Modal Analysis of Rotating Machines

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Introduction: Machines with rotating components are prone to vibrations because an imbalance of the rotor would always act as a harmonic excitation force.
Aim of this work is to investigate the vibrating behavior of a machinery frame with major respect to coupled elements in the lower frequency band. Therefore an analytic attempt is compared with COMSOL Multiphysics® results. After an successful verification of the numerical model specified damper can be evaluated for rotating machines.

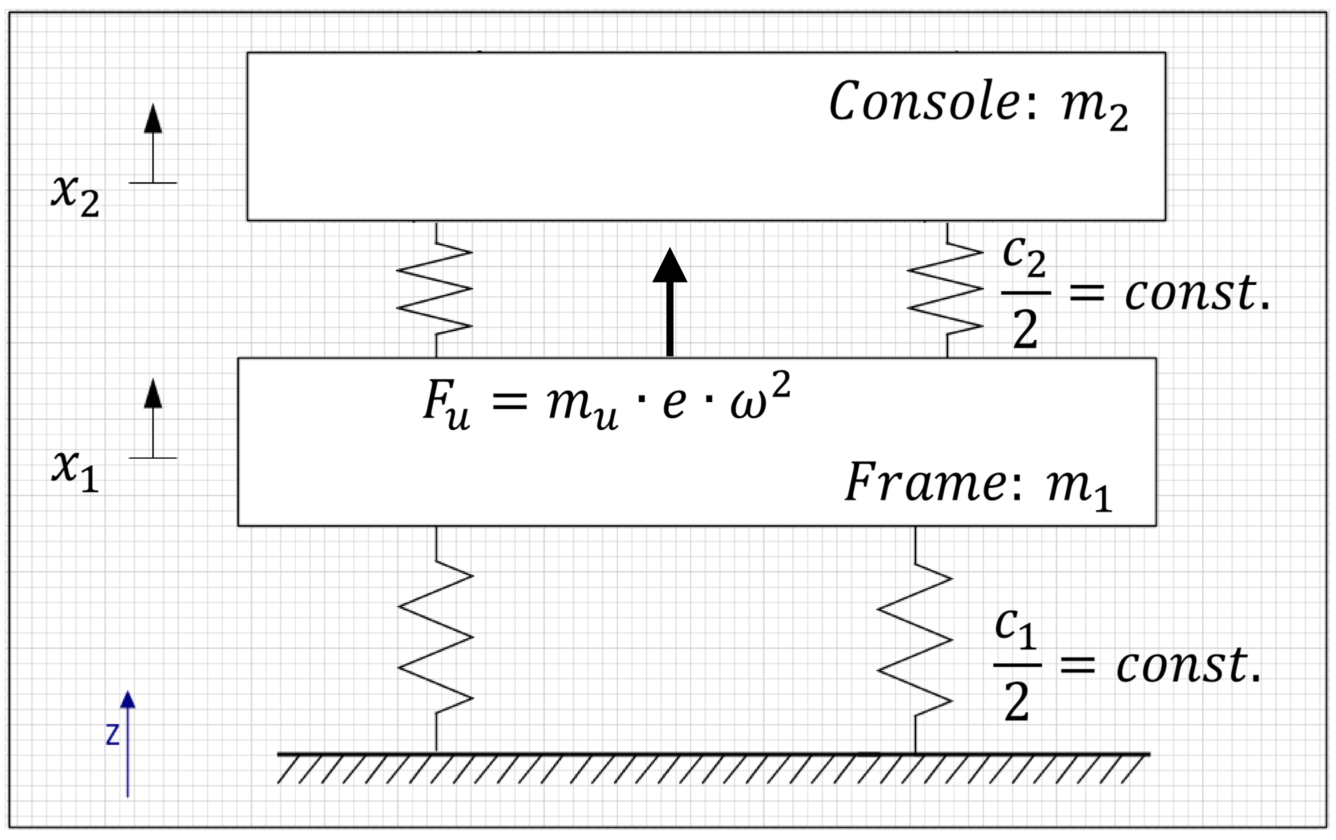

Figure 1. Analytical abstraction of the machine model without damping.

