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Thermoplastics pipes for the conveyance of fluids — Determination of the stress-rupture resistance of moulding materials using plain strain grooved tensile (PSGT) specimens

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Thermoplastics pipes for the conveyance of fluids — Determination of the stress-rupture resistance of moulding materials using plain strain grooved tensile (PSGT) specimens

Tubes en matières thermoplastiques pour le transport des fluides — Détermination de la résistance à la rupture sous contrainte des matériaux de moulage, au moyen d'éprouvettes de traction rainurées à déformation plane

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ISO 23228:2011(E)

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Foreword

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ISO 23228 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*.

Introduction

ISO/TC 138 provides test methods for determining the resistance to internal pressure which are essential for assessing the properties and durability of thermoplastics piping system parts. These test methods constitute a basis for the determination of short-term and long-term strength characteristics. However, with regard to moulding materials for pipes and fittings, until the publication of this International Standard, no satisfactory test method has existed in which the material can be exposed to stress conditions that mimic internally pressurized pipes.

The method specified here has been demonstrated to replicate the stress conditions of internally pressurized end-capped pipes by the use of plaque specimen having a reduced section in the form of a groove positioned perpendicular to the uniaxial loading direction. This method is useful for evaluating the stress-rupture resistance of moulding materials and experimental resins being developed for pipes and fittings as well as for those pipes that are difficult to test, such as larger diameter pipes.

Thermoplastics pipes for the conveyance of fluids — Determination of the stress-rupture resistance of moulding materials using plain strain grooved tensile (PSGT) specimens

1 Scope

This International Standard specifies a method for the determination of the time-to-failure of thermoplastics resins and compounds for piping and fitting applications by the use of a plane strain grooved tensile specimen in a stress-rupture test.

The grooved tensile specimen produces a biaxial state of stress on uni-axial loading, which is taken to be indicative of the stress conditions found in pressurized solid-wall plastics pipes. The ratio of the stress in the axial direction to the transverse direction approximates that for a pressurized end-capped solid-wall pipe specimen[4]–[7].

It is intended that the data generated on these specimens be utilized to determine the stress-rupture (time to failure) resistance of moulding materials for pipes and fittings as well as experimental piping resins.

This method is also applicable to stress-rupture evaluations of pipes which are difficult to test, e.g. larger diameter pipes, including their batch release tests.

This International Standard is not intended to replace the stress-rupture test of ISO 1167[2], which uses internally pressurized end-capped pipes.

2 Normative references

The following referenced document is indispensable for the application 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 3126, *Plastics piping systems — Plastics components — Determination of dimensions*

3 Terms and definitions

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

3.1
stress-rupture test
test at which a constant nominal stress is applied and maintained until specimen rupture (failure)

3.2
failure time
t_f
time at which a specimen fails by gross yielding or by through thickness slow crack propagation on stress-rupture loading

NOTE The failure time is expressed in hours.

3.3
applied nominal stress
σ_n
applied stress calculated using the undeformed minimum groove cross-sectional area

NOTE The applied nominal stress is expressed in megapascals.

3.4
plane strain condition in the groove
zero strain condition in the groove axis where there exists no change in displacement along the groove on load application perpendicular to the groove axis

NOTE In PSGT specimens, the stress biaxiality is developed in the groove as a result of the plane strain condition in the groove. Plane strain condition also occurs in the end-capped pipe when internally pressurized.

3.5
long-term hydrostatic strength
σ_{LTHS}
quantity with the dimensions of stress, which represents the predicted mean hydrostatic hoop strength at a temperature, T, and failure time, t_f

NOTE The long-term hydrostatic strength is expressed in megapascals.

3.6
long-term strength
σ_{LTS}
quantity with the dimension of stress, which represents the predicted mean strength at a temperature, T, and failure time, t_f

NOTE 1 The long-term strength is expressed in megapascals.

NOTE 2 Long-term strength σ_{LTS} is similar to long-term hydrostatic strength σ_{LTHS}; however, they differ in the mode of loading, tensile versus hydrostatic.

4 Principle

A plane strain grooved tensile (PSGT) specimen is made from a moulded flat plaque of finite width and length dimensions having reduced area (see Figures 1 and 2). The concave grooves are made along the width of the specimen and perpendicular to the axis of the direction of uni-axial loading. The plane strain condition in the groove is induced by the deformation constraint in the groove. This is the result of the difference between the reduced thickness, e_g, of the groove and unreduced thickness, e, of the test specimen, as illustrated in Figure 2.

