INTERNATIONAL STANDARD

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ISO 294-5:2017(E)

Plastics — Injection moulding of test specimens of thermoplastic materials —

Part 5: Preparation of standard specimens for investigating anisotropy

Plastiques — Moulage par injection des éprouvettes de matériaux thermoplastiques —

Partie 5: Préparation d'éprouvettes normalisées pour déterminer l'anisotropie

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Contents

Page

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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 on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 9, *Thermoplastic materials*.

This third edition cancels and replaces the second edition (ISO 294-5:2011), which has been technically revised.

The main changes compared to the previous edition are as follows:

— the size of the plate has been changed from 80 mm × 90 mm × 2 mm to 80 mm × ≥90 mm × 2 mm, preferably 80 mm × 120 mm × 2 mm;

— the maximum mould-locking force in 4.2 has been recalculated.

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

Introduction

Reinforced and self-reinforcing injection-mouldable thermoplastics are used in a wide variety of applications, some of which can be safety-related. During the injection-moulding process, reinforcement fibres can preferentially align with the flow of the molten material and not across the flow direction. This preferential alignment causes an imbalance in the properties of the moulded thermoplastic so that, in the flow direction, the alignment of the reinforcing fibres causes a higher strength and stiffness than in the cross direction with fewer aligned fibres. This difference in properties is termed anisotropy and it may result in an injection-moulded component having less than the desired or designed strength. To aid designers in understanding the potential strength of an injection-moulded component, it is desirable to know about the anisotropy of an injection-moulded component.

During the development of this document, it was found that injection-moulded test specimens do not exhibit the same fibre alignment across their thickness, but that the outer layers have fibres preferentially aligned in the mould filling direction while the core has randomly oriented fibres (i.e. no preferential alignment). The ratio of the cross-sectional area of aligned-fibre orientation (i.e. “skin” layer thickness) to that of random-fibre orientation (i.e. “core” thickness) is affected by the specimen thickness and the mould filling rate, i.e. the average injection velocity. Thicker specimens exhibit a lower proportion of aligned fibres than do thinner specimens. Slower mould fill speeds lead to thicker “skin” layers with aligned fibres. As a result, to obtain meaningful data on a particular design of moulding, an investigator should prepare specimens with the maximum anisotropic properties, as this data will best represent the upper and lower bounds of a composite structure. Since the specimen thickness and injection velocity have a significant influence on the final anisotropy, this document should only be used for determining information that is useful in designing mouldings and not as a quality control test for the plastic material itself.

A survey of more than 10 raw material suppliers worldwide carried out from 2010 to 2013 clearly indicated that the preparation of plates which provide a suitable degree of anisotropy requires plates with non-square shape to ensure a fibre orientation in flow direction. Under the conditions of this study, the highest degree of anisotropy was obtained using a plate with dimensions 120 mm × 80 mm × 2 mm. It can be considered that plates longer than 120 mm will show at least as good results. Square plates (e.g. 80 mm × 80 mm × 2 mm or even 150 mm × 150 mm × 2 mm) resulted in problems sometimes independent of the size. Within this study, the plate with size 90 mm × 80 mm × 2 mm as required in the previous edition of this document did not perform well in any case.

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Plastics — Injection moulding of test specimens of thermoplastic materials — Part 5: Preparation of standard specimens for investigating anisotropy

1 Scope

This document specifies a mould (designated the type F ISO mould) for the injection moulding of plates with a preferred size of 80 mm × 120 mm and a minimum size of 80 mm × ≥90 mm and with a preferred thickness of 2 mm for single-point and multi-point data acquisition. It has been found to provide the maximum anisotropic properties, with only a slight sensitivity to the rate of injection. Whenever possible, a two cavity mould is intended to be used. For the design of plastic parts, this will provide upper and lower bounds for the tensile properties. Matching the plate thickness to a given part thickness is not a suitable criterion because of the effect of mould filling rate and part geometry on anisotropy.

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Investigation of the anisotropy of materials is a special procedure intended to provide guidance in the design of mouldings for end-use applications and is not intended as a quality control tool.

