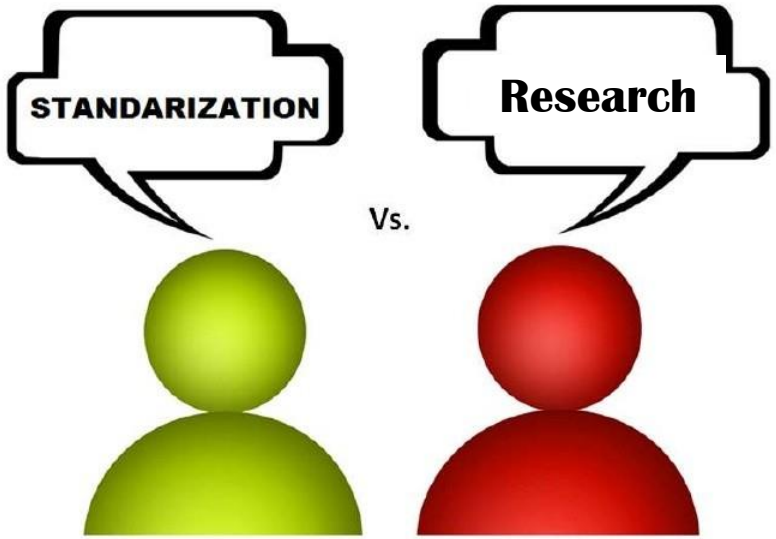
Workshop on ageing of district heating pipes

Accelerated ageing & lifetime predictions



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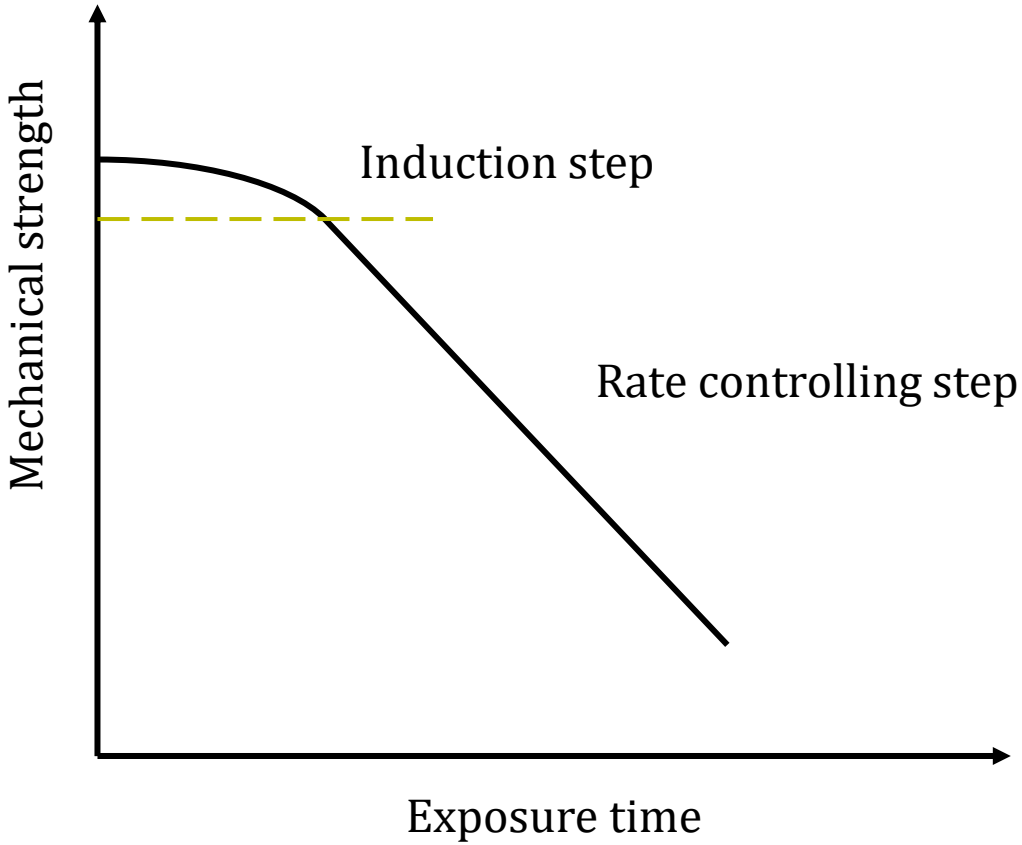
Lifetime prediction of pre-insulated DH pipes

