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MODELING AND COMPUTATION OF COMPUTATIONAL FLUID DYNAMICS FOR WATER PRODUCTION OF INTERNAL PRESSURE SERIES MBR SYSTEM

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ABSTRACT

In the Membrane Bio-Reactor waste-water treatment system,The water production of membrane modules is an important parameter to measure the working efficiency of MBR system, while the internal pressure series MBR is a common membrane module connection method. Therefore, the calculation and analysis of the water production of internal pressure series MBR system by computational fluid dynamics is carried out. In the analysis process, the geometric model of the internal pressure series MBR system is first established by the CFD preprocessor and the mesh is divided. Then the CFD solver is used to calculate the water production of the model. Finally, the CFD post processor is used to present the calculation results in an image. On this basis, this paper has carried out a large number of experimental analysis. In the analysis process, this paper compares the calculation results of the solver with the actual operating system results of MBR. The comparison results show that the calculation results of the solver are basically consistent with the actual water production of membrane modules, and have higher calculation accuracy. It achieves the purpose of accurately calculating the water production of membrane modules, and solves the problem of measuring the working efficiency of MBR system by calculating the water production of membrane modules. Which has certain reference value for MBR engineering design and research.

KEYWORDS: Computational Fluid Dynamics, Membrane Bio-Reactor, Internal pressure type, tandem, Water production

INTRODUCTION:

In recent years, with the development of science and technology, many waste-water treatment technologies have emerged, and the treatment of sewage by using the Membrane Bio-Reactor system is one of the technologies. The membrane bio-reactor (MBR) is a new type of waste-water treatment technology that combines a biological treatment unit with a membrane separation unit to replace the sand filter and secondary sedimentation tank in traditional biological treatment technology with a membrane module[1].The high activity sludge concentration is maintained in the biological reaction container while reducing the footprint of the waste-water treatment plant. When the MBR system treats waste-water, it is more effective than conventional waste-water treatment technology. But it is not enough for the treatment effect, and it also needs high processing efficiency so that it can be widely used in actual waste-water treatment projects. In the MBR system, the amount of water produced by the membrane module system can be a good measure of the working efficiency of the MBR system, and the internal pressure series MBR is a common connection method of the membrane module. Therefore, the membrane module of the internal pressure series MBR system is taken as an example, and the CFD is used to model and simulate the system water production.

In the research process, the geometric model of the membrane module system is first established by calculation of the preprocessor and structured meshing is performed. Then, the water production of the membrane module is accurately solved and calculated by calculating the built-in algorithm of the solver. Finally, the post processor is used to present the calculation result as an image. After a large number of experiments, the experimental results show that the CFD model can not only simulate the deployment of MBR system membrane components, but also describe the working environment and working process of the MBR system more intuitively, and the accuracy of the calculation results is higher. Therefore, the model of the internal pressure series MBR membrane module built by CFD is reliable, and solves the problem of measuring the working efficiency of the MBR system by using the amount of water produced by the membrane module.

1. MEMBRANE ASSEMBLY AND ITS OPERATION AND CONNECTION:

1.1 Hollow fiber membrane:

The hollow fiber membrane refers to a membrane that has a shape that is fibrous and has a self-supporting action. The hollow fiber membrane is a fiber filament processed into a hollow inner cavity by using polysulfone or dimethylacetamide as a raw material, and is divided into a high permeability polymer to have selective permeation characteristics. Since water vapor, hydrogen, ammonia, and carbon dioxide permeate faster, methane, nitrogen, argon, oxygen, and carbon monoxide penetrate slowly, which results in faster separation from permeation[2].

In the membrane module of the MBR system, the common membrane module has a flat membrane module and a hollow fiber membrane module, but has two advantages compared with the flat membrane module hollow fiber membrane module: First, the price of the hollow fiber membrane module Low cost, which is favorable for frequent replacement, and the cost of the plate membrane module is high. Second, when a small part of the hollow fiber membrane module is broken, the operation of the membrane module system is not affected, because the hollow fiber membrane module is composed of thousands. Tens of thousands of membrane filaments are formed, and when the membrane membrane module is damaged, the membrane module system cannot be operated, so the membrane module must be replaced; therefore, we use a hollow fiber membrane module in this paper[3].

