Resistance of large diameter PE pipes to internal pressure - A new approach using a cost-cutting test method

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Increasing use of large diameter PE pipes for pressure systems demand a reliable method for determining their creep rupture strength.

The hydrostatic strength requirements at 80°C for PE pipes (e.g. in EN 12201-2) were established by internal pressure tests using pipes with an outside diameter of 32 or 110mm.

Hydrostatic pressure tests at 80°C on large diameter pipes are very expensive. For this reason a joint industrial research project involving raw material producers, pipe producers, producers of pipe components and sheet manufacturers is being carried out to determine whether a low-cost specimen test can be used to assess the minimum creep rupture strength of large diameter pipes.

The basis for the validation is a correlation between results of internal pressure tests on large pipes and the rupture times of 2-notch creep test (2NCT) specimens taken from these pipes.

The test results of the investigations so far indicate that the 2NCT, according to EN 12814-3, can be used to assess the minimum creep rupture strength of large diameter pipes.

Indroduction

The design of pressure pipes made from polyethylene is based on the minimum creep rupture curves of pipes under internal pressure according to ISO 9080. These tests are performed on small pipes (OD 32 to OD 110) due to the number of specimens that must be tested.

The increasing application of polyethylene pipes with larger diameter (e. g. spirally-wounded pipes up to a diameter of 3500 mm, fig. 1) or the need to demonstrate the minimum creep rupture strength of unique pipeline components machined from a thick wall semi finished product (fig. 2) demand a reliable method to determine the actual minimum creep rupture strength related to the design curves used for the calculation.

In a joint research project with the industrial partners:

Borealis
Lyondellbasell
Frank & Krah
Reinert-Ritz
SIMONA
HESSEL Ingenieurtechnik

a standardized method (EN 12814-3) was used based on notched specimens taken from the parts to be evaluated.

Fig. 1: Spirally-wound pipe, OD 3500 mm

Fig. 2: PE 100 branch; 45 °; OD (800/630 mm) SDR 13.5; Service pressure 12.5 bar

The idea

The basic consideration to solve the problem is the answer to the question whether there is a correlation between the creep rupture times of pipes under internal pressure and the creep rupture times of specimens taken from these pipes, as is schematically shown in fig. 3.

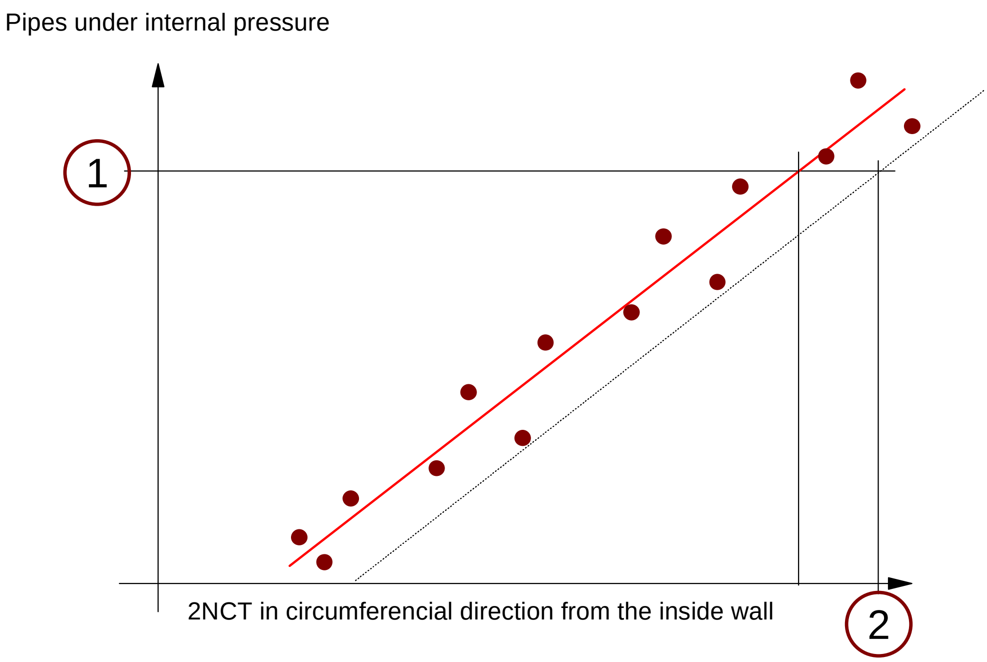

Fig. 3: Schematic diagram of a correlation between internal pressure test and 2NCT
1: Minimum requirement for pipes under internal pressure
2: Minimum requirement for 2NCT specimens

In order to assess the effect of orientation caused by the extrusion process and to have the identical direction of the dominating stress in both tests the 2NCT specimens are taken in circumferential direction from the inside pipe wall.