Lifetime is defined by the period it takes for a crucial property of a material or product to deteriorate in a given environment to an established level of the original value



According to EN 253:2019

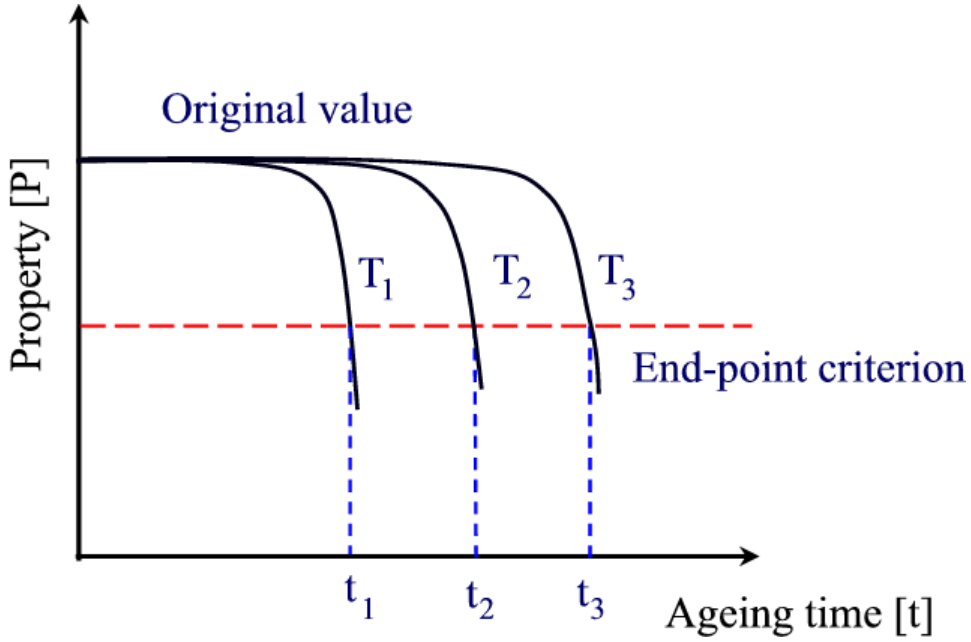
DH systems shall be designed for a service life of minimum 30 years for continuous operation with hot water at various temperatures up to 120 °C.

Shear strength τ_{ax} ≥45 % of initial value **and** 0,12 MPa

Period	– 30 years
Property	– shear strength
Environment	– 120 °C
Level	– 45% + 0,12 MPa

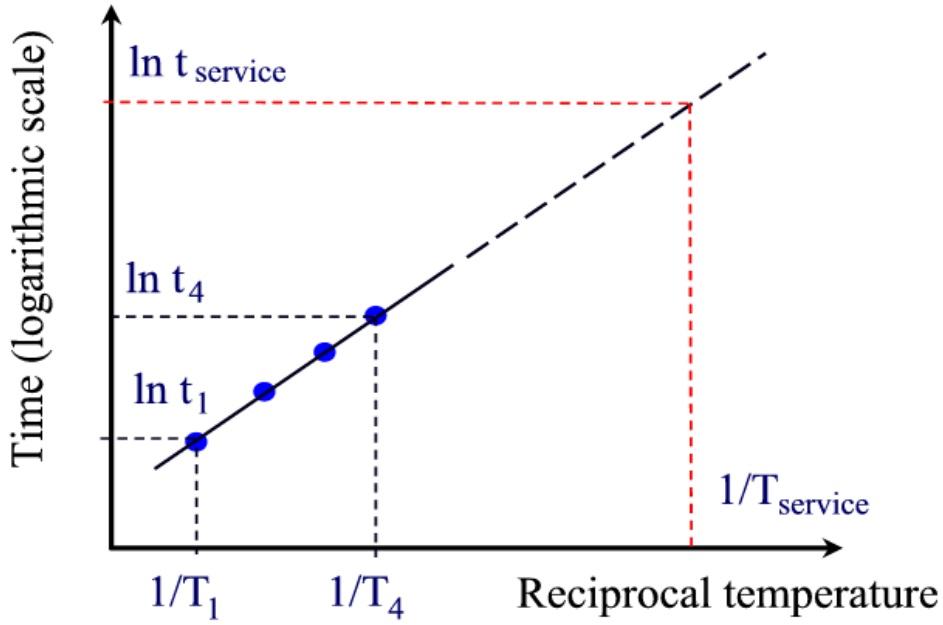
Lifetime prediction based on Arrhenius relationship

