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Polyethylene (PE) materials for piping systems — Determination of Strain Hardening Modulus in relation to slow crack growth — Test method

Matériaux polyéthylène (PE) pour systèmes de canalisations — Détermination du module d'écrouissage en relation avec la propagation lente de fissures — Méthode d'essai

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 138, *Plastics pipes, fittings and valves for the transport of fluids*, Subcommittee SC 5, *General properties of pipes, fittings and valves of plastic materials and their accessories — Test methods and basic specifications*.

Introduction

Resistance to slow crack growth is related in general to the lifetime of polyethylene and thus, the lifetime of polyethylene products, e.g. pipes and fittings. The slow crack growth behaviour can be regarded as a combination of yield stress and the capability of disentanglement of tie molecules as reported by Kramer and Brown.[3],[6],[7] The disentanglement capability of a polymer will determine its resistance against slow crack growth.

The strain hardening modulus of a polymer is a measure of the disentanglement capability of the tie molecules of this polymer and is an intrinsic property. The strain hardening modulus of polyethylene is obtained from a stress-strain curve above the natural draw ratio. The stress-strain curve of a compression moulded sample is relatively easily obtained using a tensile test apparatus equipped with an optical extensometer. The test time of the strain hardening modulus is a consequence of the speed of tensile testing and is therefore constant for all measurements and independent of the slow crack growth property of the tested material itself.

The strain hardening modulus value allows discrimination between materials. It has been demonstrated that the strain hardening modulus corresponds very well with several environmental stress cracking test methods for high density polyethylene.[4],[5],[8]

Polyethylene (PE) materials for piping systems — Determination of Strain Hardening Modulus in relation to slow crack growth — Test method

1 Scope

This International Standard specifies a method for the determination of the strain hardening modulus which is used as a measure for the resistance to slow crack growth of polyethylene.

The strain hardening modulus is obtained from stress-strain curves on compression moulded samples. This International Standard describes how such measurement is performed and how the strain hardening modulus shall be determined from such a curve. Details of the required equipment, precision, and sample preparation for the generation of meaningful data are given.

This International Standard provides a method that is valid for all types of polyethylene, independent from the manufacturing technology, comonomer, catalyst type, that are used for pipes and fittings applications.

NOTE This method could be developed for materials for other applications.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 527-1, *Plastics — Determination of tensile properties — Part 1: General principles*

ISO 7500-1, *Metallic materials — Verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Verification and calibration of the force-measuring system*

ISO 9513, *Metallic materials — Calibration of extensometer systems used in uniaxial testing*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

NOTE The symbols and their terms and definitions, as given below, are in line with ISO 527-1 and/or ISO 16241.

3.1
gauge length
l_0
initial distance between the gauge marks on the central part of the test specimen

Note 1 to entry: It is expressed in millimetres (mm).

3.2
thickness
h
smaller initial dimension of the rectangular cross-section in the central part of a test specimen

Note 1 to entry: It is expressed in millimetres (mm).

3.3
width
b
larger initial dimension of the rectangular cross-section in the central part of a test specimen

Note 1 to entry: It is expressed in millimetres (mm).

3.4
test speed
v
rate of separation of the gripping jaws

Note 1 to entry: It is expressed in millimetres per minute (mm/min).

3.5
length
l
distance between the gauge marks on the central part of the test specimen at any given moment

Note 1 to entry: It is expressed in millimetres (mm).

3.6
stress
σ
normal force per unit area of the original cross-section within the *gauge length* (3.1)

Note 1 to entry: It is expressed in megapascals (MPa).

3.7
stress at yield
σ_y
stress at the *strain at yield* (3.10)

Note 1 to entry: It is expressed in megapascals (MPa).

3.8
true stress
σ_{true}
draw ratio (3.11) multiplied with the normal force per unit area of the original cross-section within the *gauge length* (3.1)

Note 1 to entry: It is expressed in megapascals (MPa).

3.9
strain
ε
increase in *length* (3.5) per unit original length of the gauge

Note 1 to entry: It is expressed as a dimensionless ratio, or as a percentage (%).

3.10
strain at yield
yield strain
ε_y
first occurrence in a tensile test of strain increase without a stress increase

Note 1 to entry: It is expressed as a dimensionless ratio, or as a percentage (%).

3.11
draw ratio
λ
length (3.5) per unit original length of the gauge

Note 1 to entry: It is expressed as a dimensionless ratio, or as a percentage (%).

3.12
strain hardening modulus
<G_p>
slope of the Neo-Hookean constitutive model between a true *strain* (3.9) of 8 and up to the point of maximum *stress* (3.6), but not above 12

Note 1 to entry: It is expressed in megapascals (MPa).

4 Principle

Test specimens cut from compression moulded sheet are subjected to a tensile test at 80 °C. The stress-strain curve is obtained sufficiently beyond the natural draw ratio. The strain hardening modulus is determined from the slope of this curve in the area after the natural draw ratio.

5 Apparatus

5.1 Tensile-testing machine, complying with ISO 527-1 and capable of maintaining a test speed of (20 ± 2) mm/min.

5.1.1 Load cell, which shall comply with Class 1, as defined in ISO 7500-1. The load cell shall be able to accurately measure forces in the range of 40 N for 0,30 mm thick samples and 120 N for 1,0 mm thick samples.

5.1.2 Extensometer, which shall comply with Class 1, as defined in ISO 9513. The traverse displacement shall not be used as a measure of strain. For a 0,30 mm thick specimen, a non-contact extensometer is preferred.

5.1.3 Temperature chamber, to control the temperature at (80 ± 1) °C.

5.1.4 Clamps, remote operation to enable closing and opening without the need to open the temperature chamber is recommended.

5.2 Devices for measuring the thickness and width of the test specimens.

5.2.1 Thickness shall be measured with a device with an accuracy of 0,005 mm and a device with a contact dimension of less than the width of the parallel specimen section (4,0 mm).

5.2.2 Width shall be measured with a device with an accuracy of 0,01 mm. Care shall be taken not to change the width of the test specimen by deformation. Therefore, it is recommended to use a microscope to measure width to avoid deforming the test specimen.

5.3 Punch knife, in accordance with 6.1 shall be used.