With the appropriate dimensions applied (see Table 1 and Figure 2) a plane strain condition, and hence biaxial stress state, is generated in the groove on uniaxial loading. After conditioning in the test medium, the specimen is subjected to a specified constant load for sustained time duration until the test specimen fails, at which point the stress and corresponding rupture time are recorded. In this manner, it can be tested in various controlled environments, and at specified constant temperatures, in order to obtain the long-term strength capacity of moulding materials for pipes and fittings. Such a controlled environment can be accomplished by, but is not limited to, immersing the specimens in a controlled-temperature water bath or circulating-air oven.

The PSGT stress-rupture data obtained from moulding materials, experimental piping resins and samples obtained from pipes and fittings can be extrapolated in accordance with a method such as that specified in ISO 9080[3] for providing estimations on their long-term strength properties. For estimating the effect of extrusion processing on pipes, the results from PSGT specimen can be compared with the results generated with pipes according to ISO 1167[2].

5 Apparatus

5.1 Loading system

Any device that is capable of continuously applying constant load on the specimen may be used. The device shall be capable of reaching the test load without exceeding it and holding it to within ±1 % of the applied load throughout duration of the test. A loading system that utilizes an electro-pneumatic device was found to be suitable. Other constant loading systems may also be used, such as those described in ISO 899-1[1]. It is important to maintain the straight sample alignment with the load-train to avoid any bending and/or twisting of the specimen.

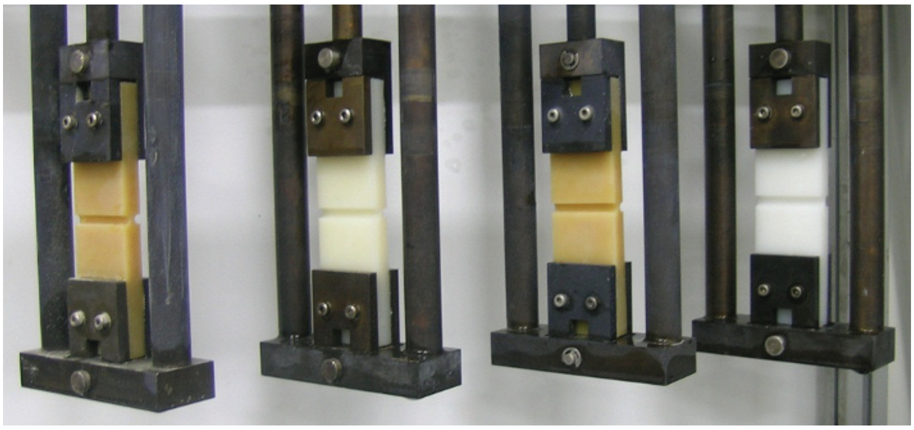


Figure 1 — PSGT specimens undergoing stress-rupture test

5.2 Constant temperature system

A reservoir capable of maintaining a fluid at a uniform temperature and which ensures complete immersion of the test specimen shall be used. The construction material for the reservoir shall not affect the environment or vice versa. If evaporation affects the medium condition, a lid shall be part of the construction so as to prevent this phenomenon. If water or other liquid medium is used, agitation is permitted to stabilize the temperature throughout the reservoir. If an air or other gaseous environment is used, provision shall be made for adequate circulation. The temperature of the environment shall be controlled to maintain the specimens at ($T \pm$ 1,0) °C, where T is the specified test temperature, in case of a liquid bath and $\left(T_{-1}^{+2}\right)$ °C when an oven system is used.

Control and measurement of the temperature in the test medium shall be done with a calibrated thermometer, thermocouple or thermistor to an accuracy of ±0,1 °C.

5.3 Timing device

A suitable timing device that can monitor time accumulation shall be used. The accuracy of the measurement shall be better than ±1 % of the elapsed time.

5.4 Failure detection device

Any device that can detect failure due to gross yielding of the sample or slow crack propagation through the groove thickness shall be utilized.

5.5 Sample grips

By means of an appropriate system, grips shall be installed at the ends of the specimen to allow transfer of the applied load to the specimen without causing slippage, damage or any other adverse effect on the test specimen during the test.