Ageing at elevated temperatures



Arrhenius diagram

$\ln t = E_a/R \cdot 1/T$



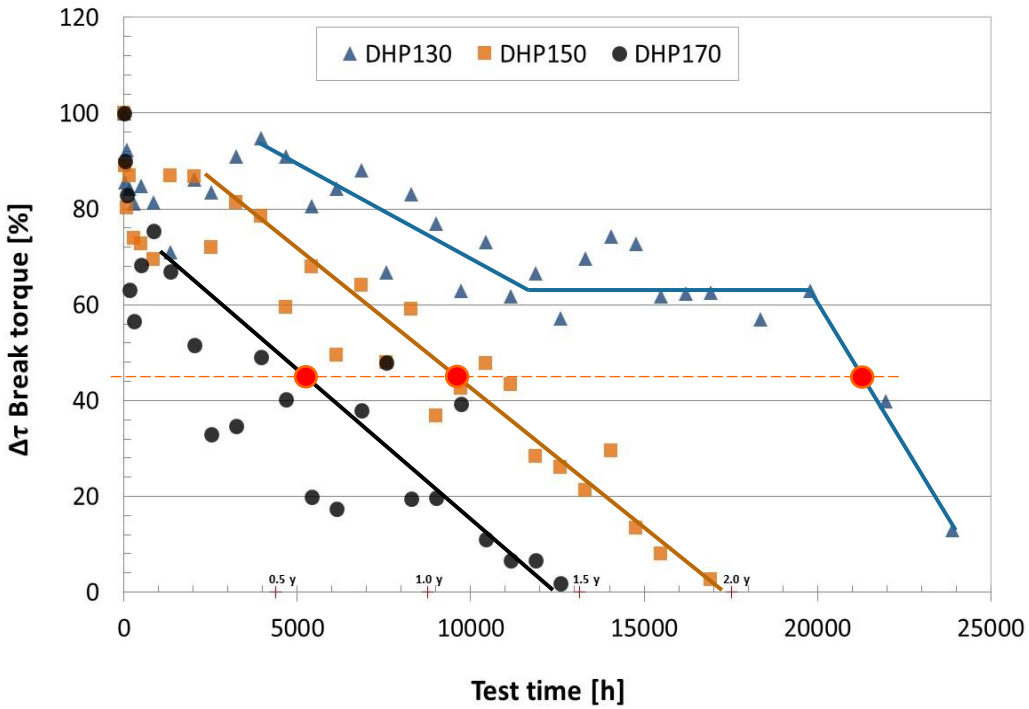
There are two crucial requirements for a relevant accelerated ageing test:

1. degradation processes are speeded up without being changed
2. all factors which might contribute to degradation of a product in the intended end-use environment are considered in the ageing test

