

TECHNICAL REPORT

A NOVEL METHODOLOGY OF INTERNAL NOTCHED PIPE TESTING AS AN ACCELERATED TEST FOR PLASTIC PIPING MATERIALS IN POTABLE WATER APPLICATIONS



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ABSTRACT

Accelerated testing at elevated temperatures and multiple hoop stresses has been the basis for various test methodologies to ensure the performance of plastic piping materials in potable water applications. The most common practice is to use the Rate Process Method (RPM) and extrapolate the failure times to end use conditions. In this paper, a new method is explored that examines the possibility of performing testing of internally notched pipe specimens. The advantage of this methodology is that the test conditions are similar to the Rate Process Method; however, data can be generated in a shorter time frame. Preliminary results are examined and discussed. Failures are compared to un-notched laboratory failures based on the Rate Process Method.

INTRODUCTION

With the increase in the use of plastic piping materials in potable water applications, test methodologies such as ASTM F2023, *Standard Test Method for Evaluating the Oxidative Resistance of Crosslinked Polyethylene (PEX) Tubing and Systems to Hot Chlorinated Water* (1) and ASTM F2263, *Standard Test Method for Evaluating the Oxidative Resistance of Polyethylene (PE) Pipe to Chlorinated Water* (2) have been developed to ensure resistance of plastic piping materials to potable water.

These methods utilize testing to failure, modeling and extrapolation to end use conditions to validate performance. As materials have continued to develop and improve in performance, longer and longer test times are required to validate performance. As well, it has been identified that the accelerated test conditions that can be used for chlorine dioxide resistance testing may be limited and result in significantly longer test requirements (3). Therefore, alternative methods of accelerating the testing while generating the same failure mechanism are being explored. One method that is currently being developed for slow crack growth type failures uses a stress concentrator to accelerate the failure (4). This method has been observed to accelerate failures

and still generate slow crack growth failures. This methodology has not, however, generally been examined in conjunction with oxidative degradation. In this paper an initial examination of the impact of internal notching on the test lifetimes of pipe exposed to water treated with chlorine dioxide is examined.

EXPERIMENTAL PROCEDURE

Polyethylene pipe samples, 16 mm in diameter, were tested. Disinfectant resistance testing was conducted in general conformance with the ASTM F2263 method with the exception of water quality. Chlorine dioxide disinfected water with a pH of 6.8 and concentration of 1.0 ppm was used. Test specimens were internally exposed to continuously flowing test water at a single test temperature and pressure conditions. Failure was defined as a loss of fluid through the wall of the pipe.

Both un-notched and internally notched specimens were tested. Notching of the inner surface was performed with ~5 mm razor blade to different notch depths.

RESULTS

Visual Examination

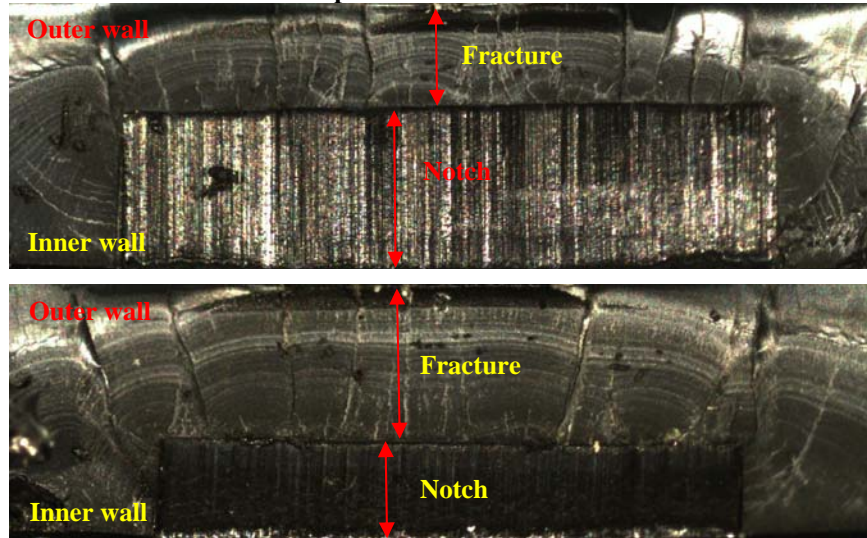
The un-notched specimens were observed to have an extensive degraded layer with micro-cracks on the inner surface. On the fracture face, slow crack growth rings were observed. All of the failures occurred through a brittle slit perforation to the outer surface. The failures appear to be typical Mode 3 (oxidative initiation, mechanical propagation) type failures (5). A typical fracture face is shown in Figure 1.

Figure 1: Typical Fracture Face of an Un-Notched Specimen



The fracture face of all of the notched specimens had similar characteristics to the un-notched specimens. Micro-cracks were observed to have propagated radially through the pipe wall from the notched area. Slow crack growth rings are observed on the fracture face. All of the failures were observed to fail in a brittle slit type failure. Typical fracture faces are shown in Figure 2.