1.2 Internal pressure type MBR system and external pressure type MBR system:

Classification from the operating mode of the MBR system can be divided into an internal pressure type MBR system and an external pressure type MBR system[4]. When the internal pressure type MBR system is operated, the waste-water which has been preconditioned flows from one end of the hollow fiber tube, the permeate flows out from the tube wall, and impurities such as the large particulate matter flow out from the other end of the hollow fiber tube, as shown in Fig. 1; During operation of the MBR system, the waste-water which has been preconditioned flows from the hollow fiber tube wall, and permeate flows out from both ends of the hollow fiber tube. Impurities such as the large particulate matter are trapped on the tube wall, as shown in Figure 2. In this paper, we choose Internal pressure type MBR system[5].

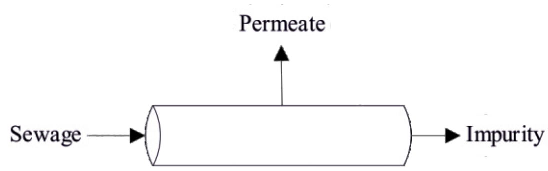

Figure 1: Internal pressure type MBR

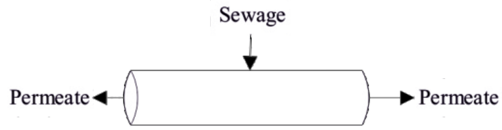

Figure 2: External pressure type MBR

1.3 Series connection method and parallel connection method:

Classification from the connection mode of the MBR system membrane module can be divided into a series connection method and a parallel connection method[6]. The tandem connection method is to arrange each membrane module in series[7]. When the system is running, the waste-water which has been preconditioned passes through each membrane module one by one, and then the permeate is collected, as shown in Fig. 3. The parallel connection method is to arrange each membrane module in parallel[8]. When the system is running, the waste-water which has been preconditioned passes through each membrane module at the same time, and then the permeate is collected, as shown in Fig. 4, the two connection methods are equivalent. In this paper, we select the series connection method[9].

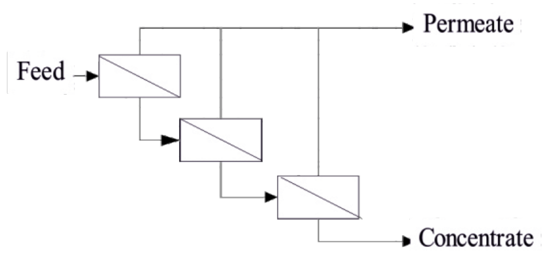

Figure 3: Series connection method

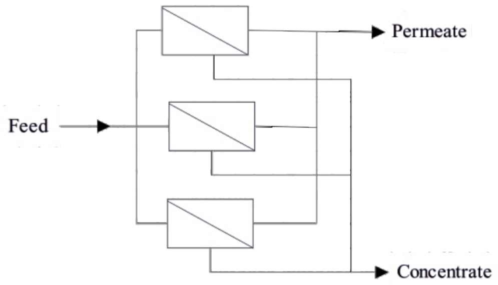

Figure 4: Parallel connection method

2. THE BASIC COMPONENTS OF CFD SOFTWARE:

There are many CFD simulation soft-wares on the market at present. The simulation software we selected in this paper is ANSYS16.0. ANSYS16.0 consists of three parts, namely CFD preprocessor, CFD solver and CFD post processor[10].The relationship between these three parts is shown in Figure 5. The main function of preprocessing is to establish geometric models and computational meshing of geometric models. The methods for calculating meshing are structured meshing and unstructured meshing. Which specific method of division should be decided according to the specific situation, I used the ICEM CFD software in ANSYS for preprocessing[11]. The function of the calculation solver is to read the geometry model of the preprocessed mesh, check the mesh and set the boundary conditions, and finally use its built-in algorithm to perform accurate calculations and generate residual curves. In this paper, we use ANSYS Fluent software to perform calculations. The post-calculation function is to display the data calculated by the calculation solver in the form of graphs or curves, such as cloud maps, streamlines, etc. In this paper, we use the CFD post processor software in ANSYS to perform post-calculation processing.