Results of accelerated ageing at RISE

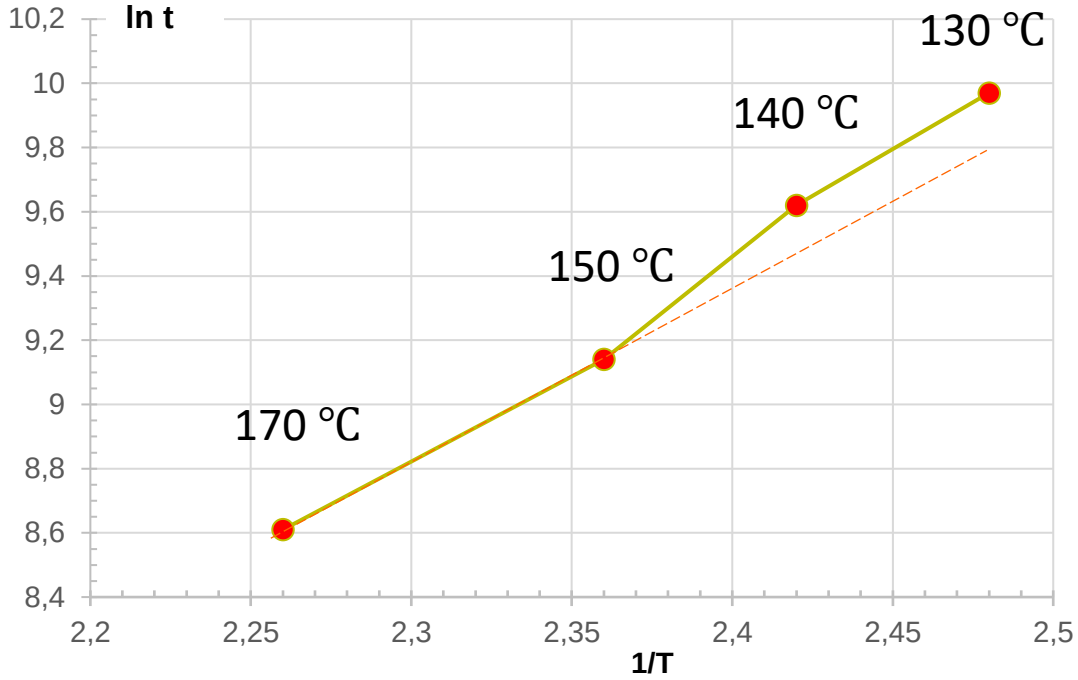
End-point criterion: shear strength 45 % of the original value

Experimental results



& 140 °C

Arrhenius diagram

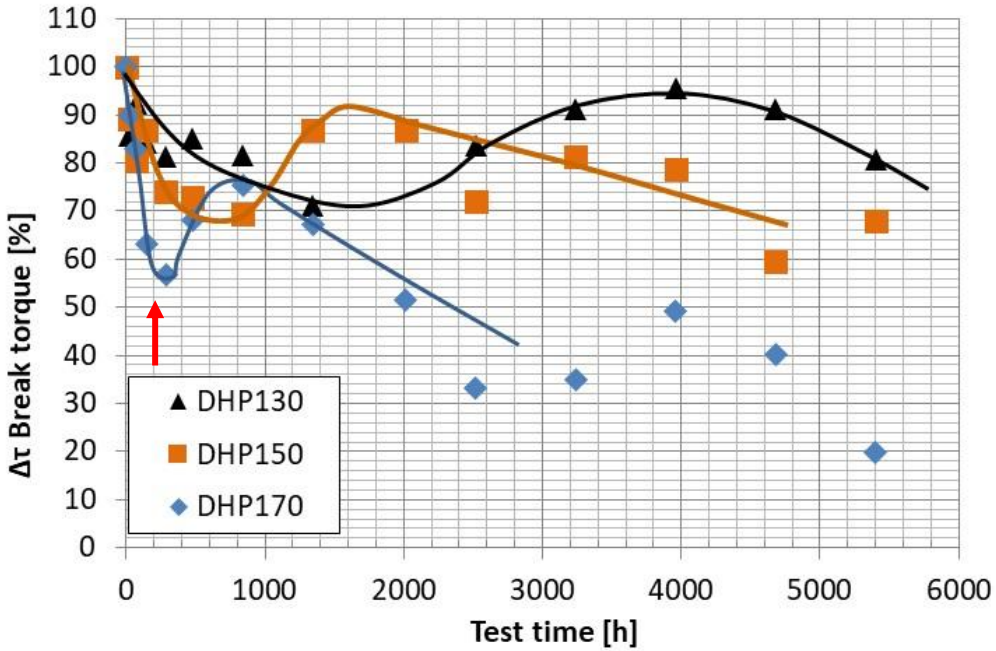


"Determination of the long-term performance of district heating pipes through accelerated ageing, Polymer Degradation and Stability A. Vega, N. Yarahmadi, I. Jakubowicz, vol.153 (2018) pp.15-22