Computational Methods: A first numerical approach evaluates simple substitution machine models with two DoF (according to Figure 1).

$$\ddot{x}_2 + {\omega_2}^2 x_2 + k_2 x_1 = 0$$

$$\ddot{x}_1 + {\omega_1}^2 x_1 + k_1 x_2 = \frac{1}{m} F_u(t)$$

The vibration can be analytical expressed by a deflection in the vertical direction x for each machine part, solving upper coupled DE's:

$$\hat{x}_1 = \frac{\hat{F}_u}{m_1 \cdot \left[({\omega_1}^2 - \Omega^2)({\omega_2}^2 - \Omega^2) - c_1 c_2\right]}$$

$$\hat{x}_2 = \frac{-c_2 \hat{F}_u}{m_1 \cdot \left[({\omega_1}^2 - \Omega^2)({\omega_2}^2 - \Omega^2) - c_1 c_2\right]}$$

The numerical model is further extended with an additional damping term to simulate a realistic vibrational absorption.
Like the reaction forces of the spring foundation – witch are coupling the frame – the forces for the console are implemented similar with a boundary force and a general extrusion coupling operator.

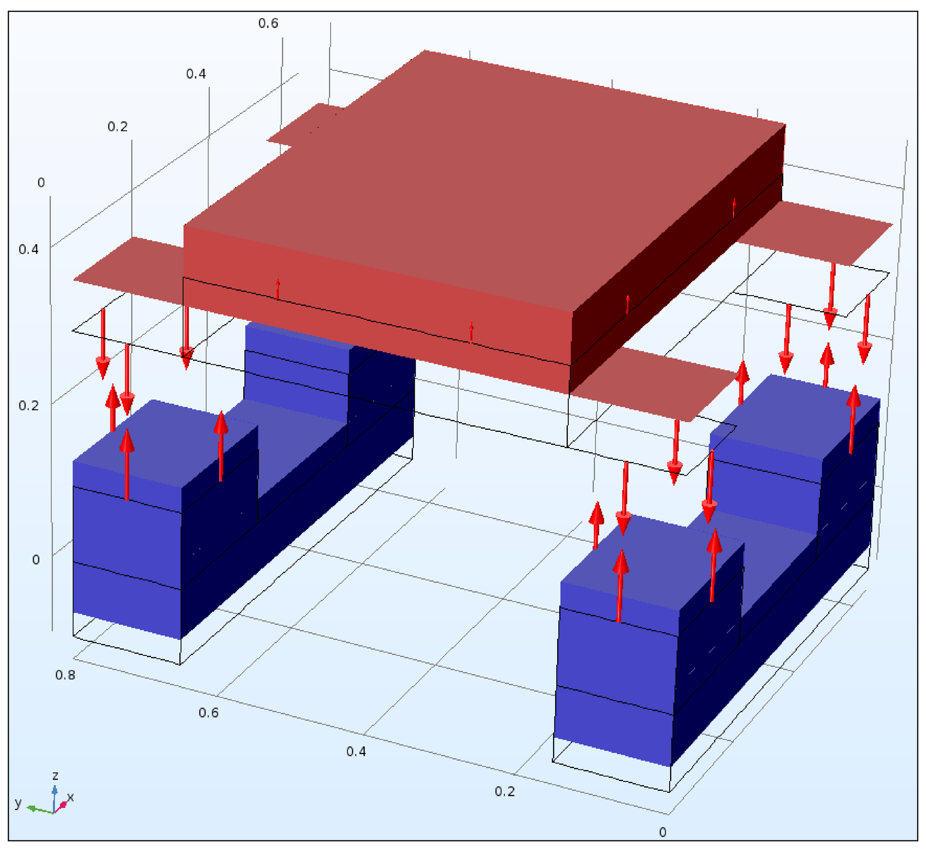

Figure 2. COMSOL® model of the abstract machine.

Results: The comparison with analytical and numerical results show a good match with a maximum deviation for $\Delta x < 0.2\,\%$ (Figure 3). With further extensions for the simple model – with more DoF and additional damping – it can be shown that the described approach corresponds with experimental test results.

