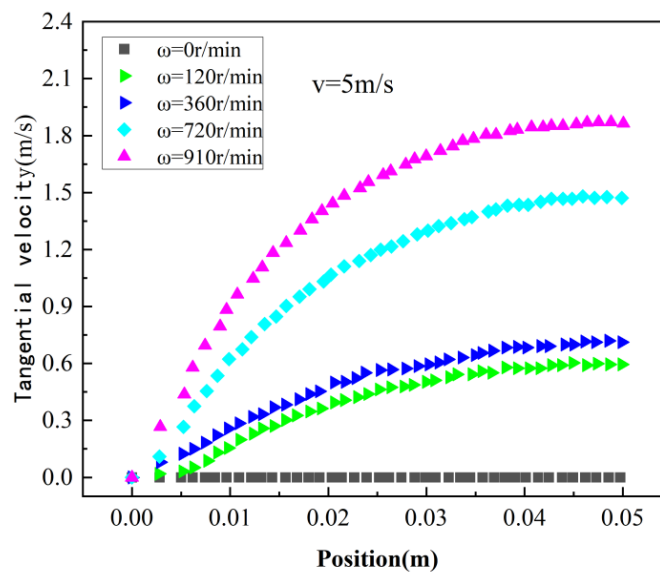
### 3.1. Effect of rotation speed on the surface flow field of filter disc

In order to accurately quantify the flow field distribution of the liquid on the surface of a high-speed rotating disc. We take a tiny droplet from the model center. Observe its flow situation on the surface of the disc. As shown in Figure 2, the motion trajectory of the tiny liquid droplet with different rotation

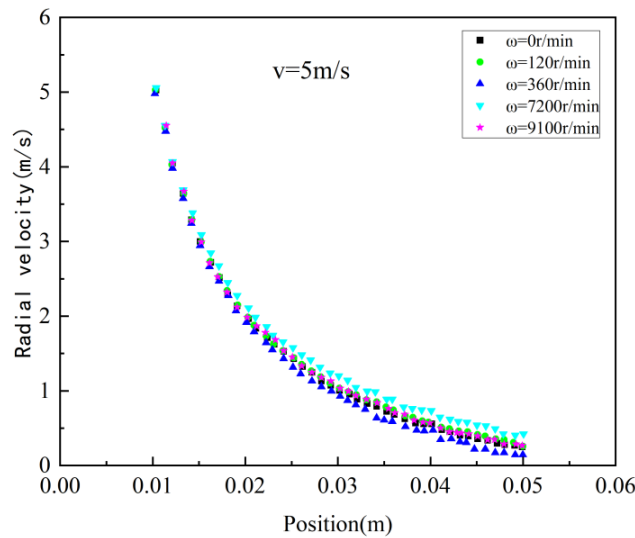
speeds is taken with the filter disk as the reference system. The tangential, radial, and total velocity curves of the droplet with reference to the filter disk are shown in figures 3, 4, and 5, respectively.



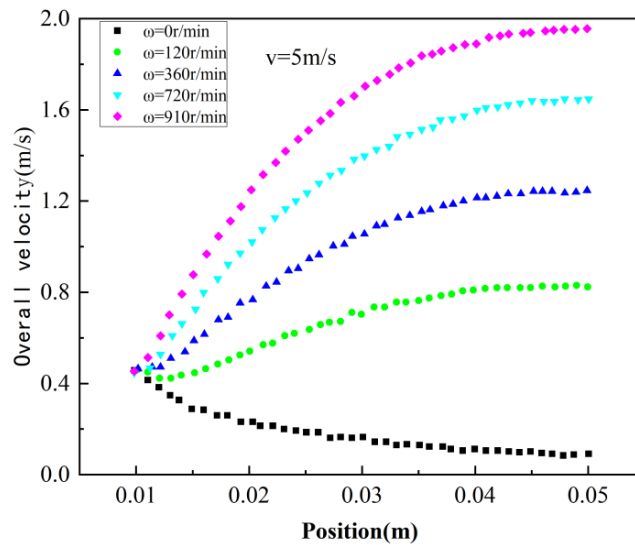
**Figure 2.** Trajectory of droplets using the filter disk as the reference frame at different rotational speeds