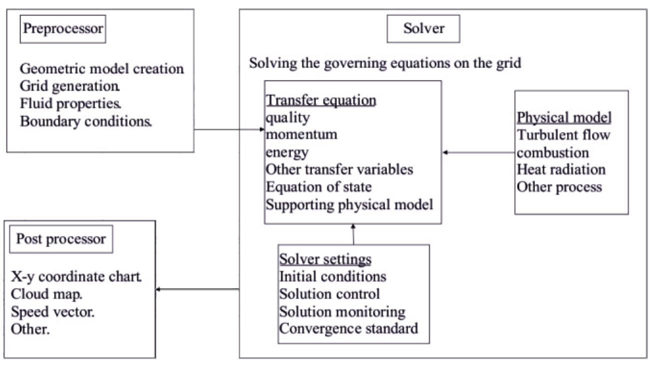

Figure 5: The internal relationship of the three major components of CFD

3. ESTABLISHING CFD GEOMETRIC MODEL AND EXPERIMENTAL ANALYSIS OF MBR:

3.1 ICEM CFD establishes internal pressure series MBR geometric model and meshing:

In the experiment, we use ICEM CFD software to build the geometric model shown in Fig. 6. This model simulates the model of the series internal pressure MBR system (The model shown in Fig. 6 is a one-stage series, and can also be multistage series.). In the model shown in Fig. 6, each large cylinder connected to the regular hexahedron represents each hollow fiber tube, and the small cylinder on each large cylinder represents a small hole in the wall of each hollow fiber tube (There are many small holes in the tube wall. Because we research the U-shaped membrane module from a microscopic point of view: we only research a single membrane filament and only small hole. Only one small hole can be opened here, and the final calculation result is the same. There are two reasons why one of the small hole models and the multiple small hole models have the same calculation results: Firstly, because the mass distribution of the hollow fiber material is uniform, and we will set the calculation method of the solver to the mean mode of the face: the solver sums the calculation results at all the small holes in the calculation, and then the result of the summation is divided by the number of small holes. Therefore, the model of only one small hole and the model of a plurality of small holes have the same calculation results. Secondly, since the particle diameter of the suspended solids in the waste-water is smaller than the diameter of the small holes in the pipe wall, only one small hole model and a plurality of small hole models can intercept the suspended solids in the waste-water: At the exit of the model, only one small hole model and multiple small hole models all have the SS volume fraction that tends to zero. Therefore, the model of only one small hole and the model of a plurality of small holes have the same calculation results.)[12]. When the MBR system is running, the waste-water flows into the hollow fiber tube from the inlet of No.1~4, and the permeate flows out from the mouth of No.5~12. The impurities such as the solid impurity particles are washed away in the tube, and finally flow out from the mouth of No.13~16. After the geometric model is established, we mesh the geometric model of Figure 6.

