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Internal Flow Field Analysis of Twin-Screw Compressor Based on Three-Dimensional Numerical Simulation

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ABSTRACT

Twin-screw compressor is a kind of rotary positive displacement pump with excellent performance. Due to its advantages of reliable operation, high efficiency, low noise and multiphase mixed transportation, it has been widely used in the fields of energy power, biomedicine, refrigeration and air conditioning, petrochemical industry, industrial construction and other rudder fields. In recent decades, although the study of screw compressor is more in-depth, but the three-dimensional flow field simulation design of twin screw compressor still needs breakthrough. In this paper, 3d flow characteristics of twin screw compressor are studied based on CFD numerical simulation. In this paper, CFD software is used for numerical simulation of twin screw compressor, and the distribution of pressure cloud, temperature cloud and velocity cloud of internal flow field is obtained.

Keywords: Twin-Screw Compressor, Three-Dimensional Numerical Simulation, CFD

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1. Foreword

In recent years, with the rapid development of CFD simulation software, screw compressor has also been a rapid breakthrough [1-2]. However, leakage, suction and exhaust flow field characteristics and other problems in the working process of screw compressor restrict the development of screw compressor [3]. The main factors affecting the performance of screw compressor are inlet and exhaust pressure, inlet temperature, rotational speed, clearance size and lubrication mode, etc., and the change of any factor has a certain degree of influence on the performance [4-6]. Structured grid division of twin-screw compressors has always been a difficult problem. In view of the grid division problem, Huang Si and other multidimensional scholars carried out numerical simulation using two-dimensional model and dynamic grid technology, and obtained the internal flow field variation with time [7-10].

To sum up, numerical simulation of internal flow field is an important way to study the performance of twin-screw compressor. Although the CFD numerical simulation is not completely consistent with the experimental results, it can greatly reduce the time and cost of compressor development. In the future, mathematical model methods and details should be continuously improved to improve the accuracy of simulation and the actual more consistent.

This paper will introduce the dynamic grid model and solution Settings, simulation flow and exhaust pressure and other results; The distribution of pressure field, temperature field and velocity field were introduced and flow field was analyzed.

2. Numerical Model

The complexity of the physical model of twin screw compressor determines the difficulty of numerical simulation, and the simplified model is very important [11]. As the rotor speed is fast, the requirements for mesh deformation, reconstruction and negative volume are very high, and the general unstructured mesh may not be qualified, so structured mesh is adopted in this paper. The use of equations and boundary adjustment can also lead to large differences in simulation results.

2.1 Physical Model

The mathematical models of positive displacement compressors, turbine compressors and twin-screw compressors can all be simplified into two dimensions. As shown in Figure 1, the two-dimensional simplified model of the N56 rotor compressor (the number of teeth of the positive rotor is 5, and the number of teeth of the negative rotor is 6) is presented.

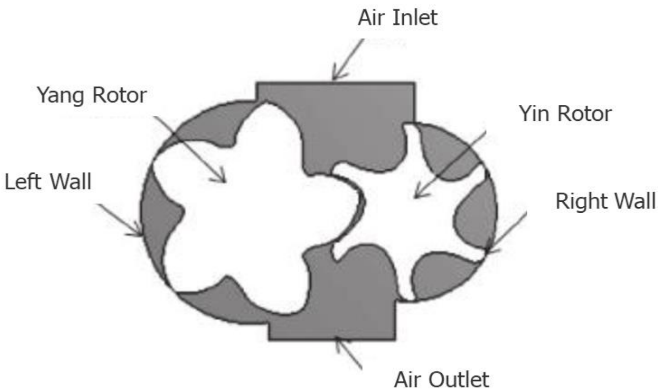

Figure 1. 2D Model of Twin-Screw Compressor

The advantage of the two-dimensional model is that the model and grid are simple, and there is almost no problem with the grid in the dynamic grid, and the numerical simulation calculation is small, so the results can be obtained quickly.

2.2 Three-Dimensional Model

Due to the complex internal structure of the twin-screw compressor, the two-dimensional model cannot reflect the flow of liquid in the actual cavity, while the three-dimensional model can intuitively see the flow and pressure changes in the volume of each element, and is more close to the actual situation, convincing. Figure 2 shows several parts of the 3D model: air inlet watershed model, elementary volumetric fluid domain and body watershed model.

The numerical results simulated by the THREE-DIMENSIONAL model are more accurate, and the flow field distribution and pressure change of a specific part can be obtained. The working mechanism of screw compressor can be deeply understood, and the distribution of internal flow field can be accurately understood.

