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Plastics — Injection moulding of test specimens of thermoplastic materials —

Part 4: Determination of moulding shrinkage

Plastiques — Moulage par injection des éprouvettes de matériaux thermoplastiques —

Partie 4: Détermination du retrait au moulage

Reference number
ISO 294-4:2018(E)

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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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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 61, *Plastics*, Subcommittee SC 9, *Thermoplastic materials*.

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.

This third edition cancels and replaces the second edition (ISO 294-4:2001), of which it constitutes a minor revision to update the reference in Clause 2. It also incorporates the Technical Corrigendum ISO 294-4:2001/Cor.1:2007.

A list of all parts in the ISO 294 series can be found on the ISO website.

Introduction

See ISO 294-1.

In the injection moulding of thermoplastics, the difference between the dimensions of the mould cavity and those of the moulded articles produced from it can vary with the design and operation of the mould. Such differences can depend on the size of the injection-moulding machine, the shape and dimensions of mouldings including any restrictive action this can have on the shrinkage, the degree and direction of flow or movement of the material in the mould, the sizes of the nozzle, sprue, runner and gate, the cycle on which the machine is operated, the temperature of the melt and the mould, and the magnitude and duration of the hold pressure. Moulding and post-moulding shrinkage are caused by crystallization, volume relaxation and orientation relaxation of the material and by thermal contraction of both the thermoplastic material and the mould. Post-moulding shrinkage can also be influenced by humidity uptake.

The measurement of moulding and post-moulding shrinkage is useful in making comparisons between thermoplastics and in checking uniformity of manufacture.

The method is not intended as a source of data for design calculations of components. Information on the typical behaviour of a material can be obtained, however, by carrying out measurements at different melt and mould temperatures, injection velocities and hold pressures, as well as at different values of other injection-moulding parameters. The information thus obtained is important in establishing the suitability of the moulding material for the production of moulded articles with accurate dimensions.

Plastics — Injection moulding of test specimens of thermoplastic materials —

Part 4: Determination of moulding shrinkage

1 Scope

This document specifies a method of determining the moulding shrinkage and post-moulding shrinkage of injection-moulded test specimens of thermoplastic material in the directions parallel to and normal to the direction of melt flow.

For the determination of shrinkage of thermosets, see ISO 2577[2].

Moulding shrinkage as defined in this document excludes the effects of humidity uptake. This is included in post-moulding shrinkage and thus in total shrinkage. For cases when post-moulding shrinkage is caused by the uptake of humidity only, see ISO 175[1].

Moulding shrinkage as defined in this document represents the so-called free shrinkage with unrestricted deformation of the cooling plates in the mould during the hold period. It is considered, therefore, as the maximum value of any restricted shrinkage.

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 294-1:2017, *Plastics — Injection moulding of test specimens of thermoplastic materials — Part 1: General principles, and moulding of multipurpose and bar test specimens*

ISO 294-3:2002, *Plastics — Injection moulding of test specimens of thermoplastic materials — Part 3: Small plates*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 294-1 and the following apply.

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

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

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

3.1
moulding shrinkage
S_{M}
difference in dimensions between a dry test specimen and the mould cavity in which it was moulded, both the mould and the test specimen being at room temperature when measured

Note 1 to entry: It is expressed as a percentage (%) of the mould cavity dimension concerned.

Note 2 to entry: The moulding shrinkage S_{Mp} parallel to the melt flow direction is determined at the mid-point of the width of the test specimen, and the moulding shrinkage S_{Mn} normal to the flow direction at the mid-point of the length.

3.2
post-moulding shrinkage
S_P
difference in the dimensions of a moulded test specimen before and after a post-moulding treatment, measured at room temperature

Note 1 to entry: It is expressed in percent (%).

Note 2 to entry: The post-moulding shrinkage S_{Pp} parallel to the melt flow direction and the post-moulding shrinkage S_{Pn} normal to the flow direction are defined in analogous fashion to S_{Mp} and S_{Mn} in 3.1.

3.3
total shrinkage
S_T
difference in dimensions between a test specimen after a post-moulding treatment and the mould cavity in which it was moulded, measured at room temperature

Note 1 to entry: It is expressed in percent (%).

