Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)

Dynamic characteristics analysis of a misaligned rotor–bearing system with squeeze film dampers

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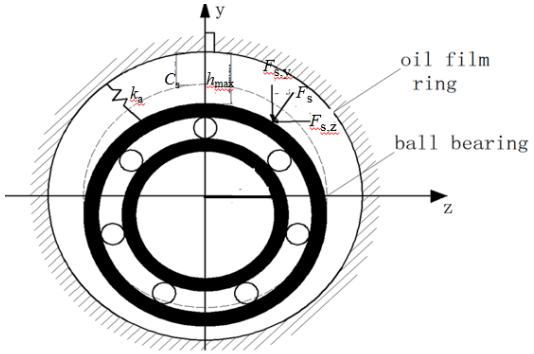
Cite this as: Liang Ma, Jun-hong Zhang, Jie-wei Lin, Jun Wang, Xin Lu, 2016. Dynamic characteristics analysis of a misaligned rotor–bearing system with squeeze film dampers. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 17(8):614-631.

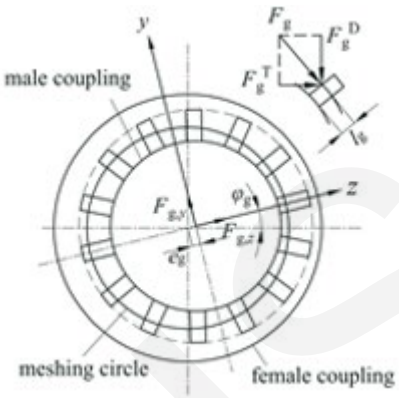
http://dx.doi.org/10.1631/jzus.A1500111

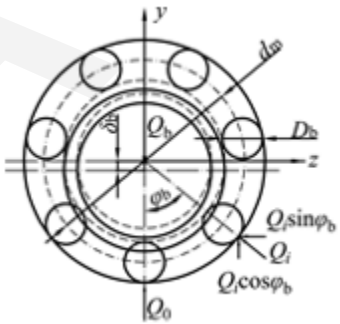
Introduction

- As an important part of the turbomachinery, such as turbines, pumps, and compressors, the rotor–bearing system has been upgraded to provide a high rotating speed in order to meet the demand of high power production.
- In such a rotor–bearing system, multi-support, multi-stage shafts connected by gear coupling might undergo nonlinear supported forces and fault excitations.
- Under such circumstances, the dynamic response analysis of the rotor–bearing system therefore becomes increasingly important and challenging in the product design, vibration control, and fault diagnosis