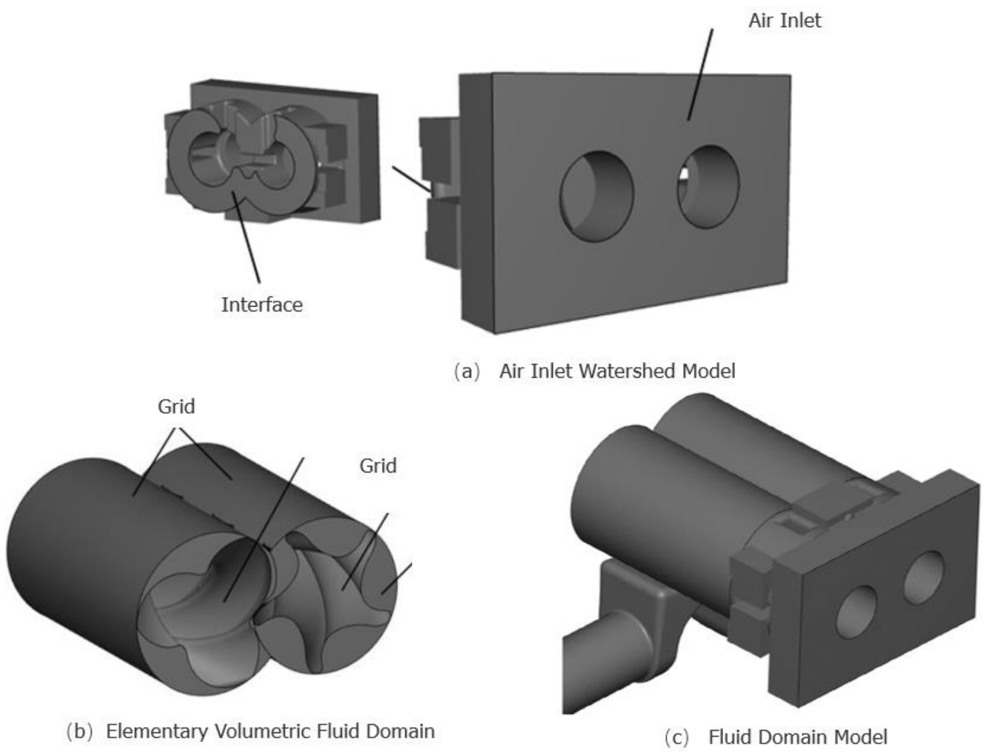

Figure 2. Each Part of the Fluid Domain

Normally compressor outlet is shorter, if carried out in accordance with the compressor entity modeling, is used to numerically simulate the in exports will produce strong backflow, affect the normal flow of the gas lead to export the pneumatic pressure difference between the actual far away, so special modeling on exports in order to simplify the model, the export model is shown in Figure 3.

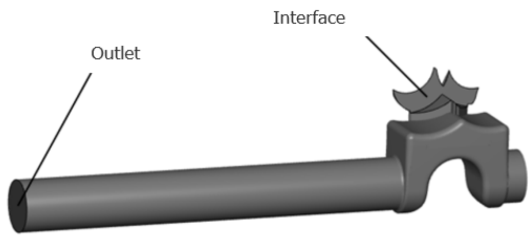

Figure 3. Outlet Model

2.3 Grid Settings

Grid is the smallest unit of fluid computing, and grid partitioning is the pre-processing of numerical simulation. It requires that each grid is divided to satisfy the governing equation and calculation equation, and multiple grids connect space into a computing domain, so the accuracy of grid also determines the calculation accuracy to a large extent.

Twin-screw compressor model in the rotor movement process, the mesh will also follow the movement, but the mesh nodes and the overall number remains the same, when the mesh is broken, to have a new mesh to replace, that is, the mesh also has to undergo deformation, distortion, reconstruction process, the quality of the mesh is relatively high. The unstructured mesh is prone to negative volume in deformation, which will lead to the failure of simulation. Under normal operation, the speed of Yin and Yang rotors is very fast. In order to ensure the consistency of each cycle and reduce the error, a structured grid with better adaptability is needed to meet the accuracy requirements.

