Proceedings of the ASME 2010 3rd Joint US-European Fluids Engineering Summer Meeting and 8th International Conference on Nanochannels, Microchannels, and Minichannels
FEDSM-ICNMM2010
August 1-5, 2010, Montreal, Canada

FEDSM-ICNMM2010-30284

Numerical Simulation of the Flow in a Large-scale Thrust Bearing

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ABSTRACT:

Thrust bearing is a key component of large-scale water turbine. It closely relates to the efficiency of large-scale water turbines, and even determines whether the large-scale turbine can operate normally. With the development of the capacitance of water turbines, thrust bearing will develop to the direction of high speed and heavy load. The structure, strength, lubrication and the characteristic of heat radiation of large-scale thrust bearing were often researched in the past. To study the flow condition of the large-scale thrust bearing and analyze the load characteristics, CFD simulation was carried out on the model of thrust bearing. In this study, CFD method was used to simulate the internal flow field of the large-scale thrust bearing. The model researched was a thrust bearing for 1000MW water turbines. The diameter of the thrust bearing was over 5.8 meters, and the maximum thrust load of the bearing can reach to 60MN. The thin gap between the runner and the pad was usually neglected in the published CFD calculations of thrust bearing. But the thin gap was taken into account in this investigation. 1/12 of the model was used as the computational field and periodic boundary was used in the calculation. The standard κ-ε turbulence model was used to simulate the thrust bearing model, and the flow field in the thrust bearing was obtained. The thin gap between the runner and the pad is a wedge. The pressure and velocity distribution in the thrust bearing and thin gap was calculated respectively with conditions of different thin gaps and different rotational speeds of runner. After that, the relationship between carrying capacity and the size of clearance or the speed of the runner through analyzing the data has been obtained from the results of the

calculation.

KeywordS

large-scale thrust bearing; numerical simulation; gap; periodic boundary

Introduction

With the development of power system, there are higher requirements for adjustable performance of electric grid. Large pumped storage hydroelectric unit is the best power unit for peak power adjustment of electric grid. There are several large pumped storage hydroelectric units such as power stations of Guangzhou, Shisanling and Tianhuangping that put into operation recent years in China. There will be many new pump storage projects like Baoquan, Huizhou, Pushihe, etc. in building or biding.

For thrust bearings with center supporting structure, bi-directional operation is the key technique to hydroelectric generators. Techniques of thrust bearing design and manufacture are very important for large capacity generators. In order to optimize the design of such thrust bearings, HEC has made an effort to investigate design and performance of thrust bearings by means of tests. A 3000 ton thrust bearing test stand in HEC provides a perfect test condition for the bi-directional thrust bearing test.

Thrust bearing is a key component of large-scale water turbine. It closely relates to the efficiency of large-scale water turbines, and even determines whether the large-scale turbine can operate normally. With the development of the capacitance of water turbines, thrust bearing will develop to the direction of high speed and heavy load. The structure, strength, lubrication and the characteristic of heat radiation of large-scale thrust bearing were often researched in the past.

Wu Zhongde, et al.[5] studied the Thermo-elastic Hydrodynamic Lubrication Performance of Thrust Bearings. ChenWeiWong[1] introduced a thrust bearing and analyzed its performances, and the load capacity of the bearing was tested. Takuji Kobayashi，Hiroshi Yabe et al.[2] Wu Zhongde, et al.[3] introduced anapproach to simulate the flow field of the thrust bearing. Yutian Sun, Zhongde Wu, Junling Wu[4] tested the performance of Bi-directional Thrust Bearing under the operating condition of 3000ton by means of computer data acquisition system. Valuable measurement data were obtained. Daniel Schafer et al.[6] investigated the large-scale thrust bearings used in Three-Gorges Hydro-generators. Feng Xue Mei, Cai RongQuan, Wang JinBao[7], Wang J B, Feng X M, Chen H. M., Cai R. Q.[8] introduced the use of VOF method in proceeding of free surface and the process of grid. Examples of solving the problem of model with small gaps are given out by Karanth, K. Vasudeva, Sharma, N. Yagnesh[10], Fujita, K.[11], Jose, Arun I, Mishra, Asitav; Baeder, James D.[12], Kristal, J. Havlica, J. Jiricny, V.[13].

