The Dependency of Dynamic Crack Growth on the Minimum Load of Elastomers

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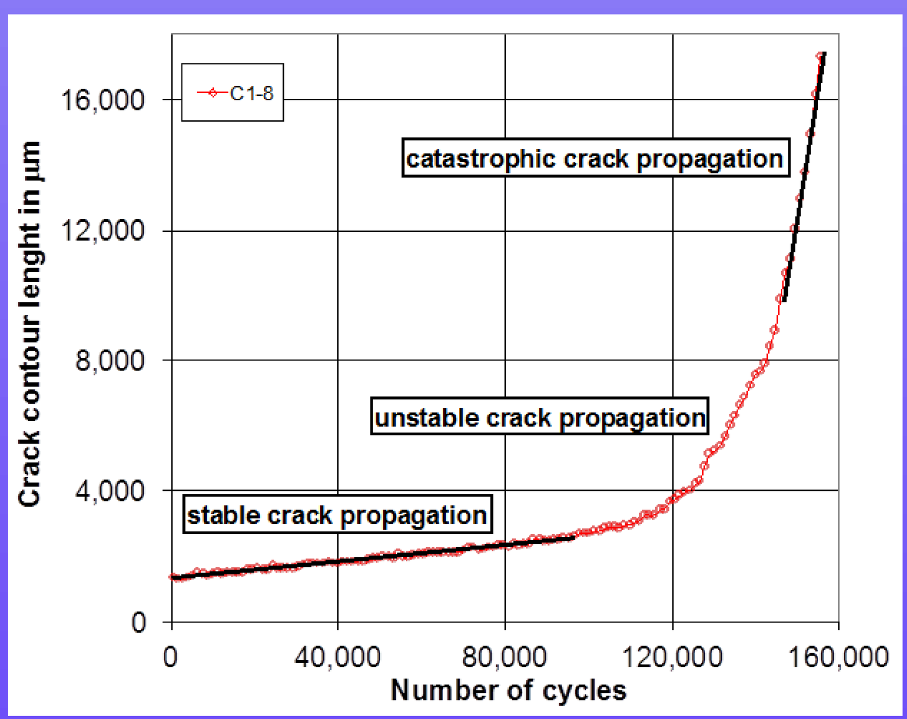
This work describes the cyclic or dynamic crack propagation behaviour of carbon black filled and unfilled non strain-crystallising elastomers, especially their dependency on strain amplitudes and static minimum load variations.

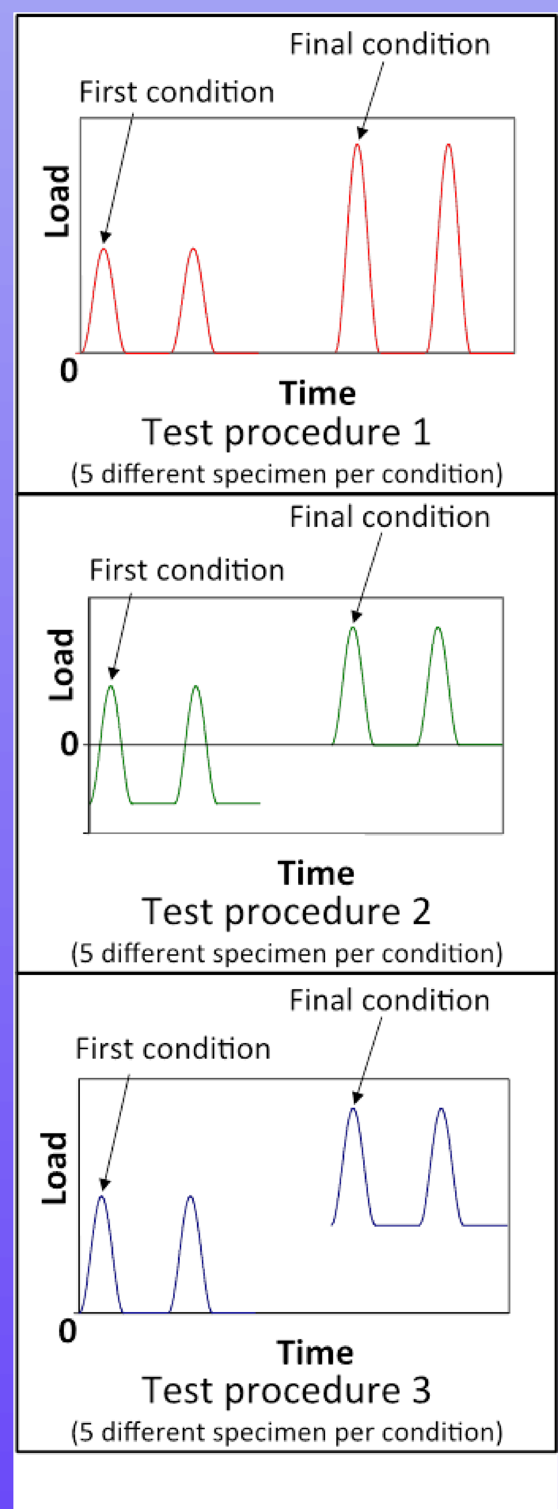
Materials:

