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[Extended Abstract]

On the influence of co-rotating frictional dissipation on self-excitation due to internal damping

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Introduction

Destabilization due to viscous internal damping is a very well known phenomenon in rotordynamics [1]. However, many applications in engineering do rather exhibit frictional damping – e.g. stemming from shrink fits, joints, interlaminar contacts in stacked rotors of electric machines, etc. – instead of velocity proportional viscous dissipation. Historically, it was this latter application which led to the discovery of the destabilizing effect of internal damping [2]. Consequently, the first contributions on this dynamical problem used the term ”internal friction” – however, since then almost all investigations involved viscous damping and the wording changed from ”internal friction” to ”internal damping”. Reviewing the literatur revealed only very few studies on the effect of co-rotating dissipation due to dry friction. Most of them focussed on forced vibrations (e.g. [3]) while the influence on stability and self-excitation has only be touched superficially [4].

This contribution aims on investigating the basic effects of internal damping due to co-rotating frictional dissipation and the interaction with external damping.

Model problem and main results

As model problem, the classical Jeffcott rotor with linear external and internal (i.e. co-rotating) viscous damping is chosen. In order to account for frictional dissipation, Coulomb elements are added, which apply parallely to the viscous internal damping in the co-rotating frame.
Figure 1 depicts the model.

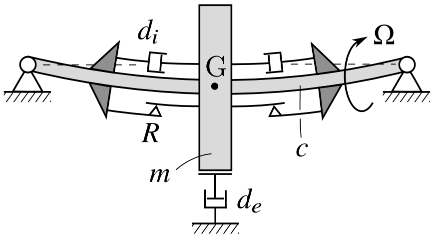


Figure 1. Model Problem.

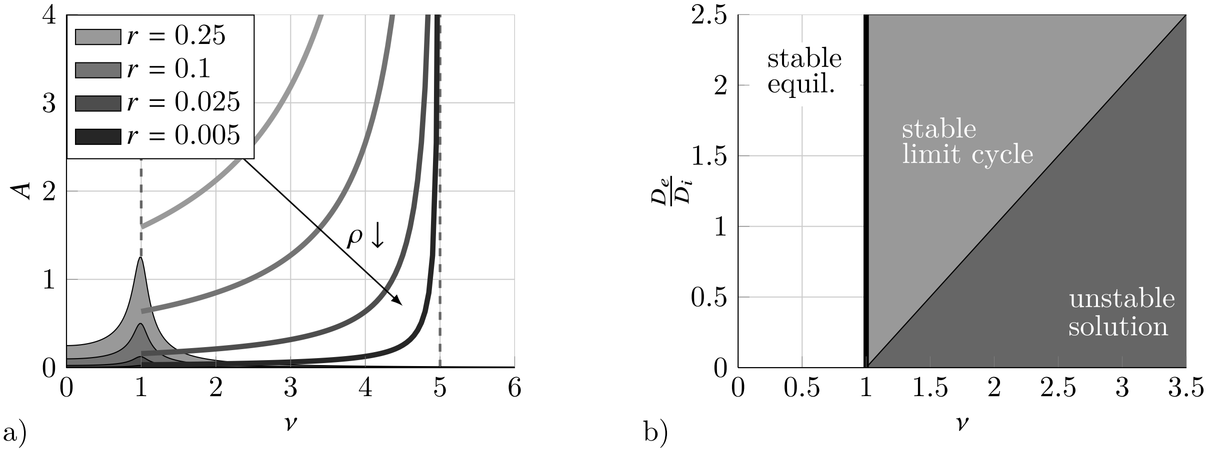
Numerical simulations as well as analytically approximations using Galerkin's method showed the existence of limit cycles for some operational conditions above the linear critical speed. The results may be summarized as follows:

- For sticking friction elements the steady state point of the smooth systems turns into a set $\mathcal{E}$ of steady states wrt. to the co-rotating frame.
- For subcritical speeds $\nu < 1$ the set $\mathcal{E}$ is attractive. For $\nu > 1$ it becomes unstable.

- As the rotor passes through $\nu = 1$ the internal frictional dissipation gives rise to a stable limit cycle. This limit cycle exists within the interval $1 < \nu < 1 + \frac{D_e}{D_i}$. An external observer will observe oscillatons at a frequency ${}^I\omega_{\mathrm{LC}} = 1$. Figure 2 a) outlines $\mathcal{E}$ as well as limit cycle amplitudes.

- As the rotation frequency ν approaches the linear stability margin $\nu_{\mathrm{crit}} = 1 + \frac{D_e}{D_i}$ the amplitude of the limit cycle grows hyperbolically. As this linear stability threshold is exceeded, the system investigated within this study is not able to predict a stationary solution anymore.

Thus, it may be concluded that co-rotating frictional damping changes the stability and bifurcation behavior significantly. For such systems, instead of assessing stability it will rather be adequate to investigate the occurence as well as the amplitude of limit cycles. Figure 2 b) summarized the behavior of stationary amplitudes.



a) b)

Figure 2. a) Limit cycle amplitudes for varying r and $D_e/D_i = 2$.
b) Enhanced stability chart accounting for internal viscous damping and as well as internal frictional damping.

References

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