COMPUTATIONAL CASES

The model used in the research is the Three-Gorge hydraulic thrust bearing. It was provided by the HEC Corporation. The diameter of the mode is more than 5 meters and the designed rotational speed of the bearing is 127 rpm. The size of the clearance between the runner and the pad is about 1 mm, see Fig.1.

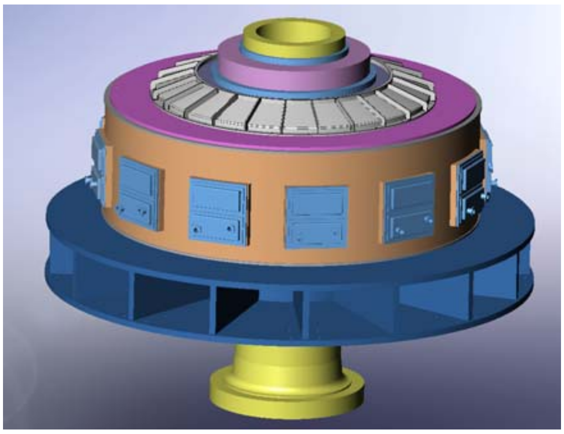

Fig.1 the whole model of the turbine

The thrust bearing studied is absolutely cylindrical symmetric, so 1/12 of the model was used as the computational field and periodic boundary was used in the calculation. The computational field of the model is shown as Fig.2.

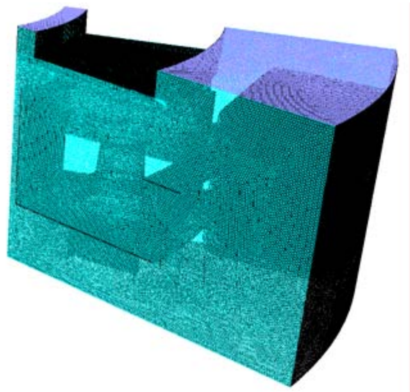

Fig.2 the computational field of the model

To improve the quality of the grid, structural grid is used in small gap such as the clearance between the pad and the runner, and unstructured grid is built in the rest parts of the model. The grid in the joint between the clearance and the main body, wedge-shaped grid is used, see Fig.3. The grid in the periodic boundary is shown as Fig.4. The quality of the grid is tolerable.

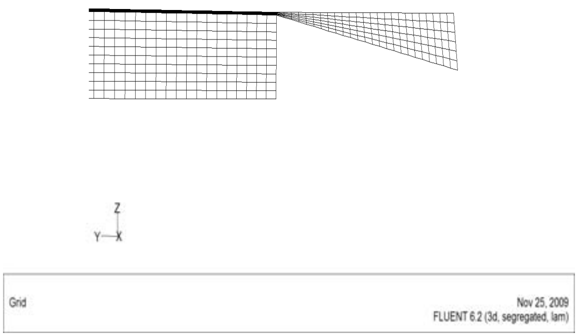

Fig.3 the connection of the clearance and the main body of the bearing

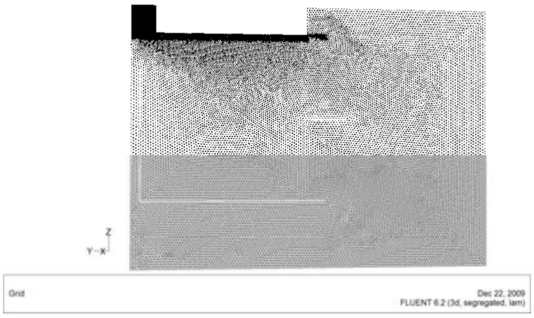

Fig.4 the grid on the boundary condition

Numerical considerations

For modeling the bearing system, we accept the following assumptions:

1. The oil in the bearing is an incompressible isothermal Newtonian fluid with a constant density.
2. The oil in the model fills throughout the bearing structure.
3. The temperature of the oil inside the bearing is invariable, so the energy equation is unavailable in the simulation.

