Nonlinear Theoretical Analysis of RD Fluid Force of the Annular Plain Seal

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Long Abstract

Introduction

The bulk-flow theory has been used for analyzing the rotordynamic fluid force (RD fluid force) for many years[1][2][3]. Conventionally, the assumption was made that the whirl amplitude was very small compared to the seal clearance. In this paper, a set of extended perturbation solutions are derived explicitly, and it enables to investigate the RD fluid force for the whirl whose maximum displacement up to about a half of the clearance. The result of this analysis is validated by comparing with finite difference analysis.

1. Methods

The annular seal model is shown in Fig.1. A set of continuous equation, momentum equation in the axial direction, and momentum equation in the circumferential direction are used. The small parameter The small parameter ε is introduced, and the case with the summation of essentricity and amplitude of the dimensionless orbit up to the magnitude of the $O(\varepsilon^{1/3})$ is considered. It corresponds to a half of seal clearance. Then, the a set of extended perturbation solutions are derived analytically and explicitly for constant component and periodic component for each equation.

Figure 2 shows the result of the theoretical analysis of RD fluid force for the case with static eccentricity. It shows the comparison with the result of finite difference analysis(FDM). They show quantitative agreement, and the varidity of the extended bulk-flow analysis is confirmed. Because of the influence of static eccentricity, despite the whirl orbit is circle, the RD fluid force orbit changes to elliptic. Its spectrum analysis is demonstrated, and it explains that the influence of the static eccentricity causes not only backward syhnchronous force component but both forward and backward super harmonic force components.

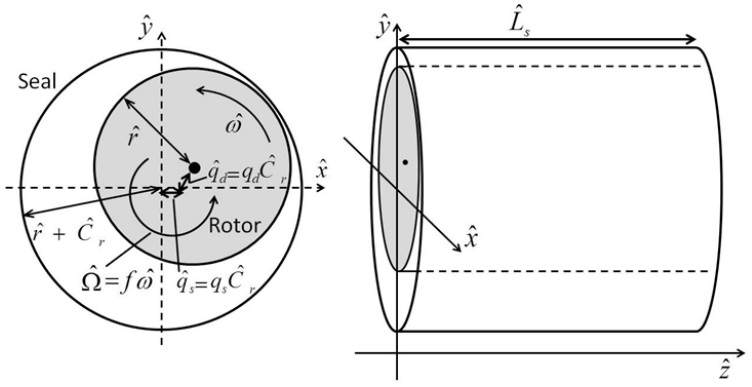
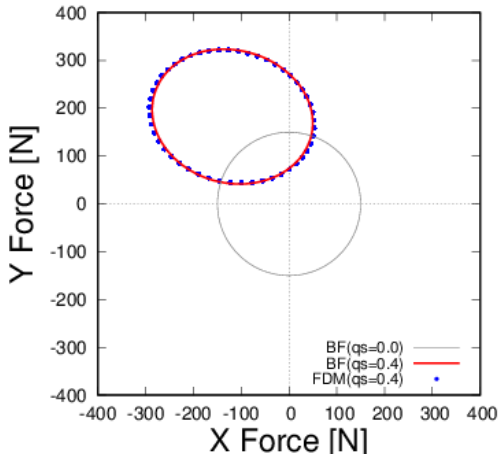


Figure 1. Annular Seal model and definition of parameters and variables



(a) Orbit of RD fluid force in xy plane

Figure 2. RD fluid force for circular whirl with static eccentricity 0.4 and whirl amplitude 0.1

References

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[3] D.W.Childs, (1993), “Turbomachinery Rotordynamics”, John Wiley & Sons, Inc.