Stability analysis of a pressurized Gas Foil Bearing for high speed applications

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ABSTRACT

One of the most efficient cooling methods for Gas foil bearings is a side feed pressurization. Besides cooling effects, experimental investigations have shown a reduction of sub synchronous vibrations, which have a major impact on the rotor dynamic performance. This current paper examines the effects of side feed pressurization on the dynamic behaviour. A multi physics model is used to calculate dynamic properties (stiffness and damping). In addition the effect of a pre-swirl side feed pressurization is considered.

1 INTRODUCTION

Over the past three decades Gas foil bearings (GFBs) have been successfully introduced in the field of high speed turbo machineries. Low drag friction, high speed operation and the omission of an oil system are some advantages of compliant foil bearings (1). In general, GFBs are based on the hydrodynamic pressure. This pressure is induced by a generated slip stream between the turning bearing journal and the bearing foil (see Figure 1b). An elastic structure comprises one or more thin top foils supported by corrugated bumps (see Figure 1a) which are the main difference to common gas bearings with a rigid bearing housing. Therefore an optimal film thickness is achieved and higher loadings compared to rigid gas bearings are possible (2). Due to friction contacts inside the corrugated structure a structural damping is induced and can be estimated experimentally (3)(4). A tuning of the compliant structure by staggering of bumps, applying coatings, using multiple bump layers results in higher load capacities and can reduce high sub synchronous whirl amplitudes (2)(5)(6).

Nevertheless, recent developments in GFB applications have heightened the need of an appropriate thermal management for high temperature environments due to limited temperature durability (7)(8). Hence, special coatings and cooling techniques have been established to prevent thermal instabilities and thermal seizure (8)(9). One of the most efficient cooling method is a side feed pressurization of GFBs (7)(9)(10). A forced cooling flow is streaming underneath the corrugated bearing structure and the clearance between bearing journal and top foil (see Figure 2a). Heat is transported by convection and conduction effects. In addition Kim et al. (10) have shown that the effect of this method reduces the sub synchronous amplitudes for low loaded bearing conditions ($W \approx 5$ N). The sub synchronous whirl vibrations have a major impact on the dynamic behaviour. To reduce sub synchronous vibration several methods and devices have been introduced (11)(12)(13)(14).

However, there has not been a discussion about the impact of side pressurization in detail and especially the impact of a pre-swirl pressurized GFB on rotor dynamic stability has not been reported. A pre-swirl has a direct influence on the velocity field inside the film thickness of a GFB. First, a 2D FE-model of the corrugated structure is coupled with the nonlinear compressible Reynolds equation, which is discretized by a hybrid finite difference scheme. A perturbation method is applied to estimate linearized bearing parameters, they are inputs of a linear stability analyses. It is limited to small orbits around a static equilibrium position. However, to estimate the onset speed of whirling motions it is an appropriate method, as shown in (11). Finally, linearized bearing parameters will be analysed in detail.