**Figure 3.** Tangential velocities of droplets using the filter disk as the reference frame at different rotational speeds



**Figure 4.** Radial velocities of droplets using the filter disc as the reference frame at different rotational speeds

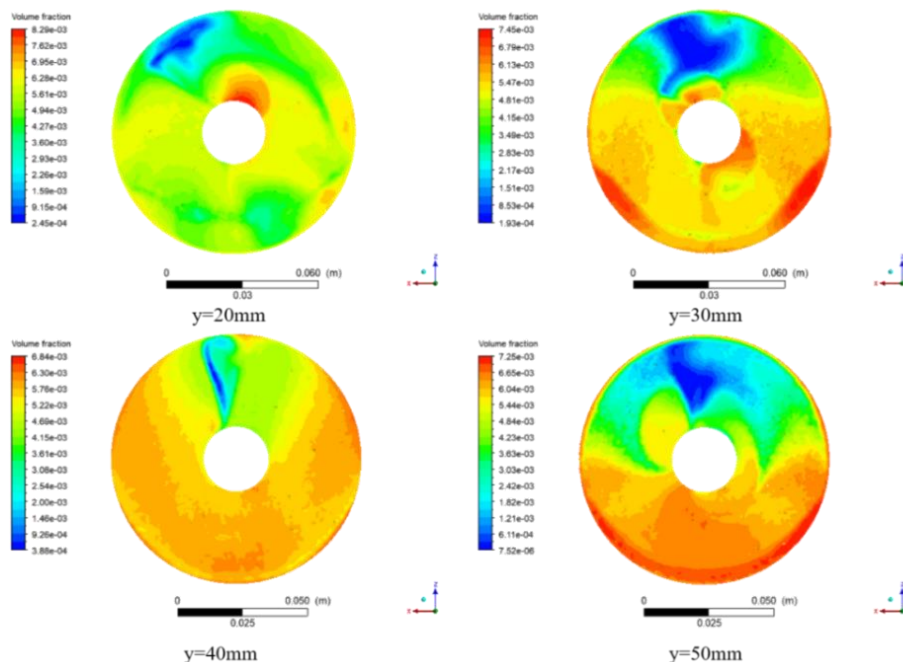


**Figure 5.** Total velocities of droplets using the filter disc as the reference frame at different rotational speeds

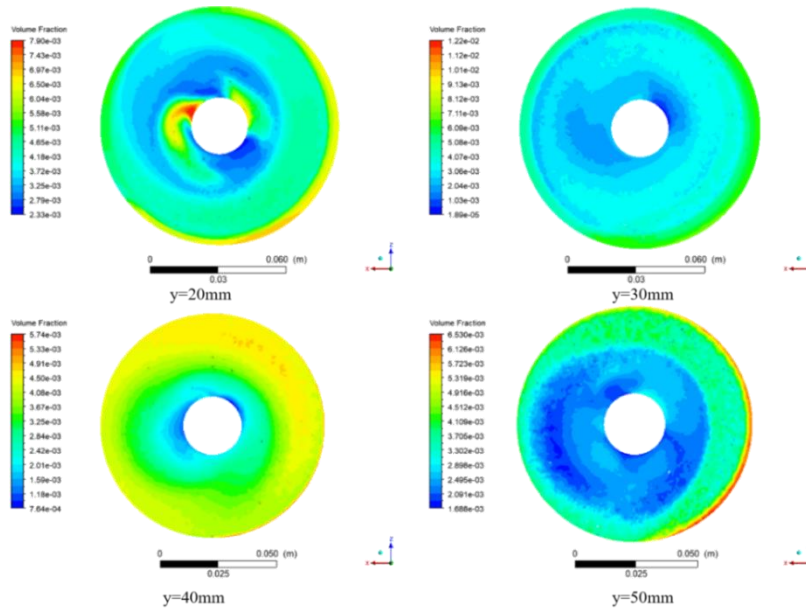
With the reference frame being the filter medium disc. The movement path of small droplets on the surface of the filter plate will become longer as the rotational speed increases. From the perspective of speed curve, there exists a strong positive correlation between tangential speed and rotational speed. This is because the centrifugal force exerted on the liquid on the surface of the filter disc will increase as the rotational speed increases. This is because the centrifugal force exerted on the liquid on the surface of the filter disc will increase as the rotational speed increases. This is due to the collision between tiny droplets in a rapidly rotating disc, which will result in energy loss. So the speed will decrease, in accordance with the law of conservation of energy. The overall speed curve increases with the increase of the rotational speed, and is similar to the tangential speed curve. Explain that centrifugal force generated by high-speed rotation plays a dominant role in the entire flow field.

