The Strain Hardening Test to quickly determine the Resistance of PE Materials to Slow Crack Growth

Slow crack growth is one of the most important failure mechanisms for installed PE gas and water pipelines. Many different test methods exist for measuring this phenomenon, like the Internal Water Pressure (Stress Rupture) test, the Notched Pipe test (NPT), the Cone test, the PENT test and the Full Notch Creep test (FNCT). However, because the properties of PE resins for pipes have been improved continuously during the last decades, testing times and testing costs have increased quite a lot. Moreover, some tests, like the FNCT show considerable inter-laboratory scatter, most likely due to degradation of the detergent.

The most recent addition of improved materials is PE100 "RC" (Resistant to Cracking). Slow Crack Growth resistance has now been improved far beyond that of a traditional PE100 material.

The new Strain Hardening (SH) test of SABIC (Netherland), published by the SABIC researchers Kurelec et al [1], McCarthy et al [2] and recently by Havermans et al [3], is now also available at our lab.
The SH test is a modified tensile test performed at 80 °C on a specially prepared thin sample (Figure 1). The horizontal axis of the stress-strain curve is transformed to the Neo Hookean Strain Measure (NHSM - Figure 2). In the region where the True Strain λ is between 8 and 12 the Strain Hardening Modulus <Gp> is calculated from the slope of the curve.
Figure 2 shows typical curves.

Figure 1. SH samples.

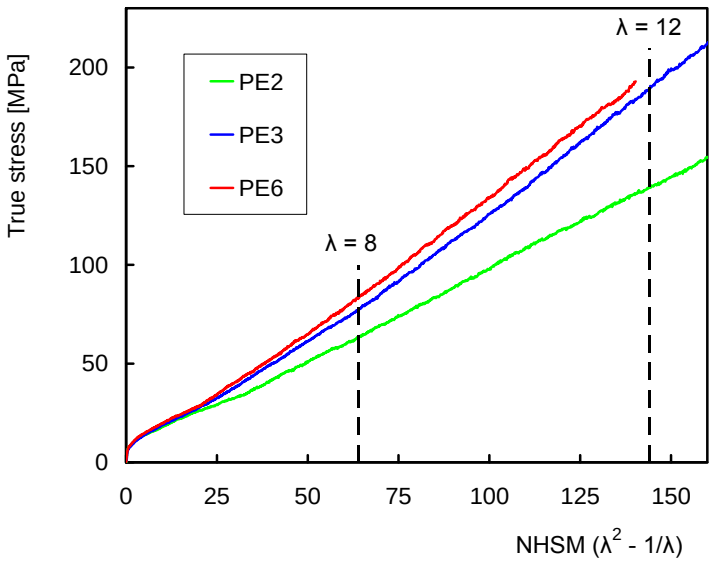

Figure 2. Results of Strain Hardening experiments on 3 PE types.

Advantages of the SH test are:

1. The test takes about 1 day to perform the measurements on five to eight samples, apart from sample preparation
2. Only a small sample mass is necessary. This allows ranking of brand new development resins from a bench-scale polymerization reactor against own reference materials or state of the art commercial resins.
3. Only simple and straightforward testing equipment is necessary.

The Strain Hardening test was used to assess the slow crack growth resistance of various PE resins. These resins range from excavated first generation PE materials via second generation HDPE and MDPE materials and third generation PE100 materials, up to the most modern PE100 RC materials.

For a series of 6 reference materials, each measured in eight-fold a typical Variability Coefficient (standard deviation divided by the average value) of 5 % was noted. Another laboratory showed a similar Variability Coefficient.
The results have also been compared with results of the range of other slow crack growth tests mentioned above.

The Strain Hardening Test is a very attractive method to assess and rank the resistance to slow crack growth of a PE resin in a short testing time and at low cost.

Contact

Technical matters
Ir. Frans Scholten (+31 55 5393 395)
frans.scholten@kiwa.nl
Ir. Ernst van der Stok (+31 55 5393 264)
ernst.van.der.stok@kiwa.nl

Commercial matters
Ing. Bert Wikkerink (+31 55 5393 445)
bert.wikkerink@kiwa.nl

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