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IDENTIFICATION OF VISCOELASTIC MODEL PARAMETERS BY MEANS OF CYCLIC NANOINDENTATION TESTING

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ABSTRACT

The nanoindentation technique is a well-known tool for the identification of mechanical properties at the micro- and nanometer scale of materials. In case of elastic or elastoplastic materials, Young's modulus can be determined from the unloading phase of the nanoindentation test results [1]. Recently, methods for the identification of viscoelastic properties from materials exhibiting time-dependent response were developed (see, e.g., [2, 3]). Hereby, the measured increase of the penetration during the so-called holding phase is compared with the respective analytical solution for the mathematical problem of a rigid indenter penetrating a viscoelastic halfspace [4]. Alternatively, a cyclic load history may be considered for identification of the viscoelastic material behavior [1, 5–7]. Hereby, an oscillating load is applied to the tip and the amplitude of the penetration history and phase shift between the peak values for the penetration and the prescribed load history is measured. With these two parameters at hand, the complex modulus and the phase angle of the material sample can be determined. Cyclic nanoindentation was applied in several studies for the mechanical characterization of polymers. In all these publications, the viscoelastic behavior of the polymers was, if at all, described by a Kelvin-Voigt model.

In this paper, a tool for identification of parameters for various linear viscoelastic models, representing the time-dependent behavior of the material sample, is presented. The parameters for a specific viscoelastic model are obtained by comparing the experimentally-obtained storage and loss moduli of the tested material sample – both depending on the frequency of the cyclic loading history – with the analytical expressions for the respective viscoelastic model (see Figure 1). The presented method is applied to low-density polyethylene, giving access to the parameters of the fractional dash-pot which is used to describe the underlying viscoelastic behavior. The obtained results are compared with results from nanoindentation (static) creep tests, considering

different maximum loads [8]. Finally, the performance of the presented method is assessed by comparing the creep-compliance functions corresponding to the model parameters identified by nanoindentation with macroscopic creep-compliance functions obtained from bending-beam-rheometer tests.

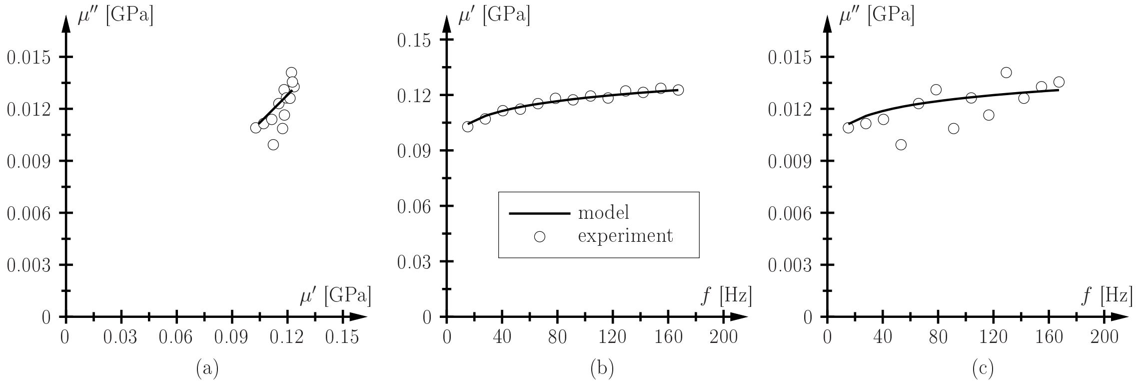

Figure 1: Comparison of experimental results and model response obtained from parameter identification: (a) Cole-Cole diagram; (b) storage modulus μ' and (c) loss modulus μ'' as a function of frequence of the cyclic load history (experimental data for low-density polyethylene tested at a maximum load of 20 μN and a load amplitude of 0.2 μN).

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