International Standard

ISO 18488

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

Second edition
2025-10

Reference number
ISO 18488:2025(en)

© ISO 2025



COPYRIGHT PROTECTED DOCUMENT

© ISO 2025
All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

Foreword ..... **iv**
Introduction ..... **v**
1 Scope **1**
2 Normative references **1**
3 Terms and definitions **1**
4 Principle **2**
5 Apparatus **2**
6 Test specimens **3**
6.1 Test specimen geometry and dimensions 3
6.2 Test specimen preparation 4
7 Test procedure **4**
8 Data analysis **5**
9 Test report **6**
Annex A (informative) **Strain hardening behaviour and the Neo-Hookean constitutive model** **7**
Bibliography **10**

© ISO 2025 – All rights reserved

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

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

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee 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*.

This second edition cancels and replaces the first edition (ISO 18488:2015), which has been technically revised.

The main changes are as follows:

— the definition for strain hardening modulus, $<G_p>$, has been improved;

— the definitions that are also in ISO 527-1 have been removed from this document;

— an improved depiction of L in Figure 1;

— the gripping distance in Table 1 has been clarified;

— the tolerance for the gauge length, $l_{0,}$ has been increased;

— regrind from PE products has been added in 6.2 to align with the product standards (e.g. ISO 4437-2 and ISO 4437-3);

— reference to ISO 293 for compression moulding has been added;

— the description of the measurement of the thickness, h, and width, b_1, have been clarified;

— the explanations of the data analysis (Clause 8) and the strain hardening behaviour and the Neo-Hookean constitutive model (Annex A) have been revised.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

© ISO 2025 – All rights reserved

Introduction

Resistance to slow crack growth of polyethylene materials is related in general to the lifetime of the material and thus, the lifetime of polyethylene products, e.g. pipes and fittings. The slow crack growth behaviour of a polyethylene material can be regarded as a combination of resistance to deformation of the crystalline phase (manifested as yield stress) and the amorphous phase (entangled chains and tie molecules) as reported by Kramer and Brown.[2],[3],[5],[6] The resistance to disentanglement of polymer chains in the amorphous phase of a polymer structure upon application of constant load will determine its resistance against slow crack growth.

The strain hardening modulus of polyethylene material is a measure of the resistance to disentanglement of the entangled chains and tie molecules of this polymer and is an intrinsic property. The strain hardening modulus of polyethylene is obtained from a “true stress vs. draw ratio” curve above the natural draw ratio. The “true stress vs. draw ratio” curve of a compression moulded sheet is relatively easily obtained using a tensile test apparatus equipped with an appropriate extensometer. The test time for measuring 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 differentiation between polyethylene materials. It has been demonstrated that the strain hardening modulus is sensitive to structural parameters of polyethylene [9],[10] and corresponds very well with several environmental stress cracking test methods for polyethylene, such as environmental stress cracking resistance (ESCR),[7] Pennsylvania notch test (PENT),[8] full-notch creep test (FNCT),[4] cracked round bar test (CRB) and notched pipe test (NPT)[11].

© ISO 2025 – All rights reserved

Polyethylene (PE) materials for piping systems — Determination of strain hardening modulus in relation to slow crack growth — Test method

1 Scope

This document 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.

This document specifies how to obtain a strain hardening modulus measurement from "true stress vs. draw ratio" curves on compression moulded samples. Details of the necessary equipment, precision and sample preparation for the generation of data are given.

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

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 293, *Plastics — Compression moulding of test specimens of thermoplastic materials*

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

ISO 7500-1, *Metallic materials — Calibration and verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Calibration and verification 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 terms and definitions given in ISO 527-1 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
length
l
distance between the gauge marks on the central part of the test specimen at any given moment

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

© ISO 2025 – All rights reserved

3.2
true stress
σ_{true}
draw ratio (3.3) multiplied with the normal force per unit area of the original cross-section within the gauge length

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

3.3
draw ratio
λ
ratio of the *length* (3.1) to the gauge length

Note 1 to entry: This is demonstrated in the following formula:

$$\lambda = \frac{l}{l_0} = 1 + \frac{\Delta l}{l_0}$$

Note 2 to entry: Draw ratio is expressed as a dimensionless ratio, or as a percentage (%).

3.4
natural draw ratio
final *draw ratio* (3.3) where further neck propagation in the narrow parallel sided portion of the test specimen stops and the strain hardening region starts

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

3.5
strain hardening modulus
$<G_p>$
slope of the Neo-Hookean constitutive model fitted to data beyond the *natural draw ratio* (3.4) between a draw ratio of 8 and up to the point of maximum stress, but not above a draw ratio of 12

Note 1 to entry: Strain hardening modulus is expressed in megapascals (MPa).

4 Principle

Test specimens cut from a compression moulded sheet are subjected to a tensile test at 80 °C. The “true stress vs. draw ratio” curve is obtained sufficiently beyond the natural draw ratio. The strain hardening modulus, $<G_p>$, is determined from the slope of this curve in the area after the natural draw ratio.

5 Apparatus

The usual laboratory apparatus and, in particular, the following shall be used.

5.1 Tensile-testing machine, which shall conform to ISO 527-1 and shall be capable of maintaining a test speed, v, of (20 ± 2) mm/min. The tensile-testing machine shall include:

5.1.1 Load cell, which shall conform to 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 test specimens and 120 N for 1,0 mm thick test specimens.

5.1.2 Extensometer, which shall conform to Class 1 as defined in ISO 9513 usable over the full elongation of the test specimen up to and including λ = 12. The traverse displacement shall not be used as a measure of strain, ε. For a 0,30 mm thick test specimen, a non-contact extensometer is preferred.

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

© ISO 2025 – All rights reserved