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Enhancing vibration mitigation in a jeffcott rotor with active magnet bearings through parameteric excitation

Zacharias Kraus[1*], Artem Karev[1], Peter Hagedorn[1], Fadi Dohnal[2]

1. Technical University of Darmstadt, Dynamics and Vibrations Group, FNB, Dolivostraße 15, 64293 Darmstadt, Germany
2. UMIT, Division for Mechatronics Lienz, Linker Iselweg 21, 9900 Lienz, Austria
* Presenting Author

Abstract: In previous studies of linear rotary systems with active magnet bearings, parametric excitation was introduced as an open-loop control strategy. The parametric excitation was realised by a periodic, in-phase variation of the bearing stiffness. At the difference of two of the system's eigenfrequencies a stabilising effect, called anti-resonance [1], was found numerically, and validated in experiments. In this work preliminary results of a further exploration of the parametric excitation are shared. A *Jeffcott*-rotor with two active magnet bearings and a disk is used for investigation. Through Floquet theory, a deeper insight into the system's dynamic behaviour is gained. Aiming at a further increase of stability, a phase difference between excitation terms is introduced.

Keywords: Flexible Rotor, Active Magnetic Bearings, Parametric Excitation, Anti-Resonance, Floquet Theory

1. Introduction

A *Jeffcott*-rotor with two active magnet bearings (AMBs) and a disk, as shown in Fig. 1, is investigated. The AMBs are controlled by a PID-controller. Parametric excitation is introduced via periodic variation of the P-component of the controller, resulting in a time variable bearing stiffness. [2]

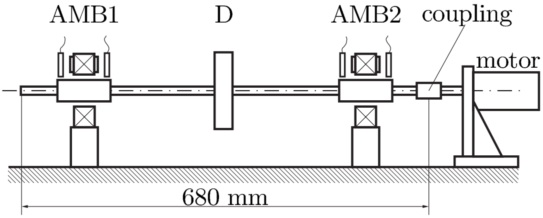

Fig. 1. *Jeffcott* rotor with active magnet bearings (AMBs), disc (D) and motor [2]

As illustrated in [2], the system shows signs of anti-resonance for an excitation frequency Ω of 170 rad/s as well as resonance for 315 rad/s and above 450 rad/s. Anti-resonance leads to a better use of the system's inherent damping due to energy transfer from a mode with lower to one with higher damping.

With Floquet theory the Lyapunov characteristic exponents λ (LCEs) can be found. The largest LCE Λ reflects the stability of the equilibrium. Instability is indicated by $\Lambda > 0$, stability by $\Lambda < 0$. [3]

2. Results and Discussion

If examined using the largest LCE Λ, only the system's resonance frequencies are revealed. For other excitation frequencies, including at the difference frequency where the anti-resonance is expected [4], Λ remains just below zero. If, however, all LCEs λ are considered (see Fig. 2), an anti-resonance at the difference frequency of the first and third eigenfrequency Δ_{31} can be found within the smaller LCEs. For the system under investigation the vibration decay seems to be dominated by LCEs which can be matched with modes belonging to the smallest eigenfrequencies of the unperturbed system.

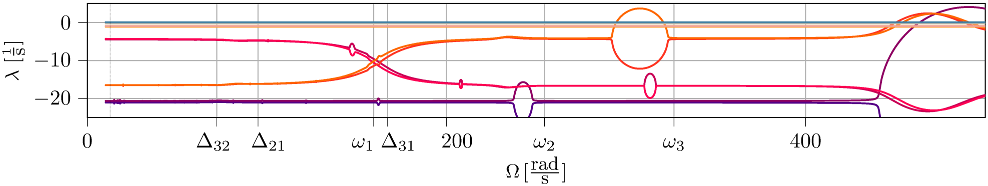

Fig. 2. LCEs λ over frequency of parametric excitation Ω, revealing anti-resonance at approx. 170 rad/s

With focus on the LCEs of the first modes, the effect of a phase difference in the excitation between the AMBs is examined, as this might increase dissipation [5]. As shown in Fig. 3, two anti-resonances are revealed at difference frequency between the third and second as well as the second and first eigenfrequency. However, the phase shift does not yield a significant increase in dissipation for this system, as the minimum at the LCEs crossing is about the same.

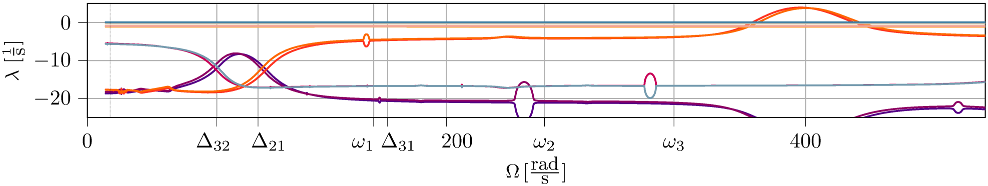

Fig. 3. LCEs λ over frequency of parametric excitation Ω for phase difference of π between bearings

3. Concluding Remarks

Through inspection of the LCEs belonging to the first modes, the anti-resonance found in previous studies could be confirmed. Varying the excitation phase difference revealed two additional anti-resonances, albeit not significantly increasing damping. The discussed approach can however be used for further investigation to find an optimal parametric excitation for maximal vibration mitigation.

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