Model of Rotor



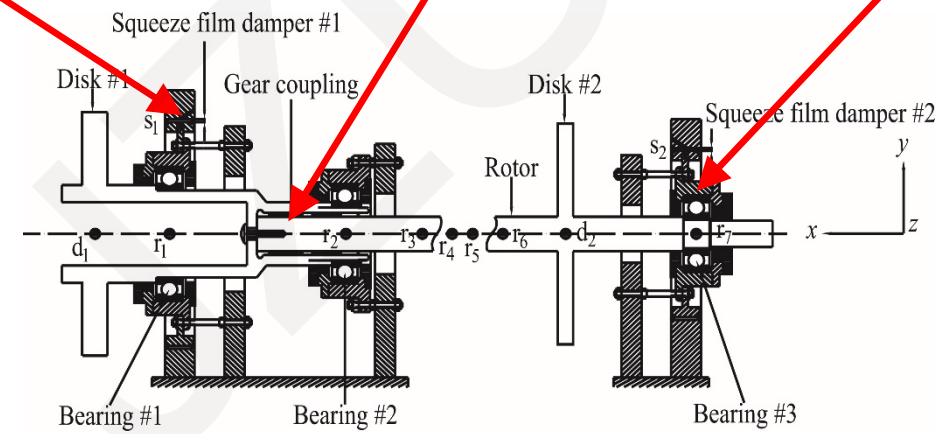




SFD

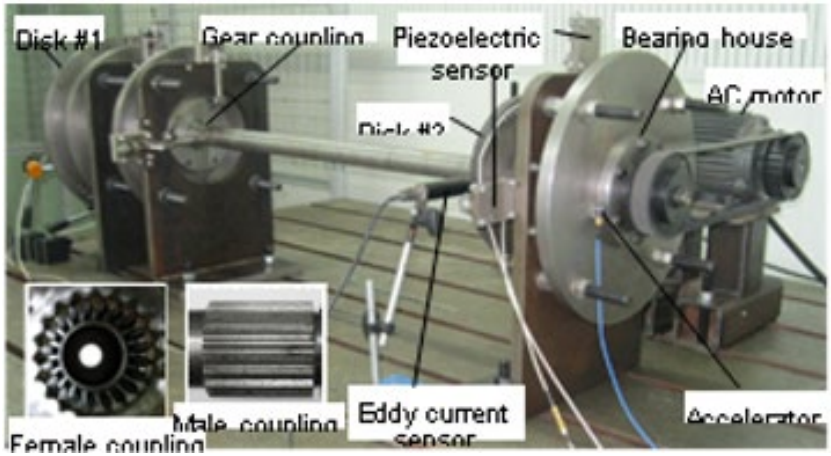
Gear Coupling

Ball Bearing



Schematic diagram of the rotor system

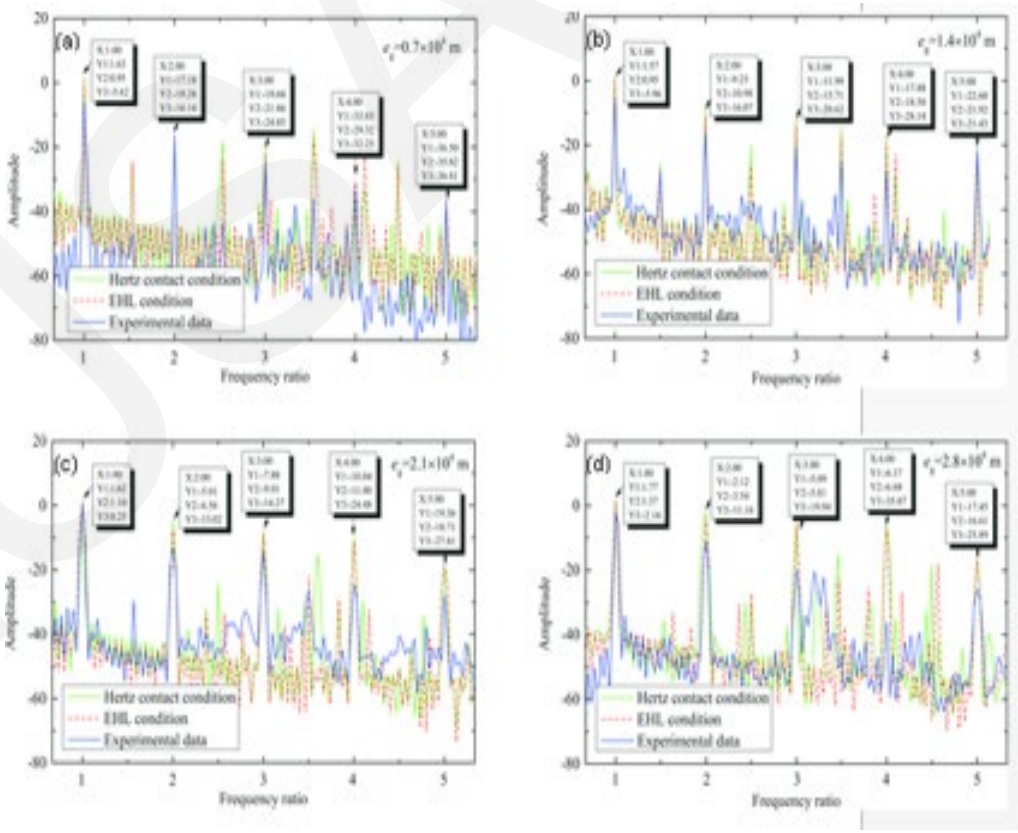
Result of Experiment



1.The experimental response at 2×, 3×, 4×, and 5× the fundamental frequency is generated by the misalignment fault of gear coupling, and this fault feature can be found in both numerical simulations under different lubrication conditions.

2.both the experimental and numerical spectra show the same trend, indicating that the response amplitude increases with the increase of the misalignment level.

