Assessment of Toughness Behaviour of Elastomers with Fracture Mechanics Methods

K. Reincke, W. Grellmann, R. Lach, Martin-Luther-University of Halle-Wittenberg, Halle/Germany, G. Heinrich, Continental AG, Hannover/Germany

Introduction
Elastomer materials with their wide application range are variously loaded that may lead to failure. This failure is caused by initiation and propagation of cracks from which the application of fracture mechanics becomes especially useful for materials assessment to be derived. Aim of this work is the consolidation of knowledge in the field of fracture mechanics for elastomer materials. For example, open questions are:

- How reliably can one apply relatively easy methods of technical fracture mechanics, which were established for the metals industry, to the toughness evaluation of elastomers?
- Do these methods work for elastomer materials with their specific deformation behaviour?

Materials

- Statistical styrene-butadiene copolymer SBR 1500, crosslinking with a sulphur-accelerator system, variation of sulphur content (0.1, 0.2, 0.3, 0.4 phr) to obtain different values of network density, filled with carbon black (0, 15, 30, 40, 50 phr; filler type: carbon black (CSR) NS30)
- Natural rubber, filled with silica (contents 0, 5, 10, 15, 20, 70 phr)
- Natural rubber, filled with nano-layered silicate (nano filler, contents 0, 5, 10, 15, 20, 70 phr)

Examinations

Impact Loading

Instrumented tensile impact test (ITT): specimen configuration double-edge notched tension (DENT) specimen, calculation of J-values, Jeq related to resistance against unstable crack initiation and propagation according to following equation:

\[ J_{eq} = \frac{P}{B} \left( \frac{a}{W} \right)^{1/2} \]

with \( P \) = ITT bending energy (J), \( W \) = specimen thickness, \( a \) = initial crack length, \( B \) = specimen width, \( A_{p} \) = energy up to the crack propagation

Example 1:
Examination of effect of carbon black (filler) content and sulphur (network density) on resistance related to unstable crack initiation and propagation for SBR vulcanizes

Test conditions:
- Test speed 2,5 m/s
- Maximum pendulum energy 4 J
- Initial crack length 2,4 mm, specimen thickness 1.5 mm, specimen width 15 mm, initial gauge length 60 mm

- Decreasing toughness of the filled vulcanizes with increasing network density because of reduced crack growth combined with reduced chain mobility
- Increasing resistance against unstable crack propagation with increasing carbon black load in maximum-40 phr-filler vulcanizes

Example 2:
Examination of effect of silicate and nano-layered silicate (nano filler) content as well as direction of taking from the specimens on resistance against unstable crack initiation and propagation for a natural rubber vulcanize

Test conditions:
- Test speed 3,7 m/s
- Maximum pendulum energy 7.5 J
- Initial crack length 2 mm, specimen thickness 1.0 mm, specimen width 10 mm, initial gauge length 60 mm
- Specimens were taken from plates (a) along and crosswise to the rolling direction

- Type of tearing of these materials: notched tip
- Changes in crack propagation speed during test == also in crack propagation behaviour
- Strong differences of stable crack propagation behaviour between the specimen directions:
  - Hardly any differences, crosswise especially filler contents of 60 and 70 phr lead to increased crack toughness

Conclusions

By these tests reported here it is possible to describe the fracture behaviour of elastomer materials. The ITT is a suitable and relatively easy method for the characterization of fracture properties of such elastomers (SBR and natural rubber). With the in situ fracture mechanics test, the stable crack initiation and propagation behaviour can be described under consideration of some requirements on specimen geometry. Further examinations should verify the specimen dimension, especially the necessary specimen thickness.