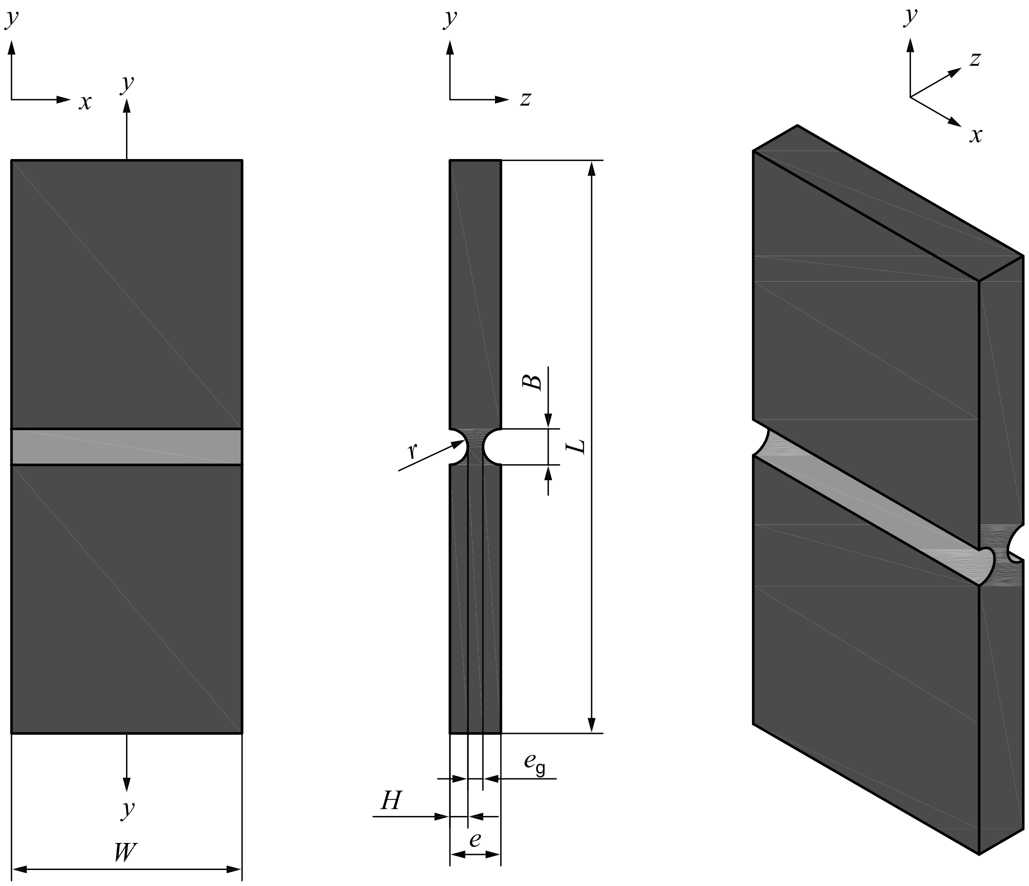
5.6 Calibration and accuracy of the apparatus

The temperature and load control systems and the equipment for measuring temperature, load and time shall be capable of maintaining the values within the specified limits and shall be calibrated regularly to maintain the required accuracy.

6 Test specimen

6.1 Dimensions

The shape of the test specimen is shown in Figure 2. A concave groove is produced along the full width of the specimen on both sides. The opposing grooves shall be parallel and centred in the specimen within ±0,1 mm. A PSGT specimen that has been used successfully is shown in Figure 2. The critical dimensions of this specimen are shown in Table 1.



Key

B groove height

e unreduced thickness

e_g reduced thickness

H groove depth

L specimen length

r groove radius

W specimen width

y loading direction

Figure 2 — Schematic diagram indicating the dimensions of PSGT specimen

Table 1 — Dimensions of PSGT specimen

Dimensions in millimetres

Variable	Dimension	Tolerance
Width[a], W	>40,0 [b]	±0,1
Groove radius, r	3,0	±0,1
Groove height, B	6,0	±0,1
Unreduced thickness[c], e	>9,0 [b]	±0,2
Reduced thickness[c], e_g	2,5 [d]	±0,1
Overall length, L	>150,0	±2,0
Distance between ends of grips	>70 [b]	±1,0
Misalignment between grooves Groove axis deviation from load axis	0,1	±0,01

[a] Groove width and specimen width are the same.