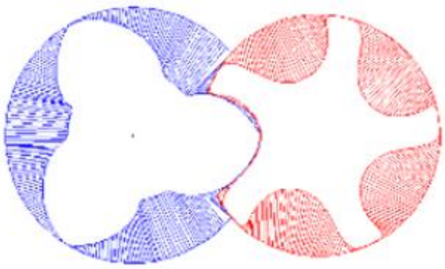

Figure 4. Rotor Watershed Interface Grid Diagram

Figure 4 is the simplified process of generating working chamber watershed grid by CFD software. In order to generate the grid of rotor watershed, a high-precision smooth structure grid needs to be established and many difficulties need to be overcome. The following is a single interface mesh generation process in rotor basin.

a) Input profile data of the Yin and Yang rotors to determine basic parameters such as the number of teeth and tooth spacing of the rotors. Taking the Yang rotor as an example, the five teeth of the Yang rotor can be regarded as five periods, and 240 grid nodes are set on the profile of each period.

b) Generate virtual curves dividing rotor profiles, namely rack lines, to better determine the clearance between rotors and avoid interaction during mesh generation.

c) The Yin and Yang rotor domains are discretized isometric, and the mesh of each section is kept consistent to ensure the mesh quality.

d) Generate meshes for each section first, and then generate O-structured volume meshes from surface meshes.

3. Analysis of Internal Flow Field

3.1 Temperature Field Analysis

Figure. 5 is the cloud diagram of temperature distribution in the whole basin of twin-screw compressor. The inlet temperature is set at 298.15K. It can be seen from the Figure that the working temperature of the rotor meshing area and the outlet is higher than that of other areas, mainly because the friction between the gas and the rotor is more intense at the interface of the Yin and Yang rotors, and the rotor compresses the gas at the meshing point, which also causes the temperature to rise. Under normal circumstances, the operating temperature of the screw compressor should not be too high. If the temperature is too high, the thermal expansion of the Yin and Yang rotors may occur, affecting the normal operation of the compressor.

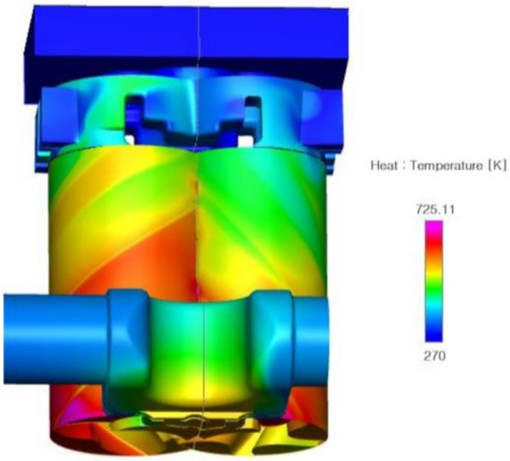

Figure 5. Temperature Field Cloud Diagram of Compressor Basin

Figure. 6 is the temperature distribution cloud diagram of the yin-yang rotor. The temperature of the yin-yang rotor is relatively high, mainly because of the constant impact of gas on the rotor and the intense friction between gas and rotor.

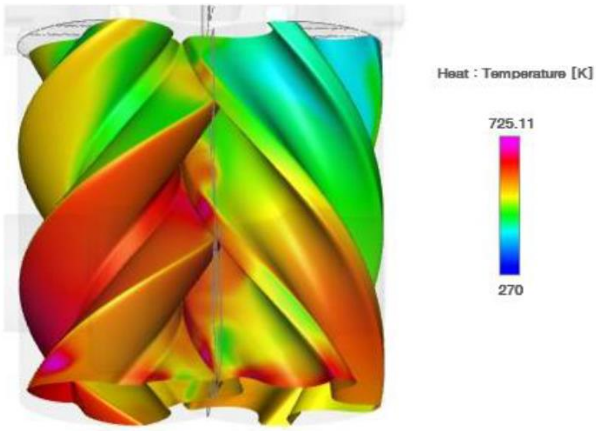

Figure 6. Temperature Field Cloud Diagram of Yin and Yang Rotor

In the actual working condition, the heat dissipation of the compressor is a very difficult problem, but also an index to evaluate the performance of the compressor. If the compressor temperature is too high, it will directly lead to the collision of the Yin and Yang rotors and the direct contact of the shell, leading to the damage of the compressor structure. Therefore, it is very important to design the cooling system of the compressor.

3.2 Velocity Field Analysis

Figure. 7 shows the velocity distribution of the internal flow field in the working process of the twin-screw compressor. It can be seen from the Figure that the fluid velocity is very high at the top of the rotor tooth, the clearance between the teeth, the meshing of the rotor, the leakage triangle and the outlet.

