ANALYSIS OF TECHNICAL RUBBER MATERIALS USING SIMPLE SHEAR DEFORMATIONS WITH ROTATING AXES

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1. Introduction

In opposition to metallic materials, technical elastomers exhibit a variety of different material properties like nonlinearity or inelastic material behavior. The measurement of those properties and the determination of the material parameters connected to them often requires several different experimental setups. In the presented article the setup of an experimental rig is introduced, which allows the measurement of dynamic parameters, while at the same time the input signals preserve a quasi-static character. With the experimental rig it is possible to decouple elastic and inelastic processes within the material as well as to investigate consider new and yet highly relevant aspects for the prediction of the fatigue behavior of technical rubber parts.

2. Experimental Setup

The following sketches show the schematics of a simple shear deformation with rotating axes. In this context it has to be mentioned, that in order to describe simple shear, it is not sufficient to consider the deformation state in respect to a reference configuration only. In fact simple shear is rather a deformation process than a deformation state, which has to be regarded in dependency of the progression of the shear measure s to consider the essential properties like for example the change of the direction of the eigenvectors of the load in the coordinates connected to the material. A simple shear deformation process with rotating axes can be divided into two phases, as is shown in the figure above. During the first phase a simple shear deformation is initiated in a material point, which is represented in the figure via a cube. Throughout the second phase the plane parallel to the base area is moved translatorically on a circular track around its original position. This is done in such a manner that all planes of the cube stay coplanar to each other. The reaction force of the deformation process is the measured quantity of the test machine. As shown in the figure the reaction force is not collinear to the direction of the deformation. Therefore it is possible to split the force into one fraction parallel to the simple shear direction and one fraction in circumferential direction. The partial force in shear direction determines the amount of the

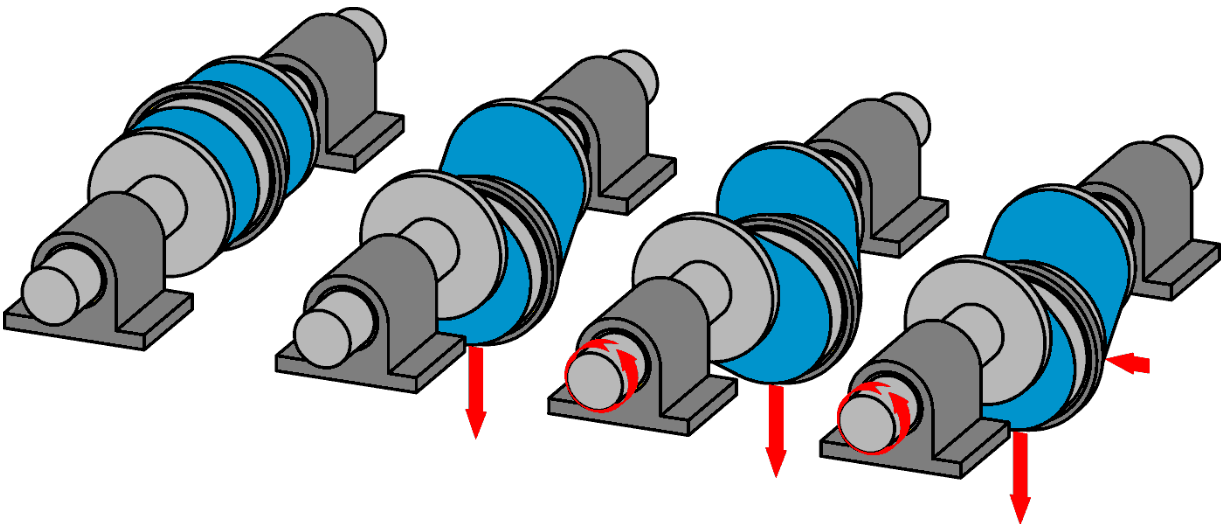

Fig. 1: Principal sketch of the test rig for simple shear deformations with rotating axes

elastic portion of the energy-balance and the partial force in circumferential direction the dissipated amount of the energy.

3. Layout of Experimental Rig

For the realization of a simple shear process with rotating axes an experimental setup on the basis of the apparatus proposed by Gent in [1] has been implemented. Figure 1 shows the principle of the proposed test machine.

The test rig consists of three bearing cases and two samples in double-sandwich-arrangement. Both outer bearing cases are fixed in their position, the central bearing case has a translatoric degree of freedom perpendicular to the axis of the bearings. Each of the two samples is mounted between one outer and the central bearing case. By means of a displacement of the central bearing case a simple shear deformation is initiated in the samples. By applying a torque at one of the outer bearing cases a simple shear deformation with rotating axes is put into practice. By mounting two force sensors in a suitable position, both components of the reaction force, one in the direction of the shear deformation and one in circumferential direction, can be measured separately. The measurement of those two force components allows a characterization of technical rubber materials concerning their different properties.

4. Experimental Results – Mechanical Characterization

The mechanical properties of technical used elastomers show a profound dependency on the loading history and the loading amplitude. With the help of the test machine for the realization of a simple shear deformation with rotating axes, it is now possible to measure the stress-induced softening of carbon black filled elastomers in respect to time and loading amplitude. Fundamental properties like shear stiffness and loss-angle are also measurable without large operating expenses in real-time.

5. Experimental Results – Fatigue Measurements

Besides the analysis of the mechanical properties of filled elastomers in the temporal close-up-range, it is also desirable to be able to predict the lifetime behaviour of industrial produced rubber parts. Regarding this background the experimental rig offers the possibility to investigate new and not yet considered aspects to determine and predict the fatigue behaviour of technical rubber materials. Common fatigue studies of rubber parts mainly deal with the variation of the loading amplitude. In addition to those investigations, simple shear deformations with rotating axes show the influence of changing loading directions onto the fatigue resistance of rubber; an aspect, which has not been considered yet in the prediction of the lifetime of rubber parts.

6. Summary

The presented experimental setup enables to analyze new and not yet considered mechanical aspects of rubberlike materials. Especially in respect to the prediction of the lifetime of rubber parts, new and highly relevant features can be shown with the help of simple shear with rotating axes, which enables to create advanced models for the simulative prediction of fatigue behaviour of rubber parts.

References

[1] Gent, A. N. Simple rotary testing machine. British Journal of Applied Physics Vol. 11. (1960).