[b] For a series of test specimens, the same dimension shall be used within the tolerance indicated.

[c] Reduced and unreduced thicknesses refer to the groove root thickness, e_g, and plaque thickness, e, respectively.

[d] The reduced thickness in the groove shall be measured at three locations, at the centre of the groove, and at the edges of the test specimen. All three measurements shall conform to the dimensions specified in this table.

Dimensions given in Table 1 are based on test specimens of polyethylene. Although considered independent of the material of the test specimen, new materials should be tested for suitability of a plane strain condition in the groove. Annex A demonstrates how a plane strain condition can be examined with respect to specimen dimensions.

6.2 Measurements

Dimensions shall be determined in accordance with ISO 3126.

6.3 Specimen preparation

6.3.1 General

PSFT specimens are typically fabricated from pre-moulded plaques using machining and grooving to obtain the appropriate dimensions. In some cases, plaques may be obtained from a pipe section by machining. When test specimens are taken from a pipe, they shall be prepared so that the orientation of the loading during the test is in the circumferential direction of the original pipe, unless otherwise agreed upon between the parties involved. If the compound is intended for moulding applications, then the test specimens should be taken in a similar fashion for injection-moulded specimens.

Specimens made from these plaques shall be free of voids.

6.3.2 Moulding

Plaques from pipe resin materials may be produced by injection moulding, extrusion, or compression moulding. The plaques may also be formed by flattening appropriate pipe-wall sections. All specimens used for a particular data set shall be prepared in the same manner, that is, all compression moulded or all injection moulded using the same gate configuration, etc. Both in injection and compression moulding, grooves may be moulded-in instead of groove machining on a pre-moulded plaque.

Injection-moulded samples may be used to study the effects of knit lines and other variables important for pipe fitting applications. The samples should be injection moulded in a same manner because, for example, the location of the gate can affect the material orientation and thus significantly influence the outcome of the test.

6.3.3 Machining

Pre-moulded plaques shall be machined to size (e.g. by milling) with smooth edges and free from burrs. The groove shall be machined in such a way that the groove surface is smooth, minimizing any machining marks on the groove surface. Appropriate fixation of the specimen is necessary to ensure that the grooves on either side are made parallel and exactly opposite to each other. In all machining operations, care shall be taken to minimize any heating and bending of the sample. Ensure that the opposing grooves are parallel to each other and perpendicular to the specimen axis within the tolerance given in Table 1. Newly moulded specimens shall be preconditioned for a minimum of 48 h at room temperature prior to machining.

NOTE A 3,0 mm radius, 4-flute ball end mill has been used successfully for machining the grooves.

7 Conditioning

Specimens shall be conditioned at the test temperature before applying the constant and sustained load. Prior to testing a minimum conditioning time of 4 h (liquid medium) and 16 h (gaseous medium) shall be used. All specimens in the test series shall be tested in the same medium. Newly machined specimens shall be preconditioned for a minimum of 48 h at room temperature prior to testing. Specimens should be cleaned and dried to remove any traces of dirt, oil, wax or other contamination prior to temperature conditioning.

NOTE The most convenient way of conditioning is to utilize the same liquid bath (or oven) and directly on the stress-rupture jig where the test is to be carried out. In this way, the test can be executed directly after the conditioning step without further handling of the test specimen.

8 Procedure

8.1 Measure and record the dimensions, as indicated in 6.2.

8.2 Attach grips to the test specimen such that the distance from the grip ends to the centre of the groove is at least 35 mm.

8.3 Position the test specimen with the grips in the test arrangement and condition the test specimen as specified in Clause 7. Ensure that no load is applied during conditioning.

8.4 After conditioning, apply the load, F, to the specimen gradually within a period of about 30 s without causing shock or other stress peaks in the specimen. When the test load is reached, initiate the timer and record the time.

8.5 Stop the test either when the specified time duration is reached, or when the specimen fails. Record the time-to-failure of each specimen. The time-to-failure shall not include periods of time during which the specimen was not under load. Failure occurs when either:

— the two halves of the specimen separate completely;

— through-thickness slow crack extension is observed;

— extension of the groove section causes the timer to be shut off (approximately 12,5 mm deflection).

