PROJECT CALL:

Cumulative Damage in Rubber Materials – Benchmark and Further Development.

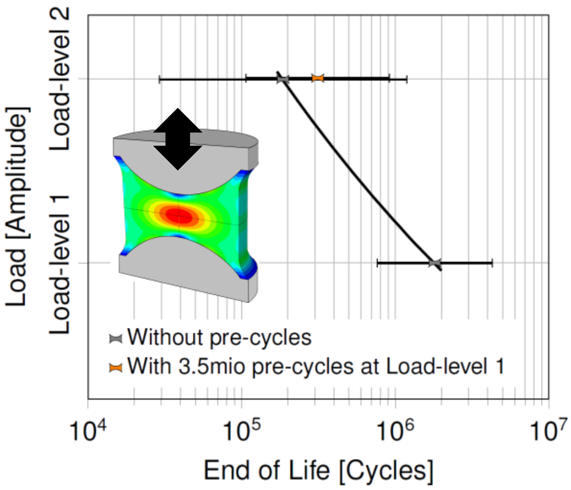

Fig. 1: Fatigue tests with constant amplitude and pre-cycles at a different amplitude. The test piece is made from a carbon filled SBR.

This project is motivated by components loaded in service. These real-life loadings are rarely of continuous cyclic constant amplitude nature. In daily use, rubber components are exposed to all kinds of loadings. However, the lifetime of such components is often predicted using fatigue data from simple test pieces which were exposed to continuous cyclic loads with constant amplitude. Unlike the test pieces, components are loaded in general with a large variety of amplitudes. One way to account for this circumstance is the use of cumulative damage concepts. The simplest among these is the linear cumulative damage concept from Miner [1]. This concept showed acceptable prediction results for natural rubber in several publications e.g. [2,3]. Ayoub et al. however, demonstrated the inapplicability of this *Miner-rule* on carbon filled styrene-butadiene rubber (SBR) in several papers e.g. [4]. Their findings were confirmed in a former project of the research institution DIK with a newly developed two-sided bonded fatigue test piece [5]. In this study, fatigue tests with constant amplitude until failure are compared against fatigue tests with many pre-cycles at a lower amplitude and a subsequent continuation at a higher load-level (see Fig. 1). The pre-cycles at load-level 1 did not influence the subsequent fatigue test at load-level 2 within this first preliminary test.

Objective

Main objective of the present project is to study the mechanisms of cumulative damage on at least two different materials. Minimum, a natural rubber shall be compared against a synthetic rubber (e.g. SBR-based) since these two classes of materials show a different lifetime sensitivity on the chronology of amplitudes.

Approach

The first step of the project consists of a comprehensive literature review starting from Miners linear cumulative damage concept from 1945, ending with rubber tailored non-linear continuum damage models. Cross-checking the existing literature revealed inaccuracies in the experimental data used for conclusions about the cumulative damage behaviour of rubber materials. E.g. Flamm et al. mention an inadequate amount test pieces [2] and Ayoub et al. report possible inaccuracies doe to variations in heat build-up within their experimental database [6]. Recently, the research institution DIK focused on the improvement of the reliability of mechanical fatigue measurements, covering e.g. controlled test piece heat build-up [7], considering the evolution of the local load with ongoing cyclic loading [8] as well as the surface-independent lifetime measurement.

This knowledge will be used for the creation of an experimental database to be able to perform a precise benchmark of cumulative damage concepts. This database shall cover, constant amplitude testing as reference, variable amplitudes in different orders and random road-load-data-like amplitudes for minimum two materials. Depending on the project progress, additional investigations with a variation of non-relaxing test conditions might be conducted. The test campaign is accompanied with advanced examination methods like computed tomography scans on interrupted fatigue tests in order to *suss out* the observed phenomena. The present undertaking shall be topped off with an application of the insights on components provided or chosen by the consortium.

Economic benefit

This project provides information about the impact of the chronology of amplitudes on the fatigue of technical rubber compounds. This knowledge enables an improved precision of finite-element-method-based lifetime prediction and can therefore contribute to a reduction of prototypes in the design-cycle of components.

Time, project management and contact details

- Funded by industry
- Approx. project duration: 3 years
- Expenses: 85 000 EUR/year. However, with a limit of 20 000 EUR/year per participant
- Deadline for response of interest: 18. June 2021

Deutsches Institut für Kautschuktechnologie (DIK) e. V.
Oliver Gehrmann
Eupener Straße 33
30519 Hannover
Email: Oliver.Gehrmann@DIKautschuk.de

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