Simulation Research of Rotor Misalignment Fault Based on Adams

Jie Lu, Tingfeng Ming*, Chenbao Zhang
Power Engineering College Naval University of Engineering Wuhan, China

*Corresponding author e-mail: 15150681701@163.com

Abstract. Misalignment is a common failure of rotating machinery, it can cause many problems such as vibration and bearing loss. The research on misalignment usually uses rotor failure test platform, it is a common equipment in various mechanics laboratories that has a mature development. But it still has some defects such as cumbersome operation and high cost. This paper had analyzed the existing rotor failure test platform in the laboratory, according to its actual size and materials, a rigid-flexible hybrid model was established. Based on the method of Adams vibration analysis, the model is simulated and analyzed in parallel misalignment and angle misalignment. According to the results, it was proved that simulation and study of rotor faults based on ADAMS simulation method had a certain feasibility and extensive applicability, and the theoretical basis for virtual prototype was provided.

1. Introduction
Misalignment is one of the most common typical failures of rotating machinery, rank second only to imbalance [1]. According to statistics, 60% of the failures in rotating machinery is related to misalignment [2]. Misalignment produces additional force, which causes vibration, bearing loss, oil film instability, rotating shaft bending deformation and other failures. So, it is important to study the misalignment for the device and maintenance of the equipment.

Rotor test-bed is mainly composed of rotor, spindle, motor, bearing and load equipment, which is a common equipment for the research of misalignment. At present, the test platform has been well developed, but in the process of its use, there are still some defects such as cumbersome operation, limited experimental scope and high cost. These disadvantages restrict the efficiency of research and increase the cost, so it is very important to simulate the vibration of test-bed by modeling and simulation.

2. Brief Introduction of Rotor Test-Bed
The rotor test-bed referenced in this paper is shown in Fig. 1, which is driven by a motor and is connected by a rigid coupling between the motor shaft and the spindle. By adjusting the position of the housing and the number of studs on the rotor, the test bed can set up the common faults of the misalignment and unbalance subsystems. When there is a certain misalignment between the two axes, the axis of the two axes tends to coincide under the action of Bolt force. Misalignment will bring excitation force with the speed to the coupling, for the parallel misalignment, there will be clear one time and twice time frequency in the spectral diagram of its radial vibration signal, and the twice time frequency is greater than the one time frequency; for the angle misalignment, it has a similar result in its axial vibration signal, but the one time frequency is greater than the twice time frequency.
3. The Construction of Simulation Model
In this paper, we used the rotor test-bed as research object, and the rigid-flexible hybrid model was established according to its structure and material. Firstly, based on the drawing of the test-bed, the three-dimensional model and virtual assembly were built on the SolidWorks software. Because the main problem of this paper is the vibration response of rotating shaft in misalignment, we simplified the coupling, load device and console of the test-bed, and got the assembly model as shown in Figure 2.

Subsequently, the resulting model was imported into the dynamic analysis software Adams as Parasolid format. Then we established a rigid-flexible hybrid model, as shown in Figure 3. The bolt connection was simplified to a fixed joint, then we loaded the rotating shaft by applying resistance torque, the two couplings were connected by bushing, and the bearings between shaft and housing were simplified to bushing with axial and horizontal direction stiffness. The stiffness of cylindrical roller bearings used in the test stand could be set according to the rigidity of the sliding bearing of the same size. Finally, we used the flexible tool of Adams to do the meshing, by this way the rigid-flexible hybrid model was established.
4. The Analysis of Simulation Results
In order to verify the validity of the model, we simulated the model in parallel displacement misalignment and angle misalignment. By adjusting the position of the housing on the pedestal, we can simulate the misalignment fault of the rotor system when the axis is offset.

4.1. The Results of Parallel Misalignment
When the model was simulated, the simulation speed was set to 600r/min, and the time was 2s, the sampling frequency was 200Hz, and the parallel misalignment is 0.2mm, 0.4mm and 0.6mm. The radial vibration velocity signal was measured by taking the measuring point on the bearing seat, then we got the simulation results as shown in Figure. 4 and Table 1. In Fig. 4, the time domain and frequency domain were graphed in the case of the parallel misalignment was 0.2mm. In Table 1 we listed the one time frequency and the twice time frequency.

![Figure 4. The time domain and frequency domain.](image)

| Misalignment (mm) | One time frequency (mm/s) | Twice time frequency (mm/s) |
|------------------|--------------------------|-----------------------------|
| 0.2              | 3.7234e-5                | 6.9897e-5                   |
| 0.4              | 7.4304e-5                | 1.3812e-4                   |
| 0.6              | 1.1153e-4                | 2.0648e-4                   |

It can be seen from the simulation results that the vibration of the rotor gradually intensifies with the increase of the misalignment. A significant one time and twice time frequency are graphed in frequency domain, both of them increase with the misalignment, and the twice time frequency is greater than the one time frequency.

4.2. The Results of Angle Misalignment
The simulation speed was set to 600r/min, the simulation time was 2s, the sampling frequency was 200Hz, and the simulation was carried out under the condition of 3 degree, 4 degree and 5 degree. The radial and axial vibration velocity signals were measured by taking the measuring point on the bearing seat. As shown in Fig. 5 and Fig. 6, the time domain and frequency domain were graphed for radial and axial vibration velocity signals at 5 degrees, and the data in other cases were summarized in table 2 and table 3.
Figure 5. Time domain and frequency domain of radial velocity at 5 degrees.

Figure 6. Time domain and frequency domain of axial velocity at 5 degrees.

Table 2. The Radial Result of Angle Misalignment

| Misalignment (degree) | One time frequency (mm/s) | Twice time frequency (mm/s) |
|-----------------------|---------------------------|-----------------------------|
| 3                     | 4.8941e-4                 | 0.0039                      |
| 4                     | 5.4350e-4                 | 0.0053                      |
| 5                     | 8.4776e-4                 | 0.0065                      |

Table 3. The Axial Result of Angle Misalignment

| Misalignment (degree) | One time frequency (mm/s) | Twice time frequency (mm/s) |
|-----------------------|---------------------------|-----------------------------|
| 3                     | 0.2391                    | 0.0497                      |
| 4                     | 0.3204                    | 0.0845                      |
| 5                     | 0.3855                    | 0.1202                      |

The simulation results show that when the angle misalignment occurs, its spectrum of radial vibration velocity signals shows clear one time and twice time frequency, and the twice time frequency is greater than the one time frequency. As for its spectrum of axial vibration velocity signals, there are clear one time and twice time frequency, and the one time frequency is greater than the twice time frequency.
5. Conclusion and Prospect

It can be seen from the results that the dynamic simulation results of the rotor fault test-bed based on the Adams software basically conform to the theoretical deduction and practical experience. It is feasible to simulate and study the rotor fault by this method, which provides a theoretical basis for using virtual prototype technology to construct the rotor test platform.

The virtual experiment platform of rotor fault based on Adams can be used to simulate the faults in the rotor's rotation, as well as the problems of unbalance, shaft bending, and shaft crack and so on. The virtual prototype of the rotor fault test platform can be constructed by this method, which saves the time and cost of carrying out the solid experiment, this method also has a certain significance for the research and teaching of the rotor fault.

References

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