From the failed specimens record the type of failure, i.e. brittle or ductile or other.

9 Calculation

Calculate the nominal stress applied to the grooved tensile test specimen as follows:

$$\sigma_{\mathrm{n}} = \frac{F}{W\, e_{\mathrm{g}}} \qquad (1)$$

where

σ_n is the nominal stress, in megapascals;

F is the applied load, in newtons;

W is the groove width, in millimetres;

e_g is the reduced thickness, in millimetres.

10 Test report

The test report shall include at least the following information:

a) a reference to this International Standard;

b) the type of materials and the complete identification of the sample;

c) the measured dimensions, e.g. nominal reduced thickness, groove height and width, overall length and unreduced thickness of the specimen, as appropriate;

d) the preparation process of test specimens (moulding, machining and grooving details);

e) test temperature, T;

f) the applied nominal stress, σ_n, the applied load, F, and failure time for each specimen;

g) indicate the direction of the load with respect to processing particulars, if applicable (e.g. for those specimens taken directly from the pipes, the load should be applied in the equivalent to the pipe's hoop direction; report if otherwise and for other applicable cases, e.g. injection-moulded plaques);

h) the nature of the environment (air, water or other specified liquid);

i) the type of grip used;

j) the number of specimens tested;

k) the conditioning time;

l) in the event of failure, the type of failure;

m) any unusual observations made during and after the test;

n) any factors that could have affected the results, such as any incidents, test interruptions or any operating details not specified in this International Standard;

o) the description of the stress-rupture apparatus;

p) the date of the test or dates between which the test was conducted.

Annex A
(informative)

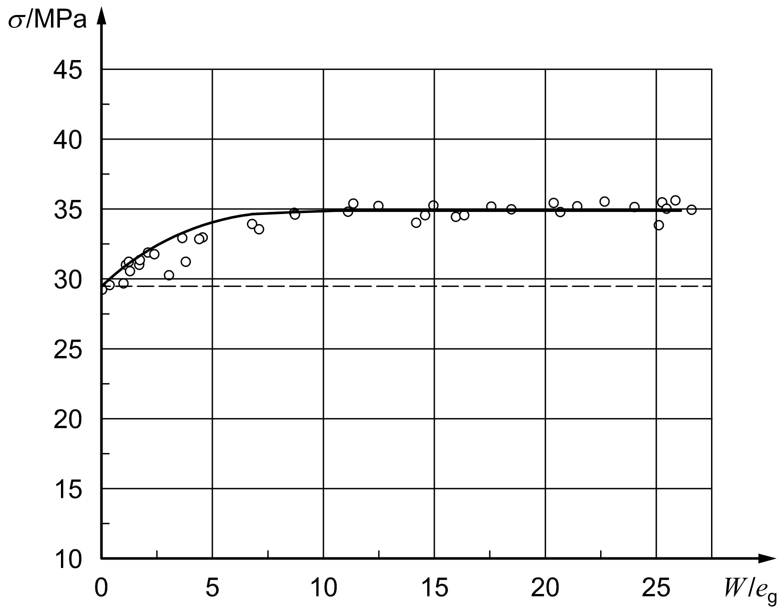
Determination of specimen dimensions for the plane strain condition

In order to determine PSGT specimen dimensions that provide plane strain conditions in the groove of the specimen, the following procedure may be useful.

Prepare specimens with different width, but having the groove height and reduced thickness given in Table 1. Test at least three specimens having a width dimension of less than 5 mm. For other groove heights and reduced thicknesses, see Reference [5].

Perform tensile tests on specimens with increasing width, measuring the yield stress, and determine the width to reduced thickness ratio at which the yield stress becomes constant. The yield stress plateau should be at least 15 % above the yield stress determined for less than 5 mm wide specimens. Continue testing until the width to reduced thickness ratio is at least 50 % higher than the value at which the plateau is first reached (as shown in Figure A.1).

NOTE From Figure A.1, a width/reduced thickness ratio of at least 18 is an appropriate choice for making PSGT specimens.



Key

W/e_g width/reduced thickness ratio

σ yield stress

Figure A.1 — Development of plane-strain condition with increasing width/reduced thickness ratio in high density polyethylene pipe grade resin

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