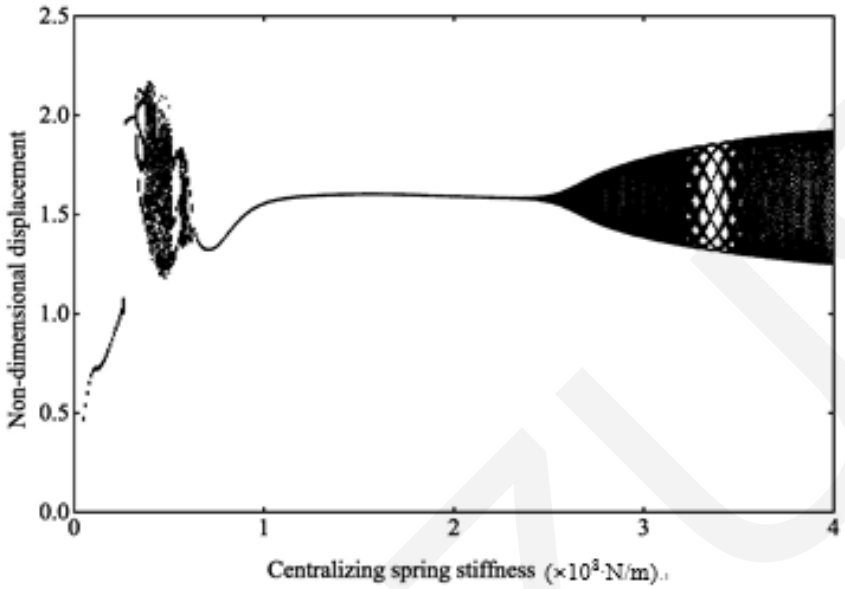
3.It can be concluded that the numerical results agree with the experimental data in most of the frequency region for different values of misalignment, especially at even multiples of the fundamental frequency.