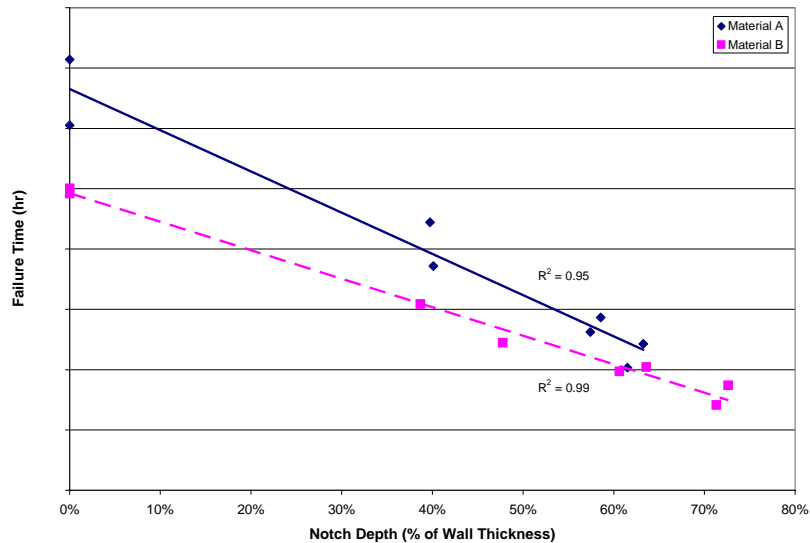
Figure 2: Typical Fracture Face of Notched Specimens



Failure Times

In Figure 3, the trends in failure times with notch depth (in % of wall thickness) are shown. For both samples, based on the testing performed, the trend appears to be linear. The correlation of coefficient is also observed to be relatively high ($R^2 = 0.95$ and 0.99).

Figure 3: Failure Time versus Notch Depth



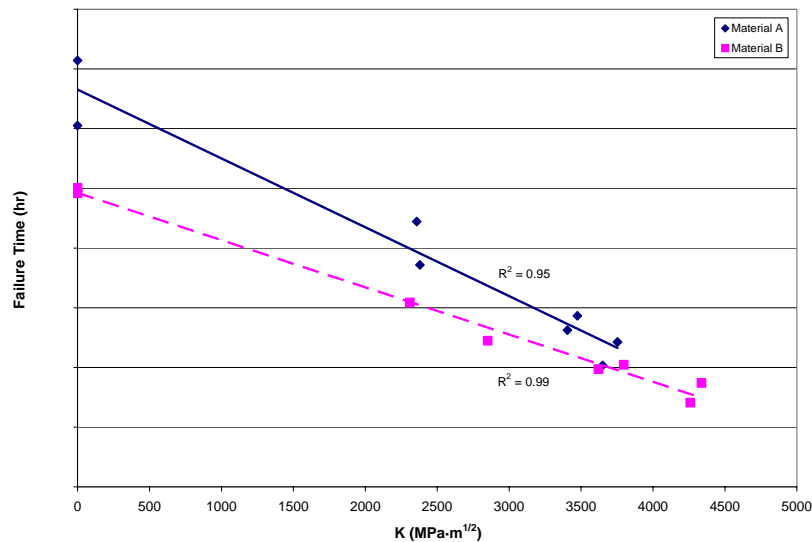
DISCUSSION

One method to accelerate testing is to increase the test stress. However, there is a risk that the failure mode may change at higher stresses. With internal notch testing, the intent is to intensify the stress at the crack tip while generating the same type of failure observed on un-notched specimens. Based on the testing performed, it would appear that the internal notch has achieved this - the same Mode 3 type of failure is observed with the un-notched and notched specimens. In addition, the internal notch can significantly reduce the overall test time.

The stress intensity factor, K , was calculated based on a model for internally pressurized tube (6, 7). The results are shown in Figure 4. There appears to be a linear relationship between failure time and the stress intensity factor. This is consistent with the linear relationship observed with notch depth and suggests that testing of internally notched pipe for oxidative resistance may be a viable method to accelerate the testing.

It is important to note that these results are preliminary and are based on limited data. Additional testing of different polyethylene materials, different pipe sizes and at different notch depths and test conditions is required to determine the full potential of this methodology and its limitations. Based on the current results, the methodology appears to be a promising method of reducing overall test times while generating the appropriate failure mode. The use of this method with the Rate Process Method also needs to be explored.

Figure 4: Failure Time versus Stress Intensity Factor



CONCLUSIONS

The use of internally notched pipe as a method of accelerating testing of plastic piping materials for potable water applications appears to be a viable method. The method is able to generate the same failure mode as observed with un-notched pipe specimens and significantly reduce failure times. Additional research is required to refine and validate the methodology.

ACKNOWLEDGEMENTS

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