### 3.2. Analysis of the volume fraction distribution of impurity particles on the surface of the filter disc

Intercept the gaps between the filter discs, namely the upper surface at  $y=20\text{mm}$ , the lower surface at  $y=30\text{mm}$ , the upper surface at  $y=40\text{mm}$ , and the lower surface at  $y=50\text{mm}$ . Analyze the volume fraction of the particles on four surfaces. As shown in Figure 6, the cloud map of the volume fraction of particles on the gap surface during dead-end filtration. From the figure, it can be observed that the fluid flows into the device from the negative direction of the Z-axis at a certain velocity, and after colliding with the wall, it diffuses towards the top of the device under the effects of the reaction force and initial velocity. Resulting in the device's top being far away from the entrance end, impurity particles gather here to form a highlighted area as shown in Figure 6,  $y=50\text{mm}$ . And keep this state gradually spreading throughout the entire device. Due to the aggregation of impurity particles far away from the entrance end, a thicker filter cake layer is formed and continues to accumulate. The serious weakening has greatly reduced the filtration flux at that location, resulting in the affected filtration efficiency at that location. And under the application of a certain rotation speed, this condition is significantly improved. As shown in Figure 7, it is the volumetric fraction distribution cloud diagram of impurity particles at a certain rotational speed. From the picture, it can be seen that when the fluid enters the device with a certain initial velocity, impurities particles will still gather at one end. However, under a certain rotating speed, the filter disk does not disperse particles like in Figure 3-2, starting from one end, but instead disperses relatively uniformly towards the edge of the filtration chamber due to the effects of inertia and centrifugal force. And gradually adsorb and filter from the edge of the filter disc to the center with the porous filter disc. Due to the relatively even distribution, impurity particles are allocated to various positions of the filter disc. The thickness of the filter cake formed on the surface of the filter plate is basically the same. Improved the issue of uneven distribution of filtration flux on porous media and extended the required backwashing time for the device.