Results from accelerated aging at temperatures ≥150 °C follow a different slope/trend than from temperatures below 150 °C

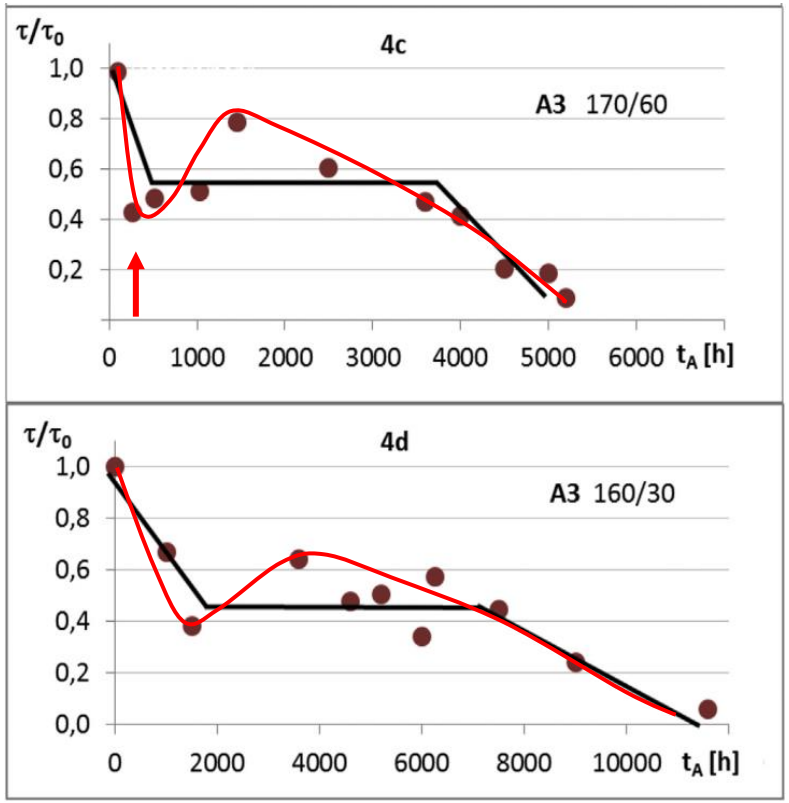
EN 253: 5.4.2 Shear strength of the pipe assembly after ageing

"pipe shall be aged at temperature of 170 °C for 7 days" (168 h)



"Determination of the long-term performance of district heating pipes through accelerated ageing, Polymer Degradation and Stability A. Vega, N. Yarahmadi, I. Jakubowicz, vol.153 (2018) pp.15-22

