BTO Executive Summary

Slow crack-growth and residual stress modelled in Comsima provides clearer picture of pipe failure causal factors

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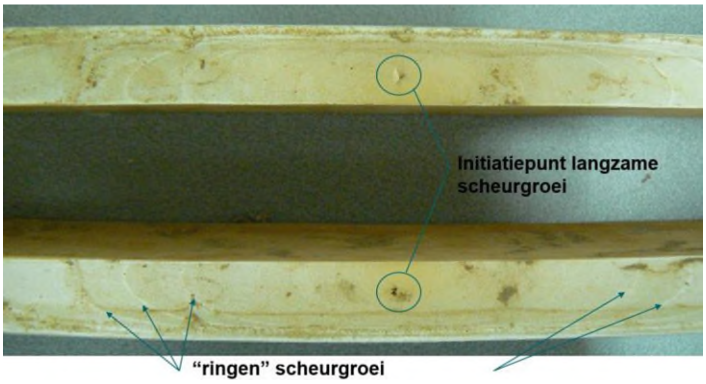
Slow crack-growth and residual stress are two important aspects that contribute to the premature failure of pipes made from PVCU, which is the material most used in the Dutch drinking water distribution network. By modelling these aspects in *Comsima*, a pipe-condition calculation tool, the tool can make a better estimate of the failure probability of a PVCU pipe. A sensitivity analysis with this tool, once it has been extended in this manner, reveals which information is crucial for a good assessment of the pipe condition. The extent of the flaws, the water pressure, the residual stress all strongly influence the premature failure of PVCU pipes, as do combinations of extreme values, for example, for wall thickness, pressure, pipe depth and the size of the flaw.



The modelled aspects of pipe degradation. Left: fracture surface of a crack caused by slow crack-growth. Right: overlap caused by residual stress in a ring extracted from a PVCU pipe.

Interest: understanding PVCU failure and degradation is crucial for asset management

PVCU (unplasticized PVC, also known as 'hard PVC') is the pipe material that is most used in the Netherlands. It has been used since 1950 and now accounts for more than half (60,000 km) of the country's drinking water distribution network. Understanding the failure and degradation behaviour of this extensively used pipe material is therefore important for the good asset management of the drinking water distribution network.

Approach:

On the basis of a literature study, mathematical and physical models were created for the most important degradation mechanisms of PVCU. These models were embedded in *Comsima*, a pipe-condition calculation tool. By means of sensitivity analysis, using the extended *Comsima* tool, a study was then conducted into the parameters that most influenced the condition and degradation of PVCU pipes.

Results: flaw size, water pressure and residual stress influence premature failure

A mathematical-physical model for slow crack-growth, including the influence of residual stress, could be integrated in *Comsima.* The literature study showed that the influence of physical aging on slow crack-growth is not adequately confirmed and described to provide the basis for modelling.

The *Comsima* predictions based on the implemented model are first and foremost very sensitive to the size of the flaws in the material and, secondarily, to the water pressure and the residual stress in the material. Moreover, an interaction of unusually high or low values of different parameters (for example, wall thickness, pressure, pipe depth, flaw size) is required for premature failure.

Application

The mathematical-physical models for the most important PVCU degradation mechanisms can be used to assess the interaction of model parameters, and the implicit uncertainties, in terms of the total probability that the situation of a specific main is not satisfactory; for example, in terms of the probability of its failure within 100 years. The successful application will depend primarily on the collection of the relevant input data. In this regard, an informed estimate of the material parameters of old mains (such as typical flaw size, crack-growth parameters and residual stress) will in particular require substantial efforts.

Report

This research is described in the report *Een model voor scheurgroei in PVCU buizen, toegepast in Comsima* (BTO 2020.001).

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