The gap between the teeth, the speed of the tooth tip, the meshing part of the rotor and the leakage triangle are mainly due to the high pressure when the gas flows from these places, but the flow gap is very small, resulting in the flow speed here is higher than other places. The velocity at the exit is large, mainly because the pressure of the gas is several times of the external atmospheric pressure after the rotor is pressurized for many times. Therefore, the eddy current intensity at the exit is higher than that at the entrance, and the flow speed will be very large.

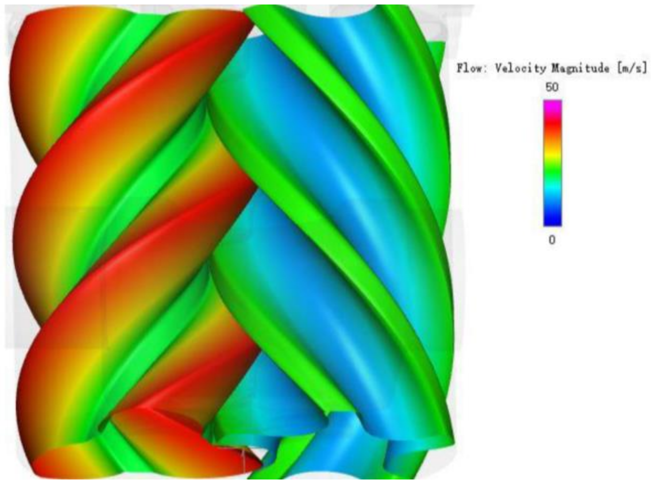

Figure 7. Velocity Field Cloud Diagram of Compressor Basin

It can be seen from the Figure that the gas flow at the inlet is relatively regular, but the gas disturbance at the outlet is very severe, which is mainly due to the increased pressure of the gas after compression and the high velocity at the outlet, resulting in high intensity of gas vortex at the outlet.

3.3 Pressure Field Analysis

The working process of the twin screw compressor includes: suction, compression, exhaust three processes, the process of Yin and Yang rotor constantly experience meshing, separation cycle, volume between teeth also experience increased, decreased cycle, we can observe the pressure cloud of the rotor working chamber to intuitively understand the process.

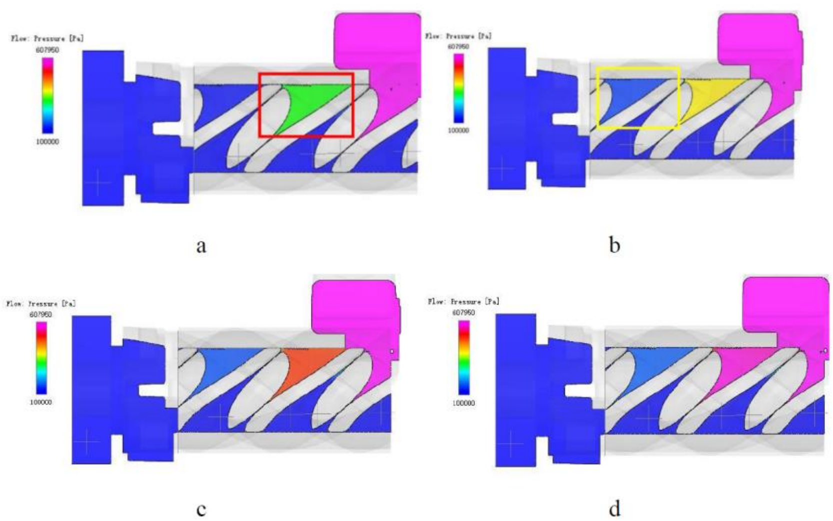

Figure 8. Pressure Field Cloud Diagram of Section at Different Time

The Figure above only shows the pressure cloud diagram of the working chamber, and the internal pressure cloud diagram cannot be observed. For this reason, a plane is made along the Yin and Yang rotor lines. Figure.8 is the pressure distribution cloud diagram on the interface.When the speed is 6000rpm, a working cycle process in this case is 0.01 seconds. Figure. 9 is the pressure cloud diagram in the working process of the twin-screw compressor.

When we can see from the picture began to exhaust pressure maximum, with volume and exhaust end connected between your teeth begin and exhaust volume between the tooth also gradually decreases, and the next exhaust volume between tooth pressure gradually increases, when the first exhaust process at the end of the next volume replacement between teeth, reciprocating cycle.