3.1 *Equations*

The flow in the thrust bearing can be described with the equations below. The steady Reynolds time-averaged continuity and Navier-Stokes equations for incompressible flow read

$$\frac{\partial u_i}{\partial x_i}=0$$

$$\frac{\partial u_i}{\partial t}+u_j\frac{\partial u_i}{\partial x_j}=\frac{1}{\rho}\frac{\partial}{\partial x_j}\left[-p\delta_{ij}+\mu\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}-\frac{2}{3}\delta_{ij}\frac{\partial u_k}{\partial x_k}\right)+\left(-\rho\overline{u_i' u_j'}\right)\right]$$

Where

$$-\rho\overline{u_i' u_j'}=\mu_t\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}\right)-\frac{2}{3}\left(\rho k+\mu_t\frac{\partial u_i}{\partial x_i}\right)\delta_{ij}$$

μ_t is turbulent viscosity, k is turbulence kinetic energy, $k=\overline{u_i' u_j'}/2$.

In this work, the fluid in the bearing was considered incompressible. Standard κ-ε turbulence mode was used in the calculations. The standard k-ε turbulence model can ascertain the distributions of various complex length because the standard k-ε turbulence model considered the transition of the turbulence velocity and the transition of the turbulence length. At the same time, the basic form of the standard k-ε turbulence model is simple, and it can describe flow and reversed flow in shear layer. k-ε turbulence model can describe the physical process of kinds of flow authenticly. It has the charictoristics of commonality, fine precision and little calculational quantity.

3.2 *Boundary conditions*

1/12 of the model was used as the computational field and periodic boundary was used in the calculation. The computation of the thrust bearing includes the main body of the bearing and the clearance between the runner and the pad.

To improve the precision of the simulation the grid in the clearance was built into structural grid. The grid inner the bearing was made into the unstructured. There are about 3.2 million cells in the model to simulate the flow in the thrust bearing.

To study the relationships between the load capacity and the size of the clearance, and the relationship between the load capacity and the rotational speed of the runner, different conditions with differennt runner speed and models with various gap size were computed. The rotational speed of the runner was set as 100 to 200rpm, pressure-inlet boundary condition was given to the free surface of the oil inside the thrust bearing. The size between the runner and the pad was set to 0.4-1.2mm.

Discussions

After setting up the boundary conditions, the simulations was carried out by using the Fluent software. Fig.5 is the whole pressure distribution of the bearing. Fig.6 shows the pressure distribution of the runner. It was the induced that the highest pressure origin is on the middle of the runner from the figure. And Fig.7 is the velocity distribution surrounding the clearance.