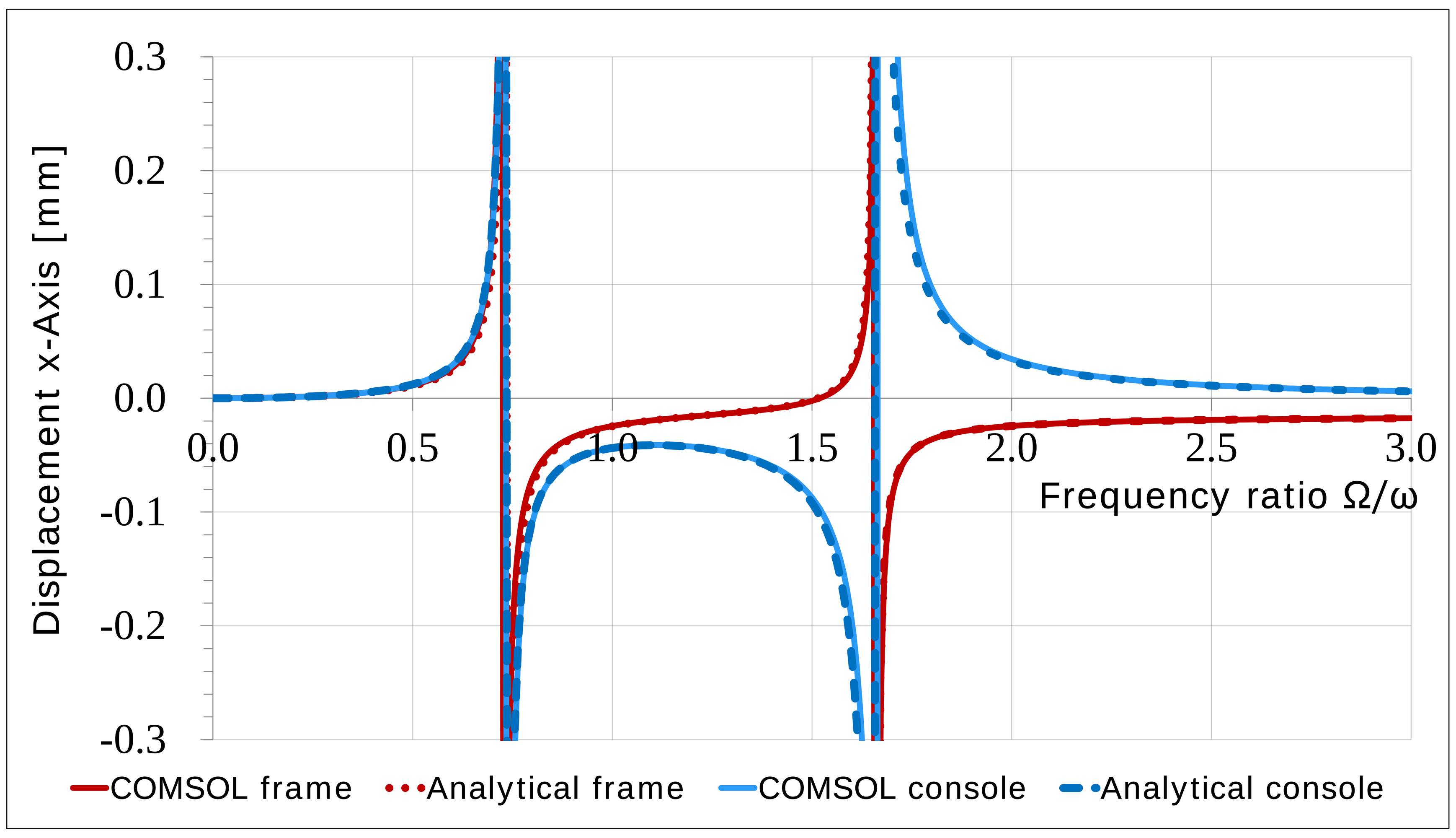

Figure 3. Excitation of 2 DoF System without damping.

Conclusions: The current study is an successful approach to a universal model for rotating machines e.g. used in separation processes. Deviations of compared experimental data are noticed for vibrations occurring at lower eigenfrequencies in range of $3 - 10\,Hz$ $(180 - 600\,RPM)$ and in the magnitude of deflection for vibrational peaks. These deviations are assumed to be found in a more sufficient description of dampers.

References:

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