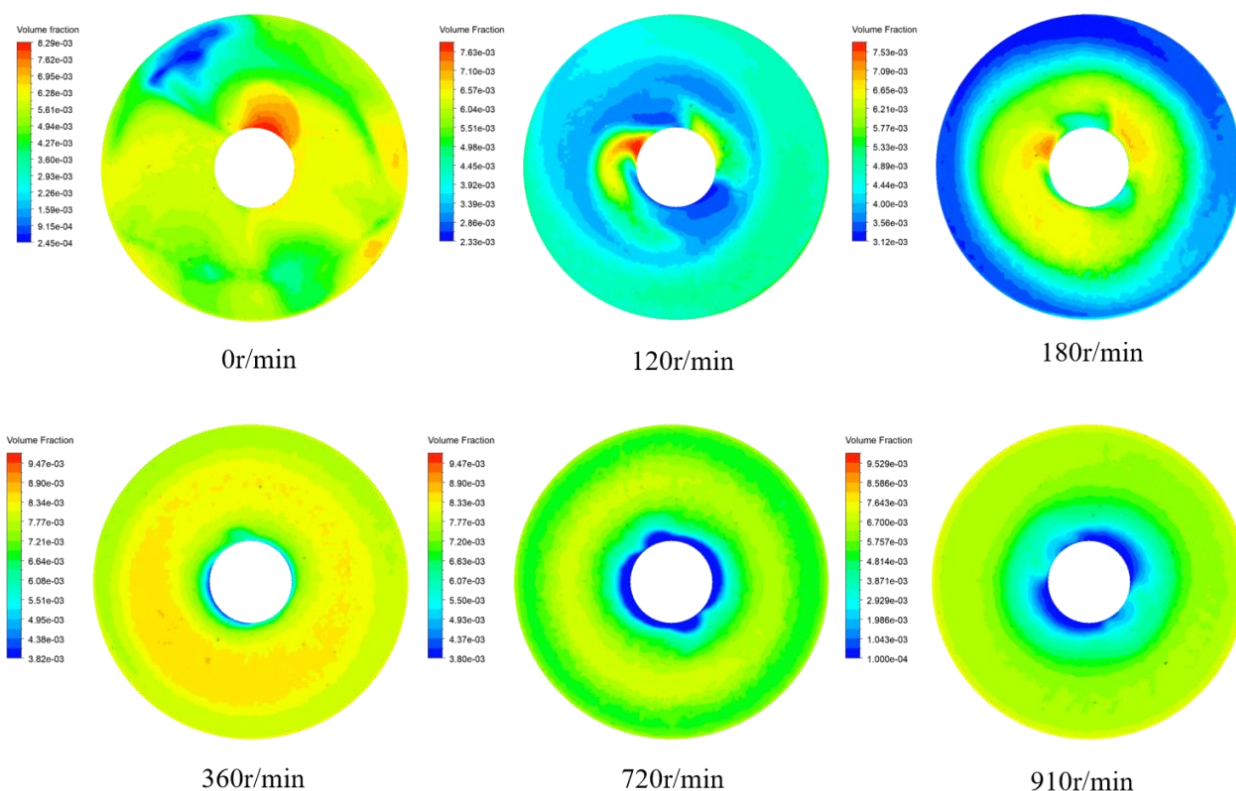
**Figure 6.** Cloud image of particle volume fraction distribution during dead-end filtration



**Figure 7.** Cloud map of particle volume fraction distribution at a certain rotational speed

### 3.3. Influence of rotation speed on the distribution of impurity particles on the surface of the filter disc

As shown in Figure 8, the distribution of impurity filter layers on the surface of the filter disc under different speeds is fixed while other parameters remain unchanged. From the diagram it can be seen that the thickness of the impurity filter cake formed on the surface of the filter disc is uneven and irregular, and can only be determined by the direction of the liquid inlet. When the speed is 120r/min, there will be changes in the filter cake layer at the center and the edge of the filter disc, and the thickness of the filter layer at the edge gradually becomes even. The rotating shear force at the edge of the filter plate is greater than at the center, resulting in a thicker filter cake layer at the center compared to the edge when the speed is 180r/min. When the speed reaches 360r/min, the entire filter surface thickness of the filter cake is basically uniform, achieving stable operation. When the rotation speed is greater than 360 r/min, the filter cake layer formed by impurity particles remains in a uniform distribution state, only the thickness of the filter layer becomes thinner. From this, it can be concluded that at 360r/min, the filter cake layer on the surface of the filter disc is distributed relatively evenly, and the filtration efficiency reaches its peak.



**Figure 8.** Distribution of impurities on the surface of the filter plate at different rotational speeds

#### 4. CLOSING REMARKS

The rotating filtering disc is being increasingly widely applied in the field of solid-liquid separation in industrial production. In order to pursue its design optimization. One of the best methods undoubtedly is to accurately numerically simulate and analyze its working process through Computational Fluid Dynamics (CFD) related software. The flow field characteristics of multiphase flow on the surface of a high-speed rotating filter were investigated using Fluent software. And discuss the influence of speed on the flow field and the influence on the formation of the filter layer for filtering impurity particles. The result shows that, on the surface of the high-speed rotating filter disc, its tangential velocity field is controlled by the rotation speed. And the rotation speed has a direct correlation with the impurities layer formed on the surface of the filter disc, the larger the rotation speed, the more uniform the impurity particles in the filter cake layer are formed. At a speed of 360r/min, the uniformity is achieved, and the greater the speed, the more obvious the average distribution and the thinner the filter cake layer. This is of great significance for guiding the design of high-speed rotating filter discs.

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