Investigating Eigenfrequencies And Dynamic Behavior Of Rheological Measuring Systems

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Abstract

In order to measure all possible rheological properties, a wide range of measuring systems is available for the Anton Paar Modular Compact Rheometer (MCR) series.
Apart from the hundreds of measuring systems, which conform to the ISO, DIN and ASME Standards, every year several new custom-made measuring systems are designed and produced.
All the relevant characteristics of the measuring geometry are stored in the Toolmaster™, a contact free automatic tool recognition and configuration system, which communicates with the RheoCompass™ software in order to refine the measurements from influences such as temperature, stress and environmental factors.

In speed-controlled operation of the measuring drives, resonance phenomena often arise under high dynamic demands, preventing noise-free measurement operations. These resonances, triggered by the natural frequencies of the measuring shaft, require precise identification and targeted damping.
For the design of the measuring system is then important to identify the natural frequency through simulation, a verification with a frequency sweep on the device is as well crucial for the precision of the measurements.
The control system of the measuring drive shows that by damping the resonances, the precision and the accuracy of the measurement are enhanced, especially by frequencies below the 1000 Hz.

This work compares a classical mathematical modeling approach, in which the measuring system and the measuring drive are conceptualized with concentrated moments of inertia and torsional compliance values, to a COMSOL® simulation of the measuring geometry.
Particular attention was also paid to the influence of the measuring drive on the natural frequency in comparison to the sole measuring system and its influence on particular geometries.

The early adoption of COMSOL® in the design phase, including the LiveLink® for PTC Creo Parametric™, allows on one hand to drive the designer to a certain result and gives hints for the verification of the finished products.
The geometries are stored as COMSOL® geometry parts and stored for future reference or studies.

Products specialists on the other hand can profit of the pre-set studies and by changing the geometry, with the provided geometry parts, investigate the behavior of different measuring systems just by changing the boundary conditions.
A relevant advantage of using the COMSOL® Model in the development process is the possibility to link rheological characteristics of a measuring system to physical parameter as the diameter of the shaft or material.
Further simulations in frequency Domain can also give the rheologists indications on relevant factors as for example the minimum achievable measuring gap.

This theoretical and simulation framework lays the groundwork for an effective strategy to damp unwanted resonance frequencies and improve the fidelity of dynamic measurement systems already in the design phase.
The characterization of the behavior of the measuring system enhances the design of novel measuring systems and the understanding of the interaction with accessories, making it easier to develop tailor made systems to match customer needs.

Reference

T.G. Mezger, The Rheology Handbook, Vincentz, 2020
T.G. Mezger, Applied Rheology, Anton Paar GmbH

Figures used in the abstract

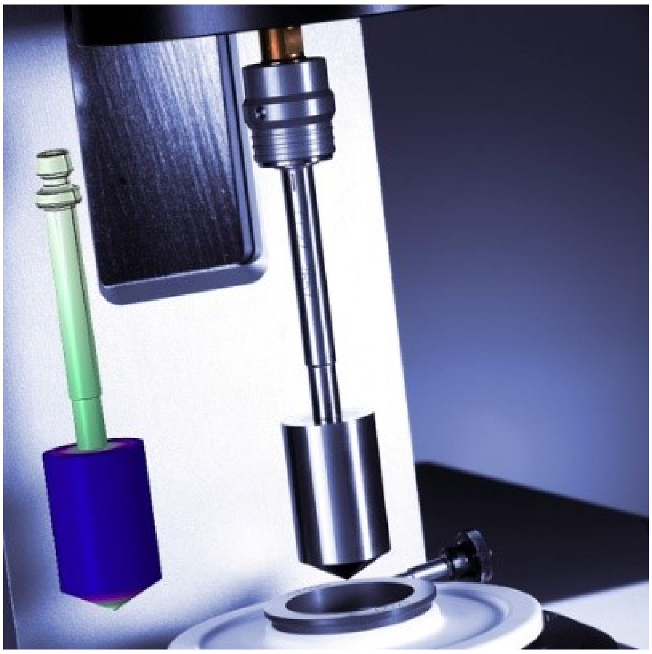

Figure 1 : A typical concentric cylinder measuring setup and its COMSOL® simulated eigenfrequency mode.