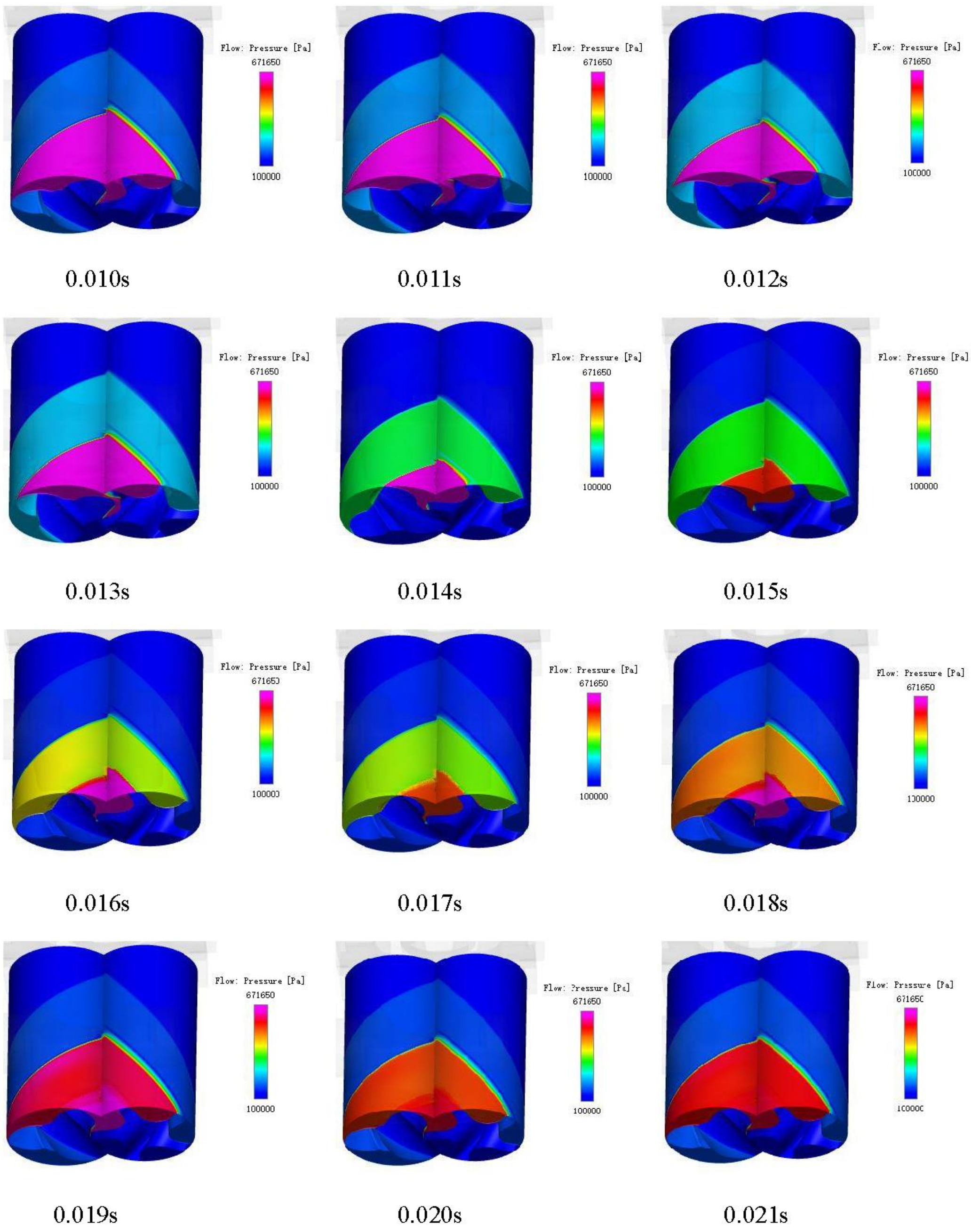

Figure 9. Pressure Field Cloud Diagram of Compressor Basin

We can see that the pressure increases gradually in the red box, which shows that the gas pressure increases gradually in the process of gas compression. The volumetric pressure in the yellow box also increases gradually, showing that the rotor gradually engages during the suction process of the compressor, and the pressure also increases gradually.

4. Conclusion

In this paper, N56 rotor is taken as an example to analyze the internal flow field of twin-screw compressor based on 3d numerical simulation, and the parameters of inlet and outlet flow rate, exhaust pressure, exhaust temperature and drainage velocity are obtained. The pressure field, temperature field and velocity field inside the twin-screw are analyzed by computational domain. It provides reference for the follow-up research and design of twin screw compressor.

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