FACTORS AFFECTING FATIGUE CRACK PROPAGATION IN POLYETHYLENE PIPE SYSTEMS

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In the rare cases of catastrophic failure seen in polyethylene gas pipe systems the fracture is of a brittle type. Whilst this characteristic should be tested for routinely, to do so is extremely difficult, expecially since the latest materials have been expressly developed against this trait. The research programme was initiated to isolate such a test, but new aspects of pipe behaviour have been found and have added to the already large list confronting the applications engineer. This paper cites a number of these newer features and to illustrate their importance considers the interaction of notch depth against loading pattern.

INTRODUCTION

This work relates to a programme designed to evolve a satisfactory quality assurance procedure for plastic pipes of which a salient feature must be the identification of any tendancy to brittle type failure processes. As with most research programmes factors emerge that whilst increasing understanding also reveal an even more complex problem than was first imagined. This paper examines just two such facets and their relative merits and demerits to an applications engineer.

DEMANDS ON THE ENGINEER

The salient factors that have to be addressed by the applications engineer are:

(1) Expected (service) life, including installation constraints.

(2) Test and service environment.

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(3) Difference in the commercial product both base polymer and manufacturing practice.
(4) Extreme correlation between test and development times and the desired service life of 50-60 years.
(5) Nature of the fracture surface.

All are of considerable importance and facets of each can relate to major variations in performance. However, some factors require an almost philosophical judgement since there are conflicting attributes both physical and financial.

FACTORS AFFECTING CHOICES OF PRODUCT

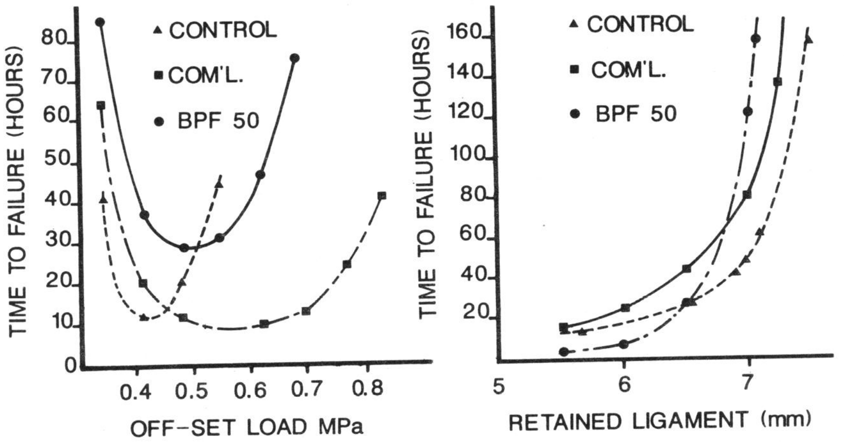
Scope There are many factors that form part of an accelerated quality test that can have a marked effect on the perceived long term behaviour. Included on this list are such things as temperature, pressure, waveform, off-set levels, frequency, rest periods, notch depth, length and form and the salient features of the test, such as time to failure, nature of the fracture, scope of pipe geometries tested, all of which may demand particular forms of test that are not necessarily compatible.

Illustration To illustrate this dilemma the data from three pipes that were subjected to two different but related tests will be considered. The materials are two commercial grades and one research grade. Figure 1A are the plots from a test at constant notch depth, but varying off-set (increasing 'R' ratio) load. Figure 1B is derived from the same materials with increasing notch depth. Corresponding curves are found for virtually, all modern grades of pipe.

Implications Figure 1A illustrates the ability of the pipe material to sustain excessive overload pressures. All have a minimum condition after which they are able to sustain even higher loads until their static (creep) load is reached. Figure 1B indicates the ability of the pipe material to withstand external damage. The plots show that there is an exchange of properties as the notch depth increases and shows that the design depth of (notch) damage may play an important part in the selection of a pipe for a particularly stringent conditions or installations. However these are relative weaknesses and all these materials are totally acceptable as products, indeed their tenacity under these adverse test conditions merely supports their suitability for pipe applications. Therefore it requires a balanced commercial judgement as to whether the perceived operational advantage between grades of such factors as; extended life, protection against untoward installation damage, greater tolerance bands or even increased line pressures could justify a higher unit cost.

CONCLUSION

Whilst fatigue has increased the understanding of plastic pipe behaviour and offers the prospect of a practical quality control procedure it has also raised a number of factors quite crucial in the selection of a pipe material. These new parameters will have to be considered in addition to those already used by those responsible for plastic pipe systems.



1A 1B

Figure 1 shows the data taken from three 90 mm O/D pipe samples tested at 80°C and 0.4 Hz square wave. One sample is the commercial grade used as a control throughout the whole programme together with another commercial grade within the range and a research sample BPF50.
1A. Samples with constant retained ligament of 6 mm and a cyclic load of 3.4 MPa ligament stress with increasing off-set load.
1B. Oscillating internal pressure ratio 0.14 to 0.84 MPa.