Figure 2 : Different standard measuring geometries (Anton Paar GmbH)

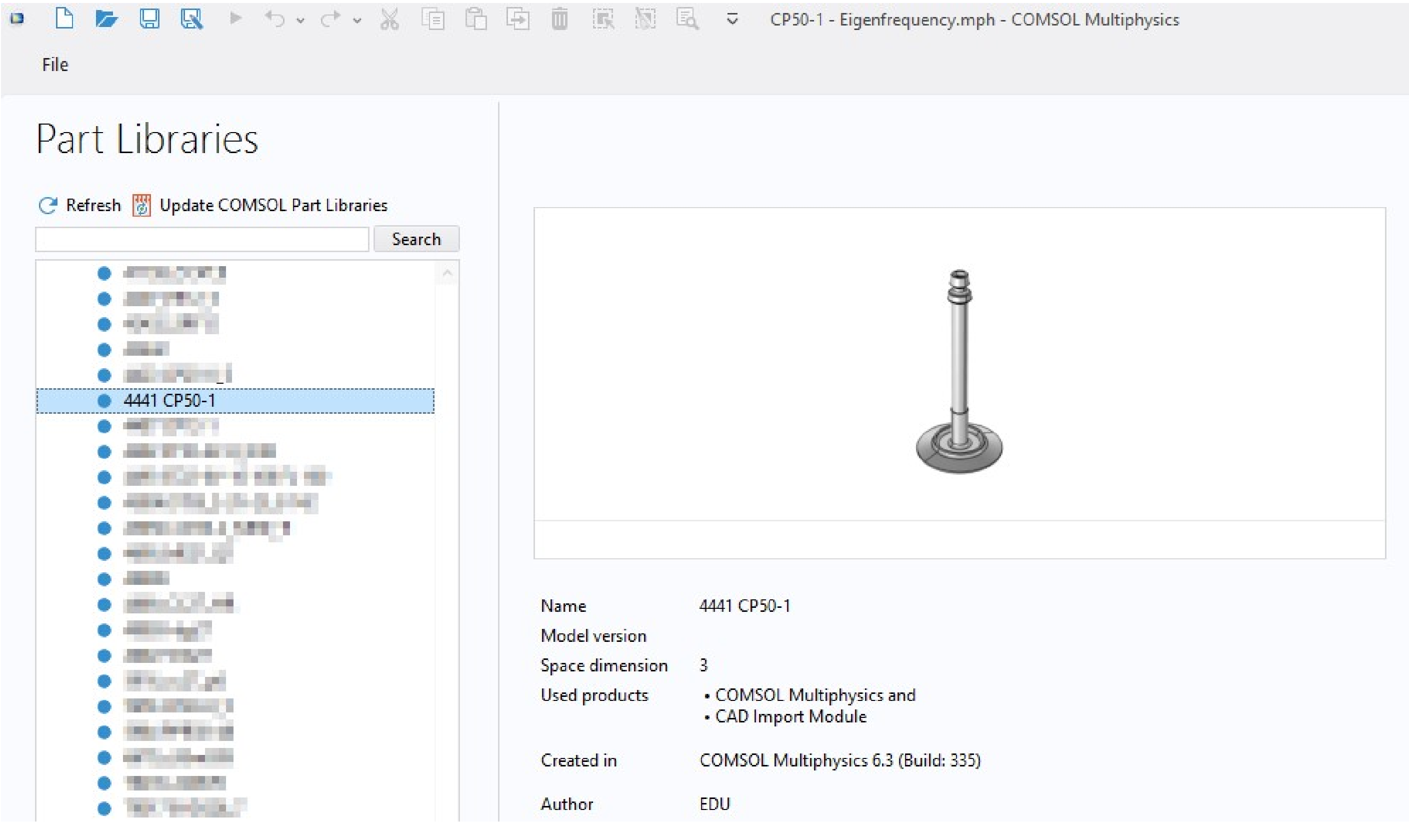

Figure 3 : Selection of the measuring system from the Part Library – Cone-Plate CP50-1 measuring system (DIN EN ISO 3219 and DIN 53019)

Figure 4 : COMSOL® array visualization of mode shapes for different eigenfrequencies for a Cone-Plate CP50-1 – not all are torsional relevant.