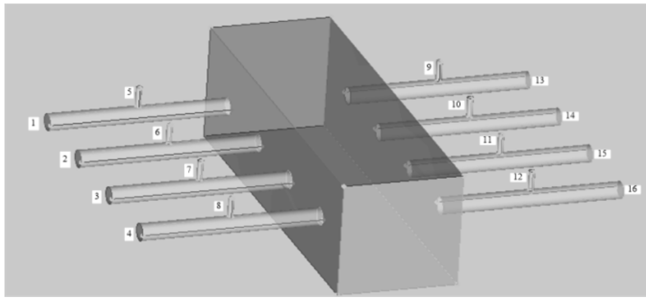

Figure 6: Series internal pressure MBR geometry model

Computational meshing is divided into structured meshing and unstructured meshing. Structured meshing include quadrilateral in two-dimensional space and hexahedron in three-dimensional space. Unstructured meshing include triangles in two-dimensional space and tetrahedrons in three-dimensional space, here we use structured meshing. The O-shaped segmentation is used for the cylindrical part in the model, and the result of the O-type segmentation is shown in Fig. 7. The final mesh is divided as shown in Fig. 8. After the meshing is finished, we output mesh format file, and then use the Fluent software for calculations[13].

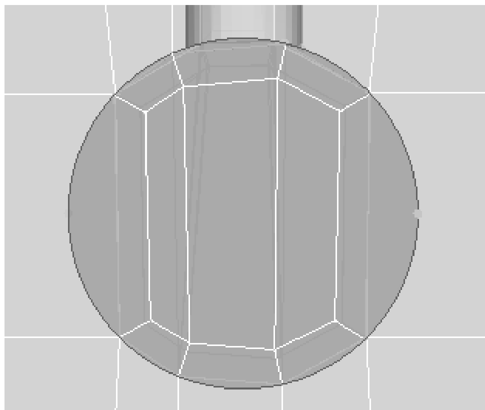

Figure 7: O-type segmentation results

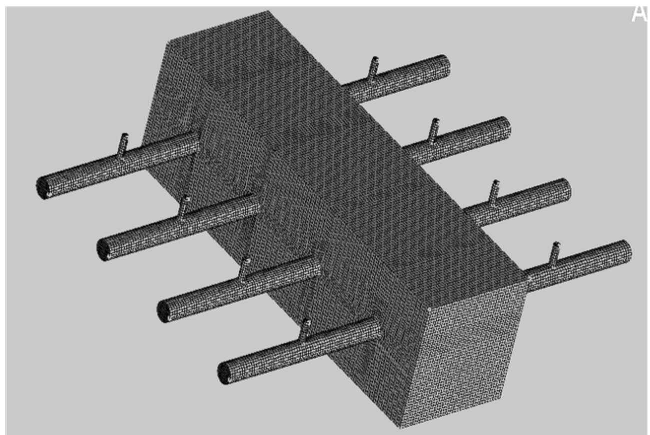

Figure 8: Final geometric model

3.2 Fluent solver calculation:

Import the above mesh file, check the grid to ensure that the minimum volume is not negative, and select the steady-state pressure-based solver by default; select the calculation model in the model node, select the laminar flow model here; select water as the fluid in the materials node Material; set the boundary condition in the boundary condition node, where I set the mass flow inlet boundary as the entry boundary condition and the free outflow boundary as the exit boundary condition. After these tasks are completed, select the solution algorithm and set the residual curve below.

There are 4 different solving algorithms in the Fluent solver, namely SIMPLE, SIMLEC, PISO and Coupled. The first three algorithms are separate algorithms, the Coupled algorithm is the coupling algorithm, here I choose SIMPLE algorithm, pressure selection PRESTO!, momentum The equation selects the Second-order welcome style[14]. Set the traffic monitoring window at the exit (Mass Flow Rate is positive for inflow, negative for outgoing), then set the number of iterations 500 times to start calculation. After calculation, the residual curve and outlet flow are shown in Figure 9 and Figure 10. (Because the filtered wastewater is flowing out of the membrane module, the Mass Flow Rate in Figure 10 is negative.) From the experimental results, we can see that when iteration is 40 times, The residual curve converges to 10^-3, and the calculation reaches convergence and stops automatically. Finally, we saves the file for post-processing.