In the injection moulding of thermoplastic materials, the flow of molten polymer can influence the orientation of fillers such as fibreglass or the orientation of polymer chains, resulting in anisotropic behaviour.

For the purposes of this document, the flow direction is defined as the direction from the gate to the far end of the mould cavity and the cross direction as the direction perpendicular to the flow direction.

The type F mould is not intended to replace the type D mould used to determine the moulding shrinkage of thermoplastics.

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 20753, *Plastics — Test specimen*

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3 Terms and definitions

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

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

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

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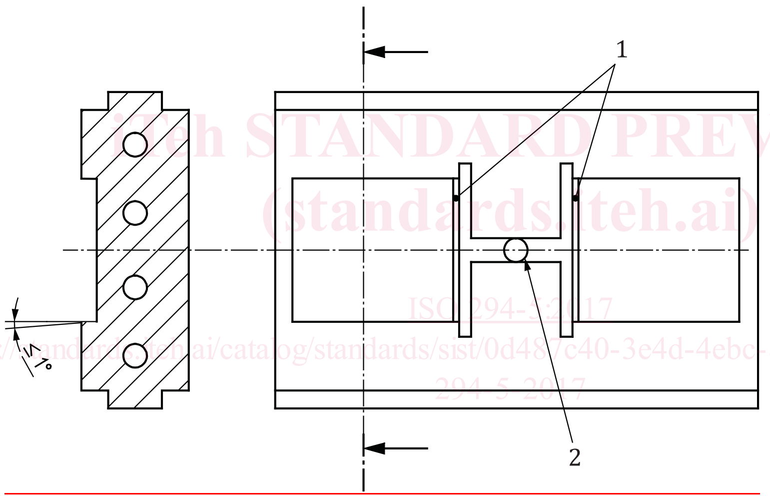
— ISO Online browsing platform: available at http://www.iso.org/obp

4 Apparatus

4.1 Type F ISO mould

Plates shall be moulded in a two-cavity type F ISO mould (see Figures 1 and 2). The preferred mould dimensions shall be such that the plates produced measure 80 mm × 120 mm (minimum: 80 mm × ≥90 mm) (the actual length and width of the mould will vary slightly because of the different shrinkage of different materials).

The preferred thickness is 2 mm, but other thicknesses may be used. A thickness of 2 mm is representative of the actual wall thickness of many mouldings and gives a skin-thickness to core-thickness ratio corresponding to the maximum anisotropic properties. Other thicknesses may be used to give different skin-thickness to core-thickness ratios.



Key

1 gate

2 sprue

Figure 1 — Type F ISO mould

NOTE The total projected area and shot volume for the runners, gates and cavities are ~20 000 mm² and ~40 000 mm³, respectively.

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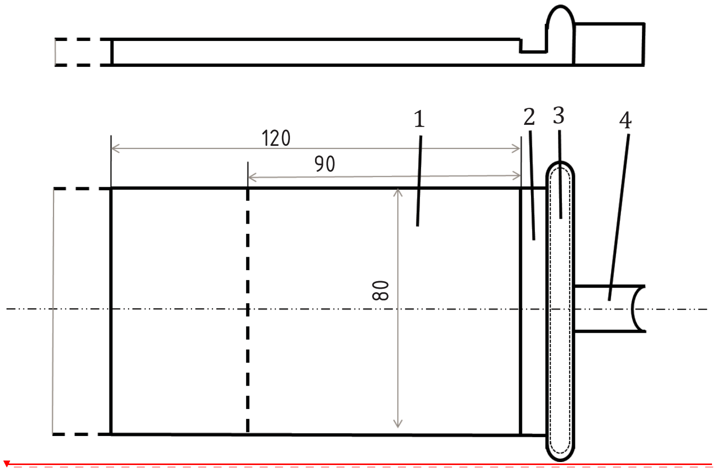

Dimensions in millimetres

	1 (cavity)	2 (gate)	3 (flood gate)	4 (runner)
Dimension in direction of flow	120^{+2}_{0} [a]	3,0	6,0	8,0
Dimension normal to flow	80^{+2}_{0} [a]	80	92	12
Depth/height	2,0[b]	1,0[c]	6,0	6,0
End radius[d]	NA	NA	>4,0	NA
Top radius[d]	NA	NA	>3,0	>3,0

[a] The actual length and width will depend on the moulding shrinkage of the injection-moulding material (see 4.1). The minimum length shall be ≥90 mm.