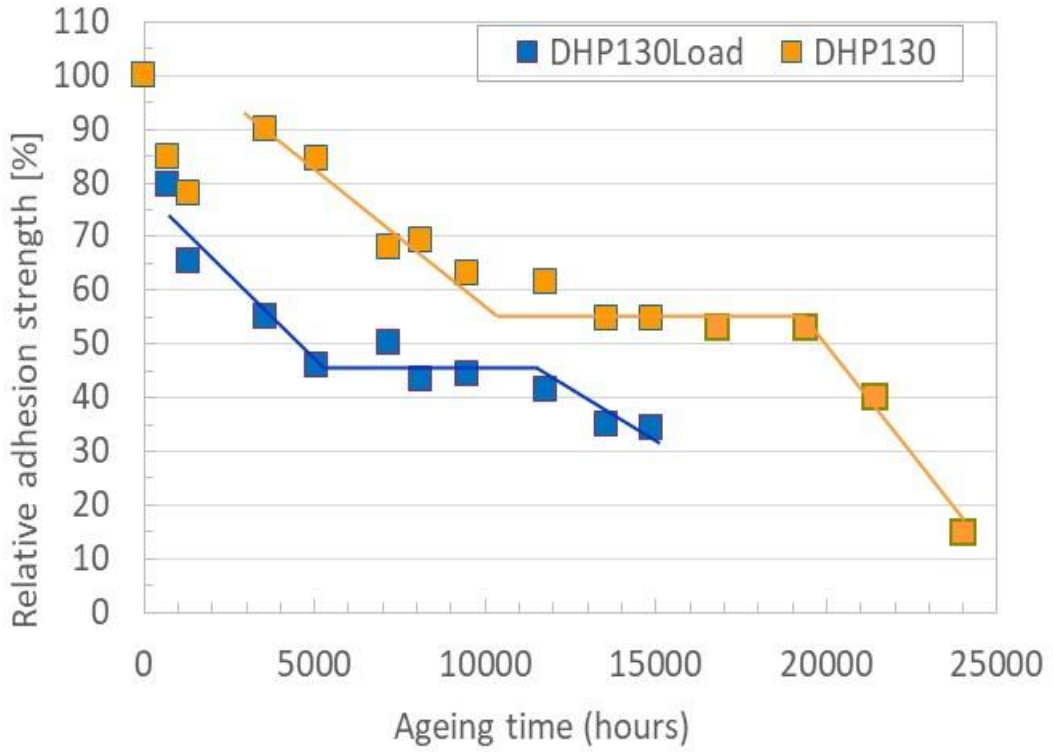
red lines are our interpretation

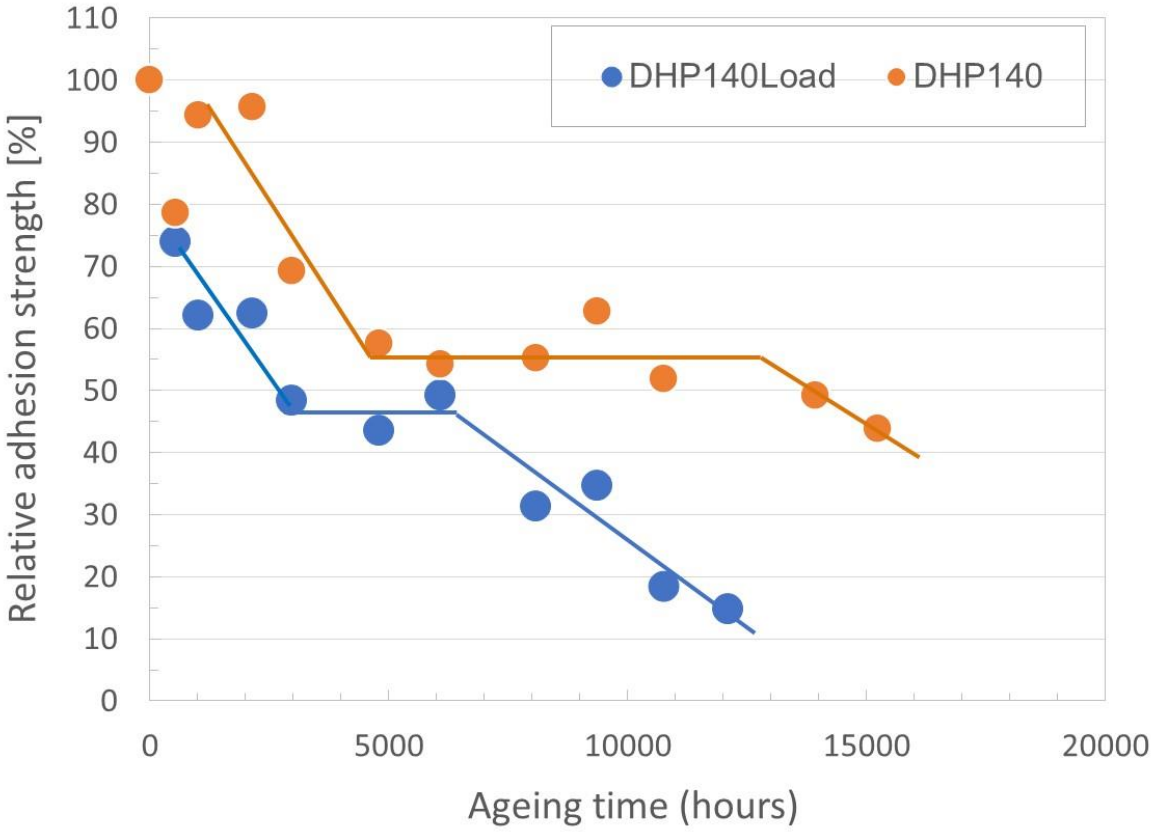


A.Leuteritz, K-D. Döring, T. Lampke,I.Kuehnert Polymer Testing 51, 2016, p.142-147

Effect of cyclic mechanical stress on the rate of degradation

It is important to consider all factors which might contribute to degradation of a product