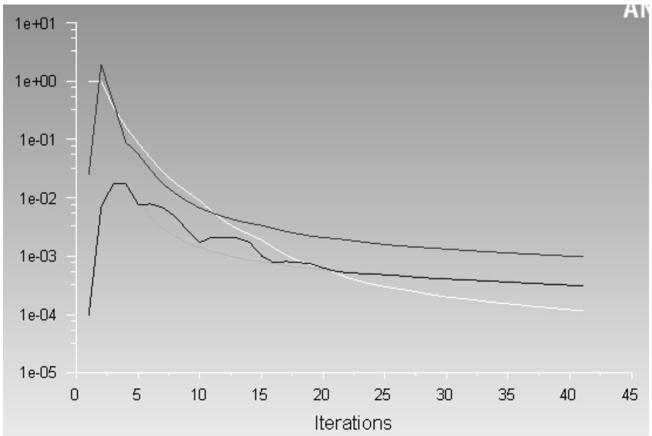

Figure 9: Residual curve

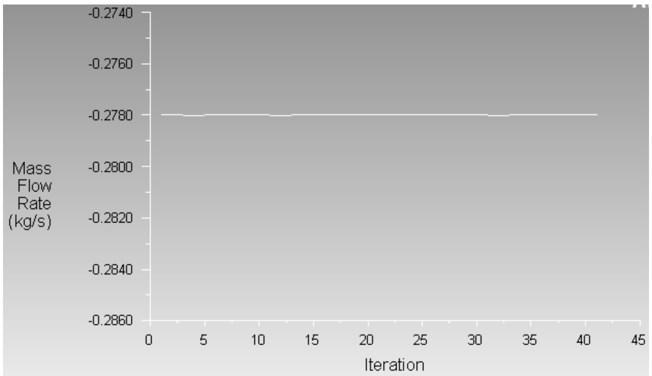

Figure 10: Export flow chart

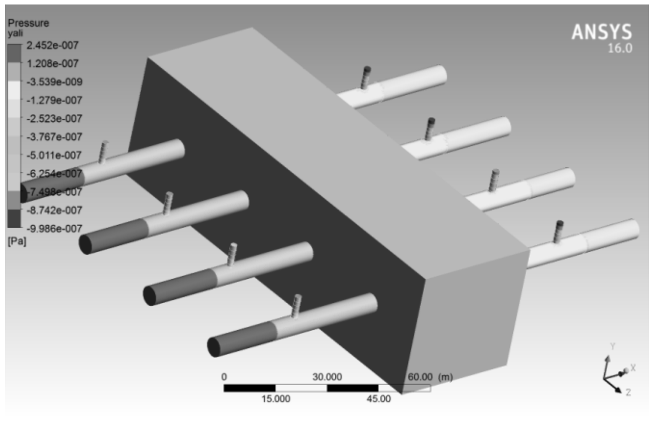

Figure 11: Pressure cloud map

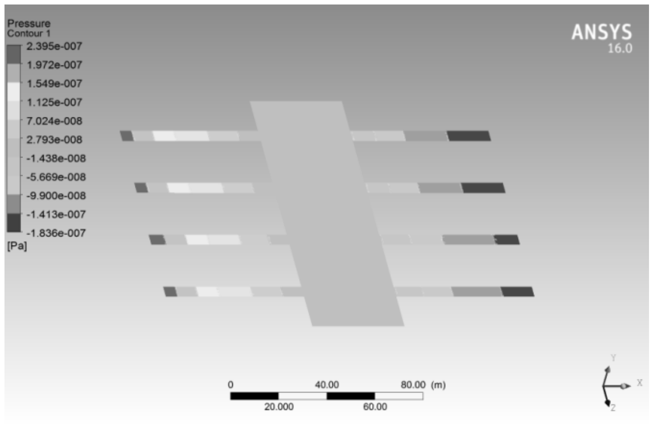

Figure 12: Pressure cloud diagram at the Cross section

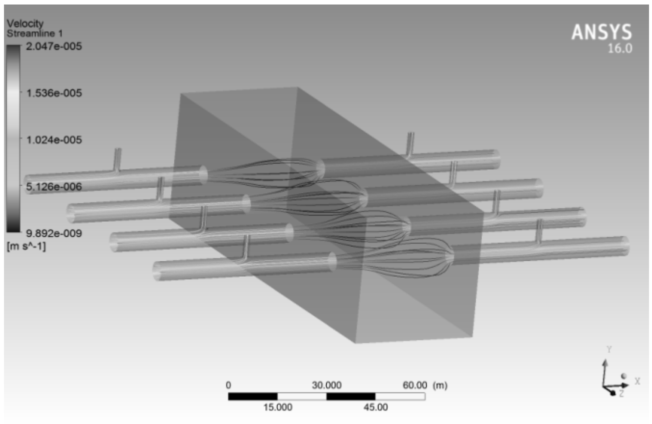

Figure 13: Streamline diagram

3.3 Post-processing display:

In the CFD post processor software, the calculation results of Fluent can be graphically represented. Here, we first import the calculation result file of Fluent above, and then establish the pressure cloud map and the streamline graph respectively[15]. In the pressure cloud diagram shown in Fig. 11, we can observe the change of the pressure of the geometrical model of the membrane module, wherein the change of the color strip on the left side indicates that the pressure from top to bottom becomes smaller. And Figure 12 shows the pressure cloud diagram of the cross-section of the membrane module geometry model.In the streamline diagram shown in Fig. 13, we can clearly observe the flow of the liquid in the model, wherein the change of the color strip on the left side means that the speed from top to bottom becomes smaller.

3.4 Experimental analysis:

In the experiment, we selected the data of a waste-water treatment plant in Shijiazhuang. Firstly, the ICEM CFD software was used to establish the geometric model of the internal pressure series MBR system shown in Fig. 6 and mesh division. The calculation results of grid division are shown in Fig. 8. Shown. The Fluent software is then used to calculate the water production of the model. The calculation results are shown in Figure 10. Finally, the CFD post processor software is used to establish the pressure cloud map and the streamline graph to observe the pressure distribution of the geometric model and the flow of the liquid in the geometric model. The experimental results are shown in Figures 11 and 12. Then select several sets of different data to repeat the Fluent calculation for the geometric model shown in Figure 8. Since the maximum trans-membrane pressure difference of the hollow fiber tube is 0.5Mpa, in order to ensure that the hollow fiber tube is