Non-linear stability analysis of a modified Gas Foil Bearing structure

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Abstract. Gas foil bearings (GFBs) have been successfully introduced in the field of high speed turbo machineries. A combination of low power loss, high speed operation and the omission of an oil system heighten the importance for small and medium sized turbo machineries, e.g. turbochargers or range extenders. However, experimental and numerical investigations have shown subsynchronous vibrations, which affect the rotor dynamic behaviour. Structural damping generated by friction contacts inside the compliant structure may reduce vibrations up to a certain level. In addition, several proved methods and devices, e.g. side feed pressurerisation, pre-loading due to shims and viscoelastic foil bearings are common techniques to decrease non synchronous vibrations. However, far too little attention has been paid to the causes of these non-linear effects. Understanding the causes may results in a higher knowledge of the overall GFB dynamic behaviour. Thus, the aim of this paper is to analyse the causes of these non-linear vibrations. A hypothesis is stated, that the non-linear vibrations are influenced by a self excitation and a forced non-linearity. The non-linear compressible transient Reynolds equation is discretised by a hybrid finite difference scheme with an implicit time discretisation while the pressure field is coupled with a 2D plate model. This plate model is linked to a spring-damper configuration. The time domain analysis shows, that the subsynchronous frequencies may excite the system eigenfrequency. In addition, good correlations between the onset speed of sub synchronous vibrations of the time domain simulations and the linearised frequency domain analysis are shown. In the second part of this paper, the effects of different bump foil configurations (bump-type GFB, shimmed GFB and a lobed GFB) on the dynamic performance are considered. It is shown, that an effective reduction of sub synchronous vibrations due to a non-uniform circumferential stiffness distribution and the use of shims is possible. Especially, the low loaded case (5N) has an increase of onset speed of subsynchronous vibration of ≈173%, compared to the same bearing setup without shims.

Keywords: Foil Bearings, Time Domain, Non-linear Vibrations, Shims