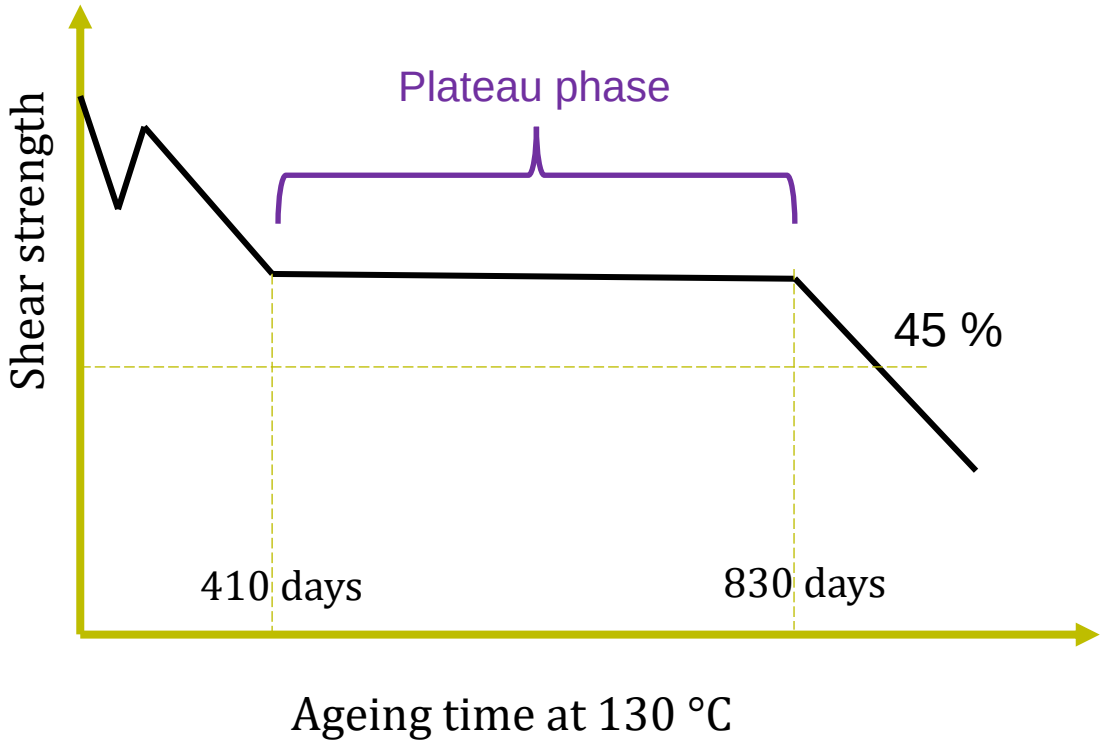


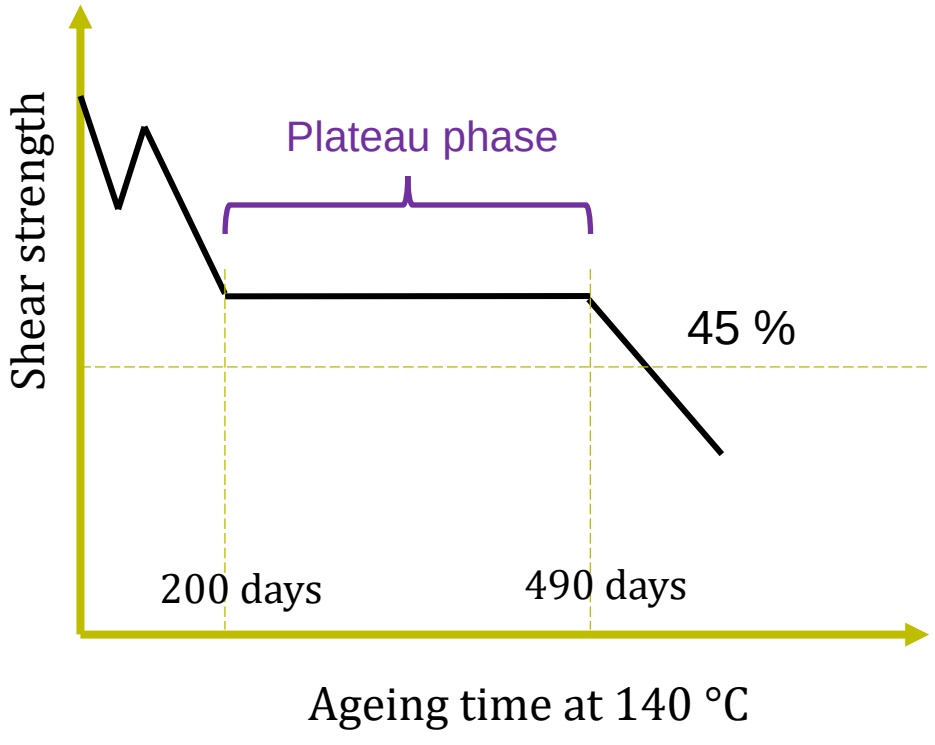
Repeated mechanical stress due to temperature fluctuations significantly increases the rate of degradation

"Effects of cyclic mechanical loads and thermal ageing on district heating pipes",
Polymer Degradation and Stability A. Vega, N. Yarahmadi, J.Sällström I. Jakubowicz, vol.158 (2020) pp.15-22

Difficulties in obtaining data within a reasonable period

The correct use of this technique requires a reasonable knowledge of both the underlying chemistry and the importance of various physical effects.





Only accel. thermal ageing time at 130 °C needs app. 900 days to reach 45%

Only accel. thermal ageing time at 140 °C needs app. 600 days to reach 45%

Prediction of service life with one data point only

Use of accelerated ageing tests at one stress level

$$A_f = \frac{t_2}{t_1} = \exp\left[-\frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)\right]$$

It is often practised to use one experimental point only and an assumed slope (activation energy)

An assumed acceleration factor A_f of 2,5 at ΔT = 10 K has been shown to give good agreement in various experiments and with E_a reported in scientific papers.

Benefits

- It is sufficient to carry out experiments at one temperature only and for a period corresponding to the requirement of service life for pass/fail decision.
- It makes it possible to compare various DH pipes operated at different temperatures by choosing a reference temperature and then recalculating periods at other temperatures to a period at the reference temperature.

Summary- new knowledge to consider for future revision of the EN 253 standard

- Accelerated ageing tests at 150 ℃ and higher temperatures cannot be used for the calculation of lifetime at the service temperature because it does not follow the Arrhenius relationship
- Test in accordance with EN 253 at 170 ℃ for 7 days does not provide any information about aging
- It is important to consider cyclic mechanical stress in accelerated ageing tests as it significantly increases the rate of degradation
- It is possible to use accelerated ageing tests at one temperature only and an assumed acceleration factor for practical reasons

References

Finished project:

- IEA- DHC 2012-2014
- National project 2014- 2016
- National project 2016- 2018
- IEA- DHC project 2017- 2019
- National project 2019- 2022

On going project:

- National project 2022- 2024
- National project 2022- 2024
- IEA-DHC TS6