Unfilled and filled ethylene propylene terpolymer (EPDM) and styrene butadiene polymer (SBR) vulcanisates have been used in this research programme. Both elastomers show no strain induced crystallisation effects. The unfilled EPDM elastomer contained standard trade EPDM Buna EP G5450 and an accelerated sulphur cross-linking system. In the case of the filled EPDM 110 phr (70 phr N550 and 40 phr N772) low active carbon black and 70 phr softener oil were added. The unfilled SBR elastomer was composed of an oil extended standard trade SBR (SBR 1712) and an accelerated sulphur crosslinking system. The addition of 70 phr of high active carbon black N234 resulted in a standard SBR tyre tread elastomer.

Photos of used Tear Analyzer System, temperature chamber with 10 test specimen installed some at different minimum loads and a sketch with test specimen dimensions.



Typical crack contour length dependence on number of cycles for a carbon black filled EPDM, tested with pulses of 50ms, at 10Hz, 20% and 2N minimum load. Only the stable crack propagation region was used for this work.

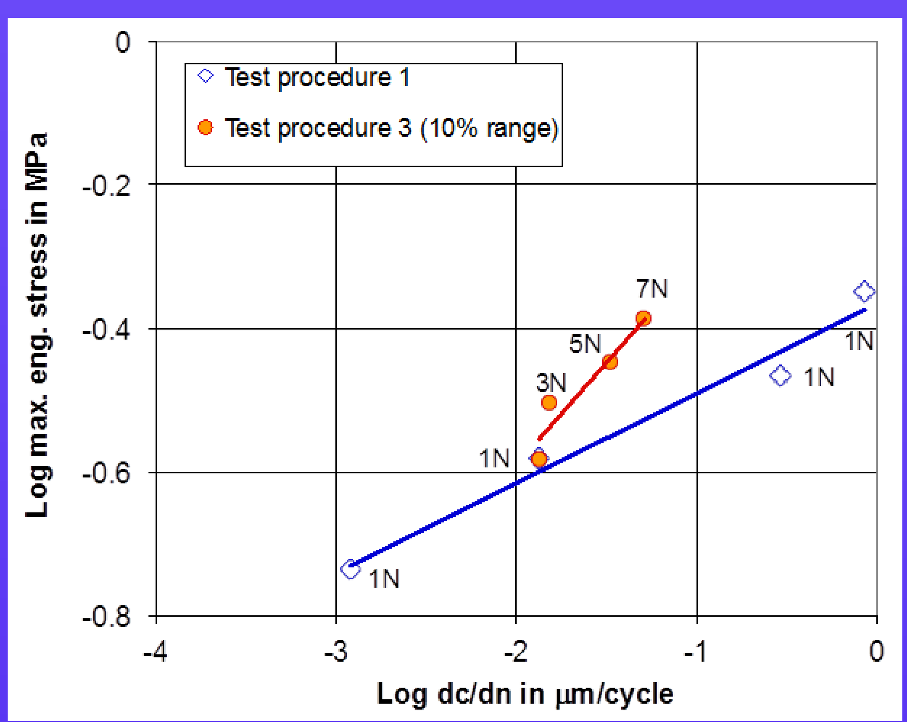


Schematic depiction of the three crack propagation test procedures.

Procedure 1:
Each specimen was subjected to tensile cycles with quasi zero minimum load. A material specific minimum load in tension was applied to avoid buckling. The dynamic strain amplitude in a test was kept constant, but was increased in subsequent tests with a new set of 5 specimens. The magnitude of the maximum load was material specific.

Procedure 2:
Each material was subjected to a single dynamic strain amplitude. The minimum load for each set of tests was initially strongly in compression, rising to a minimum of zero.

Procedure 3:
Each material was subjected to a single dynamic strain amplitude. The minimum load for each set of tests was initially quasi zero, rising to a material dependent minimum load in tension.