The 2NCT according to EN 12814-3, Annex A.2 is a creep rupture test which allows the determination of the creep rupture behaviour of specimens with a thickness > 1.7 mm (fig. 4).

The data should be generated over a wide range of quality (creep rupture times) where the required minimum creep rupture times of the relevant standards (e. g. EN 12201-2) is covered by the quality range.

The number of data points generated in the correlation tests should allow the calculation of the lower confidence limit related to the minimum requirement in the 2NCT related to the minimum requirement given in the relevant standards.

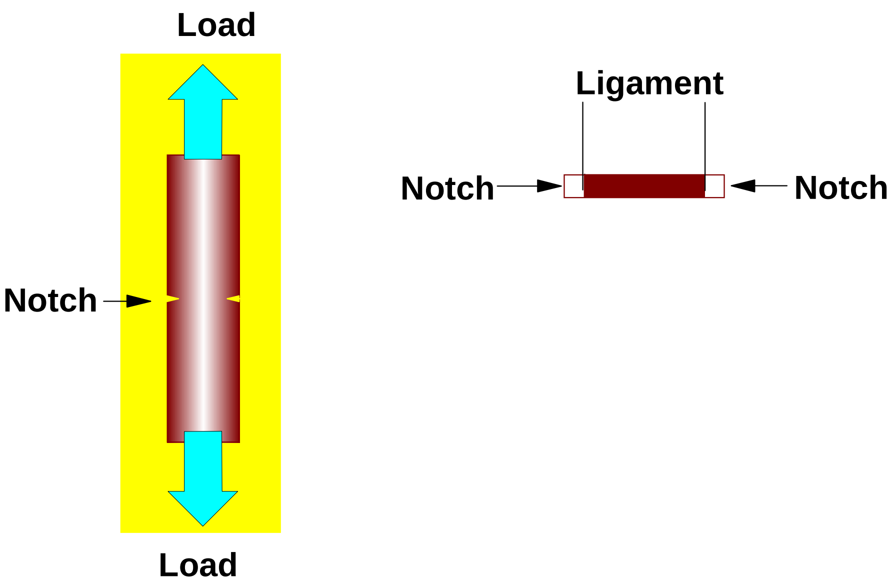

Fig. 4: Schematic draw of the test setup for the 2NCT

The basic condition to get a reasonable correlation between the internal pressure test and the 2NCT is that the failure mode of the specimens in both tests is brittle. Fig. 5 shows the fracture surfaces in the pipe wall after the internal pressure test of the pipe.

Fig. 6 shows the fracture surfaces after the 2NCT.

In both tests a brittle failure mode can be observed.