Note 2 to entry: The total shrinkage S_{Tp} parallel to the melt flow direction and the total shrinkage S_{Tn} normal to the flow direction are defined in analogous fashion to S_{Mp} and S_{Mn} in 3.1.

3.4
cavity pressure
p_C
pressure of the thermoplastic material in the cavity at any time during the moulding process, measured centrally near the gate

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

3.5
cavity pressure at hold
p_{CH}
cavity pressure (3.4) 1 s after the end of the injection time t_I

Note 1 to entry: (see Figure 1)

Note 2 to entry: It is expressed in megapascals (MPa).

4 Apparatus

4.1 Type D2 ISO mould, giving 60 mm × 60 mm × 2 mm plate specimens, as specified in ISO 294-3:2002, 4.1.

Reference marks may be engraved in the mould cavity to facilitate the measurement of the dimensions of the test specimens produced from the mould using optical techniques. Such reference marks, if used, shall be located at a distance of (4 ± 1) mm from the edges of the mould cavity.

It is recommended that such marks be at most 5 µm in depth in order to ensure that they do not restrict the shrinkage process in any way (see Introduction). Pins inserted in the correct plane have also been used successfully.

Installation of a pressure sensor, P, recommended for ISO 294-1 to ISO 294-3 [see ISO 294-1:2017, 4.1.1.4 k) and ISO 294-3:2002, Figure 2], is mandatory for shrinkage measurements.

The mould plates used shall be rigid enough to avoid the moulded plates being thicker than the depth of the cavity, for the whole range of hold pressures that result in positive shrinkage in length or width.

4.2 Injection-moulding machine, in accordance with ISO 294-3:2002, 4.2, but adding the following tolerance limits to the list of operating conditions given in ISO 294-1:2017, 4.2.2:

Cavity pressure, p_C ± 5 %

4.3 Measuring equipment, capable of measuring the length and width of each test specimen and of the mould cavity to within 0,02 mm, the measurements being made between the centres of opposite sides or between the opposite edges or between pairs of reference marks (see Annex A). When measuring the length of a test specimen, take care to include the 0,5-mm-high step at the gate end of the specimen. If a mechanical instrument is used, ensure that the jaws of the instrument do not produce a significant indentation.

It is recommended that a calibration plate be used to periodically check the measuring equipment.

4.4 Oven, necessary only if post-moulding shrinkage is to be measured, by agreement between the interested parties.

5 Procedure

5.1 Conditioning of material

As specified in ISO 294-1:2017, 5.1.

5.2 Injection moulding

5.2.1 For the basic injection-moulding conditions, see ISO 294-3:2002, 5.2.

5.2.2 The moulding shrinkage is preferably determined for one or more values of the cavity pressure at hold p_{CH} (see 3.5) selected from 20 MPa, 40 MPa, 60 MPa, 80 MPa and 100 MPa. Intermediate values may also be used, however.

For values higher than 80 MPa, a correspondingly high locking force will be necessary, and this may not be possible with normal commercial equipment.

5.2.3 Determine the hold pressure p_H which corresponds to each selected value of p_{CH} and mould test specimens at each of these pressures, taking into account of the following additional instructions.

a) Select the change-over point, between the injection and hold periods carefully to avoid a depression in the time against pressure curve (see Figure 1, Curve c) and to avoid a peak that, during the 1 s following the change-over point, exceeds the cavity pressure at hold by more than 10 % (see Figure 1, Curve b).

   Due to the inertia of the injection-moulding machine, the effective change-over time is longer than its nominal value. The correct change-over point shall therefore be adjusted individually for each value of the injection speed and for each material under test.

   NOTE Peaks in the cavity pressure lead to transient overloading of the cavity, followed by partial backflow of the melt. Thus, the mass of material injected into the cavity is not clearly defined and the orientation of the material near the gate will be perturbed.

b) Keep the hold pressure constant during the hold period.

c) For the hold time, see ISO 294-1:2017, 5.2.4. The decrease in the cavity pressure at hold to zero indicates that the material in the gate has solidified sufficiently to stop flow into the cavity.

d) Select the cooling time to be the minimum value at which the mouldings can be removed from the mould without distortion. As the cooling rate of the material is proportional to the square of the