not damaged, it is necessary to ensure that the TMP is lower than 0.5Mpa during the experiment. The calculation results and the actual system operation results are shown in Table 1. Observing the experimental results is not difficult to find, the water production calculated by the CFD simulation model is basically consistent with the actual water production, so the model meets the expected requirements for accurately calculating the water production of the internal pressure series MBR system and solved the problem of measuring the working efficiency of the internal pressure series MBR system by the amount of water produced by the MBR membrane module system[16].

Table 1: Internal pressure series MBR system water production scale

Water intake (m^3/h)	TMP (*Kpa*)	Actual water production (m^3/h)	Simulated water production (m^3/h)
2	15	1	1.008
2	17	0.99	1.008
2	18	1	1.008
2	23	1	1.008
2	25	1	1.008
2	34	0.93	1.0026

4. CONCLUSIONS:

Since the membrane module deployment method will affect the water production of the MBR system, and internal pressure series MBR is a common membrane module, the simulation and calculation of the internal pressure series MBR membrane module are carried out by CFD simulation software ANSYS 16.0. In the analysis process, the geometric model of the internal pressure series MBR membrane module is first established by CFD preprocessor, and meshed to obtain the mesh file. Then use the CFD solver to solve the mesh file and obtain the water production of the internal pressure series MBR membrane module. Finally, the CFD post processor presents the calculation results graphically. On this basis, this paper compares the calculation results of the solver with the operation results of the actual MBR system. The comparison results show that the calculation results of the solver are basically consistent with the actual MBR system operation results, which achieves the purpose of calculating the water production of the internal pressure series MBR membrane module, and solves the problem of measuring the efficiency of MBR system by calculating the amount of water produced. It has certain value and significance for the future research of MBR simulation.

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