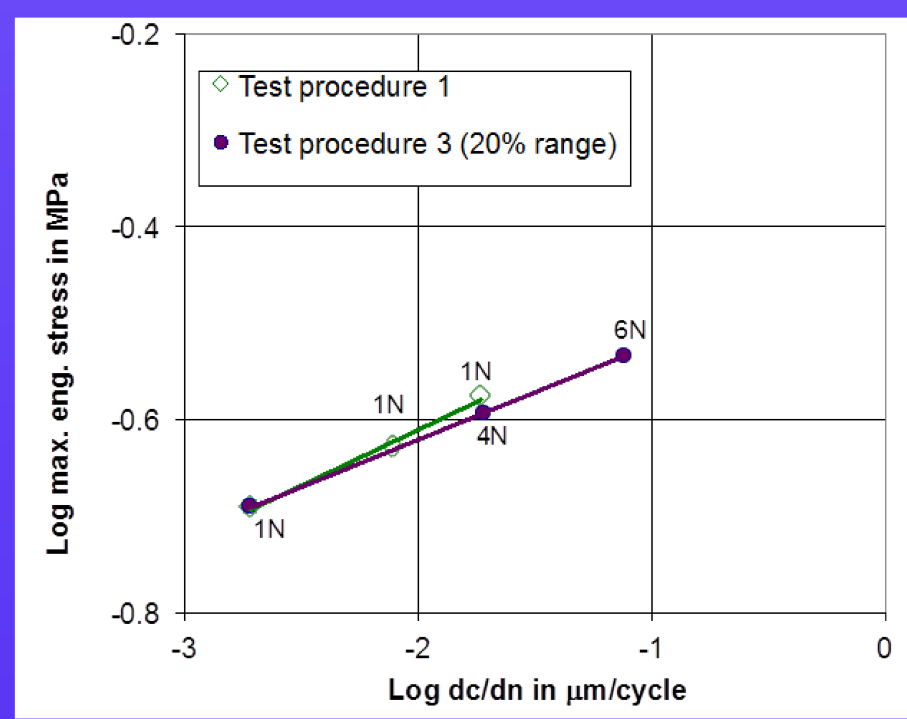


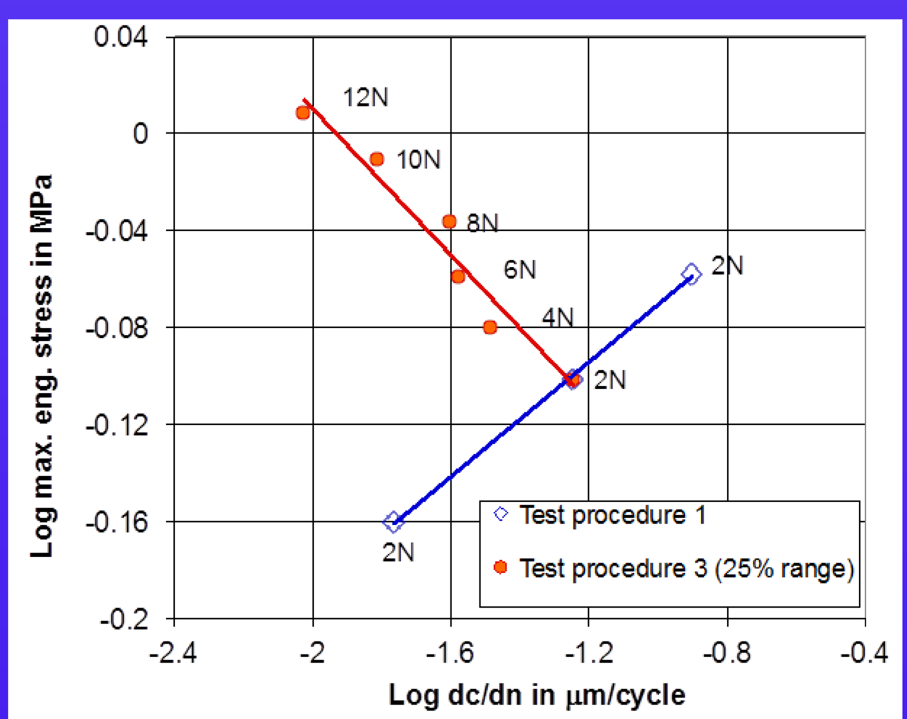
Crack propagation rate results for unfilled EPDM, showing maximum stress dependence.

Each diamond in this diagram represents the mean values of the results for a discrete strain amplitude (6%, 10%, 14%, 20%) under a constant minimum load of 1N.
A minimum load variation with a constant strain amplitude of 10% is represented by the circles in this Figure. An increase of the minimum load at constant strain amplitude and hence increased maximum stress increases the crack growth rate in contrast to the carbon black filled EPDM tests.