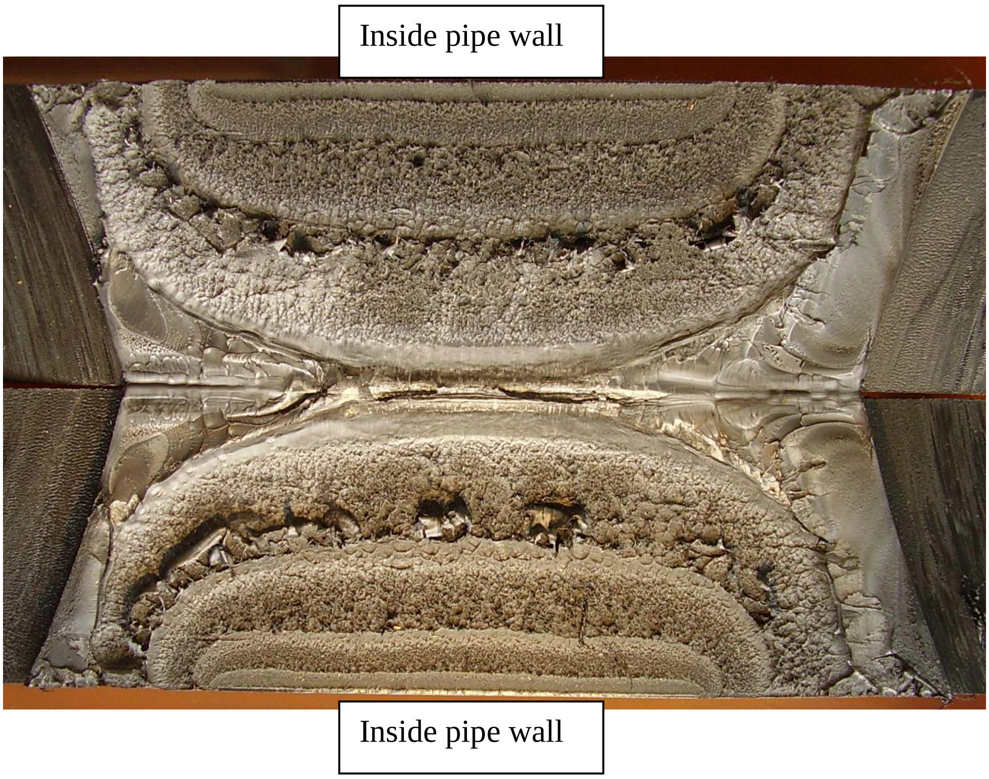

Fig. 5: Brittle fracture surfaces of a pipe after internal pressure test

Fig. 6: Brittle fracture surfaces after the 2NCT

Results

The data recorded up to the end of July 2008 are plotted in fig. 7. Fifteen correlation-tests were performed using both internal pressure tests on pipes and 2-notch creep tests on samples machined from the inside wall of these pipes. Each data point represents the geometric mean value of 3 internal pressure tests and 3 two-notch creep tests.

In order to simulate extrusion imperfections the pipes have been notched at the inside wall using a sharp industrial blade with a notch tip radius of approximately 1 µm.

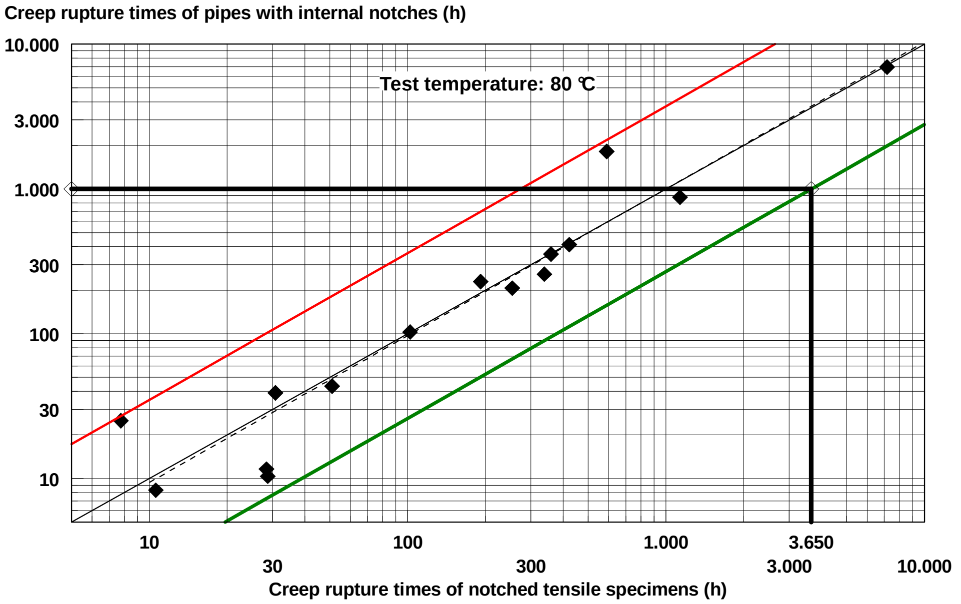

Fig. 7: Correlation of the test results in the internal pressure test and 2NCT

The linear regression analysis of the test data in a log-log scale provides a correlation coefficient of >0.9. The slope of the calculated mean curve is very close to the ideal slope of a theoretical isotropic and homogeneous material.

The minimum requirement for the rupture time in the 2NCT is calculated by regression analysis and a Student´s-factor delivering a 2.5 % minimum requirement.

The calculation leads to a minimum requirement in the 2NCT of 3650 hours if the requirement in the internal pressure test is 1000 hours (e.g. at 5 N/mm² for PE 100 or 4 N/mm² for PE 80).

Conclusion

The 2NCT according to EN 12814-3 is a cost-cutting test method to obtain information about the minimum creep rupture strength of pipes, sheets and components.

Remark:
The duration of the 2NCT can be reduced if accelerated test conditions producing a brittle failure mode are applied.