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Elastomer materials and their behavior in the high-frequency spectrum

Fraunhofer LBF will continue to research elastomer materials and their behavior in the high-frequency spectrum. In this context, Fraunhofer LBF is looking for project partners who are interested in participating an industrial collaborative project.

Automotive manufacturers and their suppliers are facing major challenges when it comes to the future of mobility. One of these challenges is how they determine the correct requirements for battery-powered vehicles and their components in order to select the appropriate materials. Selecting the right material is crucial in terms of the functional capability of the components used. Elastomers are ubiquitous in vehicle construction as vibration-absorbing and insulating components. Their uses include for bearing elements for the chassis area and powertrain, bearings for the battery packs and ancillary units, and electrical insulation and absorption elements for improved driving comfort.

As vehicles are becoming ever more electrified, the characteristic profiles of elastomer materials are being re-assessed. In addition to the requirements for temperature and media resistance, service life and mechanical loads, there are also requirements for additional physical characteristics such as high-frequency behavior. The behavior under high-frequency excitation is determined by the dynamic stiffening, loss angle and hysteresis of the elastomers. The excitation frequency ranges from 50 to 3000 Hz. Until now, there has been a real lack of reliable knowledge about the material behavior in this frequency spectrum.

In addition to the geometry of the elastomer components, the composition of the elastomer compound is crucial in the high-frequency range. The selection of elastomer compound components, such as the rubbers, fillers, plasticizers, cross-linking agents and processing aids, helps to generate, shift and reduce resonances.

This joint research project will provide a fundamental understanding of the interrelationships of formulation design with high-frequency behavior for targeted, digital component design. This will allow the characteristics of materials and components to be predicted earlier and more accurately in the design phase. The aim is to investigate, in particular, the physical characteristics of elastomer compounds with regard to filler-filler interactions and associated hardening in the low amplitude range (Payne effect) and to provide model-based optimization approaches to suppress or shift resonance peaks in a targeted manner. Another factor that influences the frequency response is the mixing process and the associated filler distribution in the elastomer matrix. This influencing factor will also be specifically addressed in the course of the project. Lastly, it will investigate the influence of the vulcanization parameters on the elastomer compound and the associated high-frequency behavior. The aim is thus to enable project participants to identify elastomer compounds that are suitable for the design of components for high-frequency applications by cleverly selecting formulation components, the optimum mixing process and processing conditions that are suitable for the formulation. In addition, the project is intended to give raw material suppliers in the elastomer sector ideas for introducing new raw materials to meet the steadily growing demand in the future mobility sector and, if necessary, to initiate new developments for the sector.

Motivation and goals

The joint research project will focus on identifying various factors that influence the high-frequency behavior of elastomers and mapping them in virtual material models. On the one hand, the intention is to present the correlations between the individual factors of formulation design, mixing process and vulcanization, and the characteristics, in particular the frequency behavior. On the other hand, these factors and their influence are to be weighted in collaboration with the project partners, and evaluated on the basis of targeted test series. The filler-filler interaction will be the main focus of attention here. A highly dynamic testing machine is available at the LBF to characterize elastomer specimens and components. Parameters such as dynamic stiffness and loss angle can be determined in the frequency range from 50 to 3000 Hz. Different pre-loads and temperatures are also possible in this range.

The following work packages are to be addressed:

Determination of the requirement profile in close coordination with the project participants

- Research on the state of the art for determining the behavior of elastomers and material modeling for simulation and design evaluation of components under high-frequency, mechanical stress
- Definition of the requirement profiles of the project participants and clustering based on typical requirements
- Definition of test specimen geometry for measuring high-frequency behavior of the manufactured elastomer compounds

Material production and characterization

- Determination of dynamic characteristics such as kd/ks and resonance peaks as a function of mechanical stress amplitude and temperature
- Determination of the factors influencing high-frequency behavior from the point of view of selected model formulations (rubber base, fillers, coupling agents, plasticizers, cross-linking systems) with a focus on filler-filler interactions
- Determination of the influence of mixing parameters in the internal mixer on the high-frequency behavior of selected compounds (number of stages, temperature during the mixing process, fill level in the internal mixer)
- Determination of the influence of vulcanization parameters on the high-frequency behavior of selected compounds in the compression molding process (temperature and time)

Simulation and modeling in the high frequency range

- Implementation of parametric material models and regression methods for determining the frequency-dependent material parameters from measurement data
- Virtual modeling of suitable specimen geometries and production of a selected specimen for measuring high-frequency behavior in the 50 to 3000 Hz range
- Verification of virtual component models based on frequency-dependent material parameters

Based on the results, structure-characteristic relationships are derived in the form of a summary with the aim of a better mechanistic understanding of the influence of formulation design on high-frequency behavior. This understanding is improved using a parametric, optimizable material model that can be used in common finite element simulations. This should result in specific recommendations for the best possible formulation design for use in the respective frequency spectrum.

Are you participating?

Then register for the industrial joint project »Elastomer materials and their behavior in the high-frequency spectrum« to projectadmin@lbf.fraunhofer.de.

Still unsure?

For further information on the content and procedure of the project, please contact Dr. Ali Golriz.

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Figure: Fraunhofer LBF, Raapke