Crack propagation rate results for unfilled SBR, showing maximum stress dependence.

Each diamond in the diagram represents the mean value of the results of a discrete strain amplitude (20%, 25%, 30%) with a constant minimum load of 1N.
A minimum load variation with a constant strain amplitude of 20% is represented by the circles in this Figure. The results show that an increase of the minimum load at a constant strain amplitude and hence increased maximum stress, increased the crack growth rate. Both procedures, strain amplitude variation and minimum load variation virtually show a single curve for maximum stress dependency.



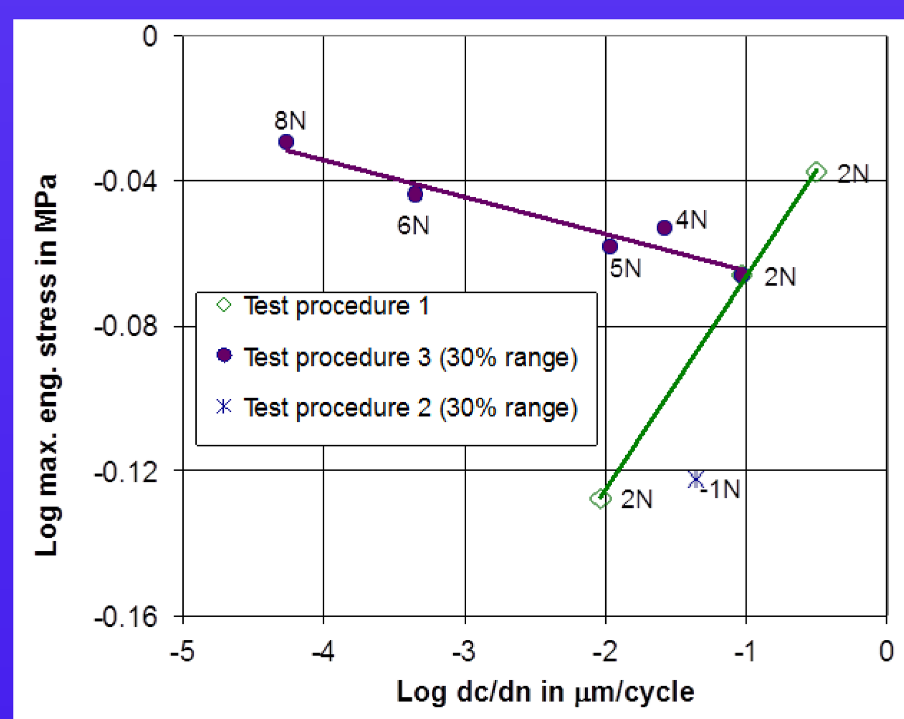


Crack propagation rate results for carbon black filled EPDM, showing maximum stress dependence.

All diamonds in this diagram represent mean values of the results of discrete integral strain amplitudes (20%, 25%, 30%) with a constant minimum load of 2N.. With increasing strain amplitude and hence maximum stresses the crack growth rate increases and the number of cycles till rupture decreases. A minimum load variation with a constant strain amplitude of 25% is represented by the circles in this Figure. The results show that with an increase of the minimum load at a constant strain amplitude (and corresponding increase in maximum load) the crack growth rate is reduced by a factor of 8 within this parameter range.

Crack propagation rate results for carbon black filled SBR, showing maximum stress dependence.

The crack propagation properties of carbon black filled SBR are shown in this Figure. Each diamond in this diagram represents the mean value of the results of a discrete strain amplitude (20%, 30%, 40%) at a constant minimum load of 2N.
Test procedure 3, where minimum load is varied at a constant strain amplitude of 30%, is represented by the circles in Figure 18. An increase of the minimum load reduces the crack growth rate dramatically by factors up to 1700 within the parameter range used.



Increasing minimum loads at constant strain amplitude under pulsed excitation decrease the crack growth rate of the carbon black filled rubber materials by some orders of magnitude. The crack propagation properties of carbon black filled SBR are shown in the bottom right Figure. Each diamond in this diagram represents the mean value of the results of discrete strain amplitude (20%, 30%, 40%) at a constant minimum load of 2N. An example of minimum load variations at a constant strain amplitude of 30%, is represented by the circles in the bottom right Figure for carbon black filled SBR. An increase of the minimum load reduces the crack growth rate of the filled SBR by factors up to 1700 within the parameter range used.

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