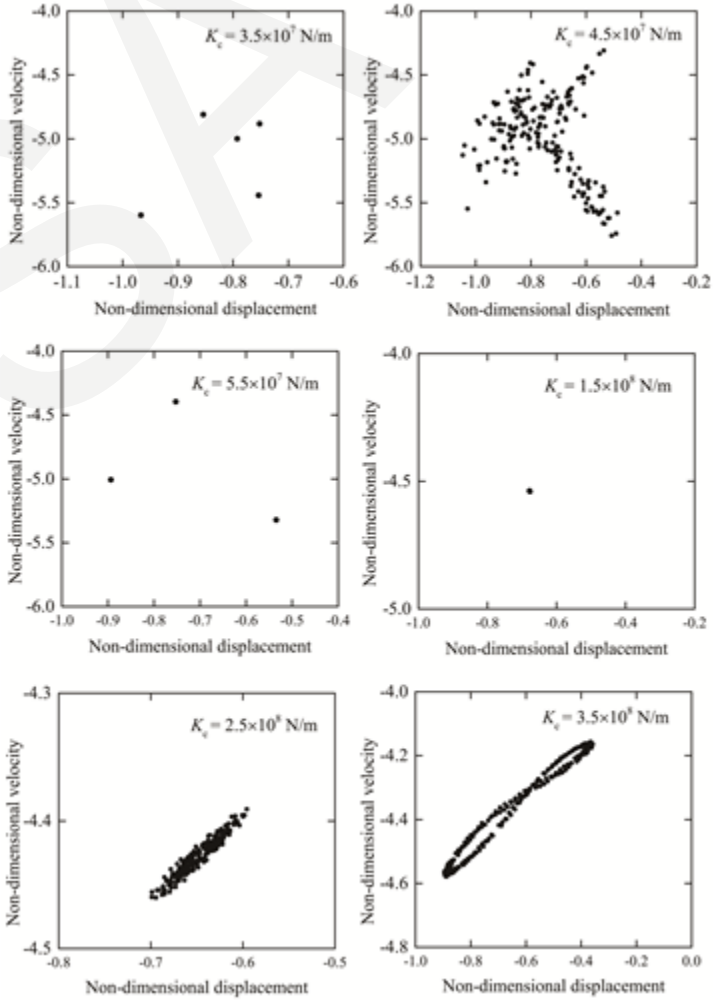


Comparison between experimental and numerical results

Result of Simulation

■Effect of centralizing spring stiffness

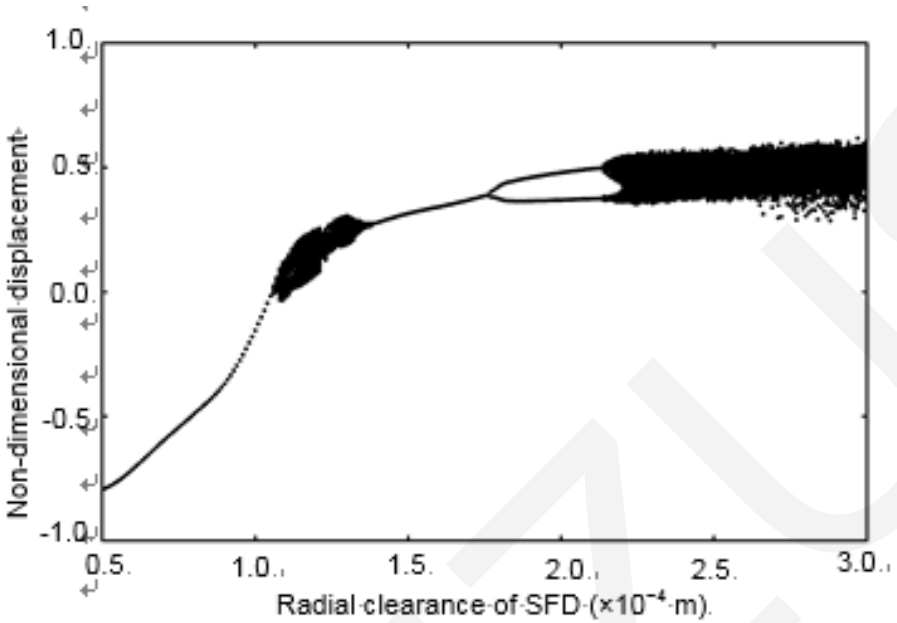


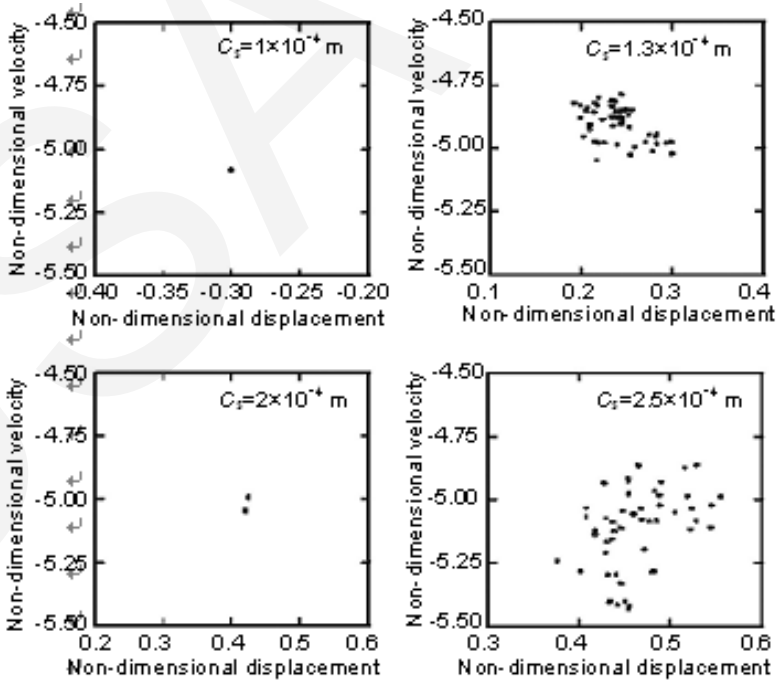


Dynamic behavior of the rotor system under EHL condition using centralizing spring as bifurcation parameter

Result of Simulation

■Effects of SFD radial clearance





Bifurcation diagram of dynamic behavior of the rotor system under EHL condition using SFD radial clearance as bifurcation parameter

Pointcaré maps of dynamic behavior of the rotor system under EHL condition using SFD radial clearance as bifurcation parameter

Conclusions

- For the rotor system with gear coupling mis-alignment under Hertzian condition, the instability rotating speed range increases from 64 rad/s (ex-cluding the misalignment effect) to 352 rad/s (in-cluding the misalignment effect) in total. When mis-alignment happens, the bifurcation onset delays a little from 1796 rad/s to 1848 rad/s, however, the stable operation range shortens considerably due to the misalignment fault of the gear coupling.
- For the rotor system under EHL condition with gear coupling misalignment, the fault charac-teristic in vibration response is completely preserved as compared with the system under Hertzian condi-tion. Moreover, the energy distribution of spectra cascade is described more precisely due to the con-sideration of the nonlinear oil film force, and more characteristics of fault variation are shown. Besides, the bifurcation onset delays from 1848 rad/s (under Hertzian condition) to 1900 rad/s (under EHL condi-tion) with the misaligned gear coupling, and the instability range of the rotating speed is shortened.
- For the rotor system with centralizing spring, the first order critical rotating speed of the rotor system as well as the vibration amplitude of the first mode increases with the increasing stiffness of the centralizing spring. Neither an excessively high nor a low stiffness of the centralizing spring is helpful for the vibration control of the rotor system. In the case of $0.7\times10-4$ m misalignment, the stiffness range is suggested to be $[0.7, 2.0]\times108$ N/m, which can keep the rotor system operating under a relatively long stable state.
- For the rotor system with SFD under misa-lignment fault, the dynamic behavior is strongly influenced by the radial clearance and the misalign-ment comprehensively. Overall, the introduction of the squeeze film increases the system stability but the effect of stability improving depends on the cor-relation between the radial clearance of SFD and the misalignment of gear coupling. According to the comparison of various radial clearance values, the case with clearance of $5\times10-5$ m is able to enhance the stable operating range when the misalignment varies within $[0.2, 4.0]\times10-4$ m.