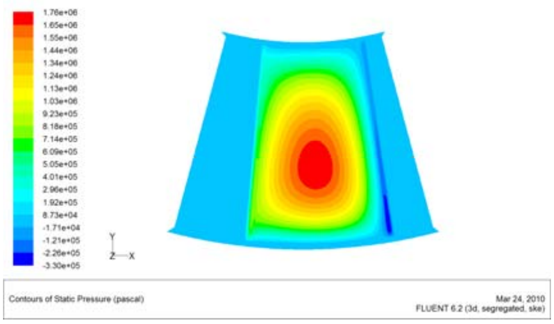

Fig.5 the pressure distribution of the runner

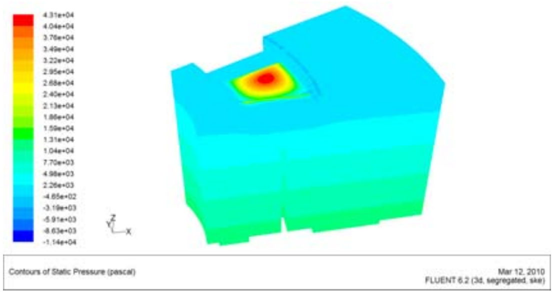

Fig.6

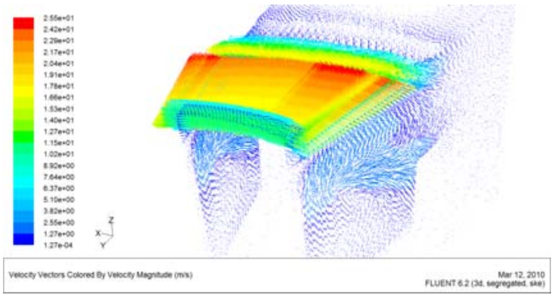

Fig.7

The forces added to the runner by the oil inside the bearing can be reported by fluent directly. After that, the relationships between carrying capacity and speed of runner or the size of the clearance were calculated.

At the rotational speed of 127rpm which is the designed operating condition the carrying capacity coefficient is calculated under different clearance size, the results is show in Tab.1

Tab.1 load capacity of the designed condition

Size of Clearance(mm)	0.4	0.6	0.8	1.0	1.2
Load Capacity(N)	579043.4	264372.3	160188.2	77921.0	56698.5

The relationship between the load capacity and the size of the clearance is then established in Fig.6. The figure imply that the load capacity of the bearing will decrease rapidly with the increasing of the gap size.

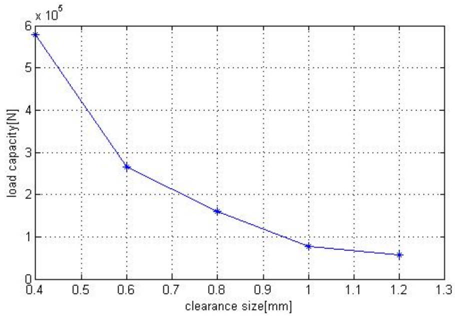

Fig.6 the relationship between the load capacity
and the size of the clearance

When the size of the clearance is set at the designed one, the carry capacity was computed as Tab.2.

Tab.2 Load capacity under different rotational speed

Rotational Speed(rpm)	100	120	140	160	180	200
Load Capacity(N)	287108.2	350791.7	416084.0	482885.6	551104.7	620657.6

The relationship between the load capacity and the rotational speed of the runner is then shown in Fig.7. The curve tells that the load capacity of the bearing will increase with the increasing of the runner speed.

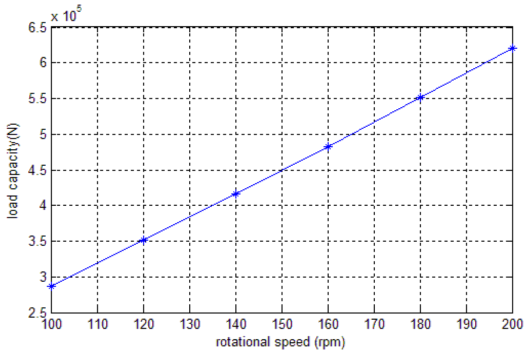

Fig.7 the relationship between the load capacity
and the rotational speed of the runner

Conclusions

The present work simulated the inner flow field of the large-scale thrust bearing and analyzed the relationship between the carrying capacity and the rotational speed of the runner or the size of the clearance between the pad and the runner.

From the above simulation we found that the load capacity of the thrust bearing can be affected by the rotational speed of the runner and the size of the clearance between the pad and the runner.

The load capacity of the thrust bearing will increase with the increasing of the rotational speed, and the load capacity of the bearing will decrease with the increasing of the size of the clearance.

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