[b] 2 mm is the preferred specimen thickness for single-point data acquisition. Cavity depths other than 2 mm may, however, be used to match more closely the thickness of the parts being designed.

[c] The gate height shall be half the cavity depth if a cavity depth other than 2 mm is used.

[d] The radius of the end of the flood gate shall be >4 mm, the radius of the top of the flood gate shall be >3 mm and the intersection of the top and end of the flood gate shall be blended to a smooth transition.

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Figure 2 — Details of type F ISO mould

A pressure sensor may be used to monitor the moulding process, but is not required. The sensor, if used, shall be located centrally with respect to the width of the cavity.

If an interchangeable cavity plate of length less than 220 mm is used, it is permissible to use a single flood gate centred on the sprue and no runners.

To obtain correct test specimens, it is essential that the dimensions of the moulded plate be as follows:

— length >120 mm;

— width >80 mm.

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The main constructional details of the mould shall be as shown in Figures 1 and 2 and the mould shall, in addition, meet the following requirements:

a) see ISO 294-1:2017, 4.1.1.4, item a);

b) see ISO 294-1:2017, 4.1.1.4, item b);

c) see ISO 294-1:2017, 4.1.1.4, item c);

d) and e), not applicable;

f) see ISO 294-1:2017, 4.1.1.4, item f);

g) not applicable (see Figure 2);

h), i), j) and k) see ISO 294-1:2017, 4.1.1.4, items h), i), j) and k);

l) to n) see ISO 294-1:2017, 4.1.1.4, items l) to n).

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4.2 Injection-moulding machine

As specified in ISO 294-1:2017, 4.2, with the following exception in ISO 294-1:2017, 4.2.5.

The projected area of the preferred mould cavity A_P is 80 mm × 120 mm = 9 600 mm². The total projected for a two-cavity mould area is therefore 19 200 mm² + projected area of runners = approx. 20 000 mm².

For a maximum mould-locking force, F_{max}, of 100 metric tons (981 kN) and a value of A_P of 20 000 mm², the maximum injection pressure is given by Formula (1):

$$p_{max} = F_{max}/A_P = 981\ \text{kN}/20\ 000\ \text{mm}^2 = \text{approx. } 50\ \text{MPa} \quad (1)$$

5 Procedure

5.1 Conditioning of material

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

5.2 Injection moulding

As specified in ISO 294-1:2017, 5.2, but with the following new text in ISO 294-1:2017, 5.2.2.

It has been found that the skin-thickness to core-thickness ratio changes with injection velocity. The slower the rate of injection, the thicker the skin (i.e. the thinner the core) and the greater the anisotropic alignment of the fibres. Also, the skin-thickness to core-thickness ratio changes with plate thickness. The thinner the plate, the thicker the skin (i.e. the thinner the core) and the greater the anisotropic alignment of the fibres. In addition, thin plates are less sensitive to changes in the injection velocity. Generally, if the ratio of the tensile modulus in the cross direction to that in the flow direction approaches 0,5, this indicates maximum anisotropy.

For type F ISO mouldings, it may be desirable to use more than one injection velocity. Several injection velocities may be used to acquire data that may be meaningful in the design and production of injection-moulded thermoplastic parts.

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5.3 Preparation of test specimen

Suitable test specimens [preferably ISO 20753 type A22 tensile test specimens or type B3 (80 mm × 10 mm) bars] shall be machined or die-cut from the plates as specified in Annex A and used to obtain information on the anisotropy of thermoplastic parts.

6 Report on test specimen preparation

The report shall include the following information:

a) a reference to this document, i.e. ISO 294-5;

b) the date, time and place of moulding;

c) a full description of the material used (type, designation, manufacturer, trade name, grade, lot number, colour);

d) details of any conditioning of the material carried out prior to moulding;

e) the type of mould used (i.e. type F) and details of the mould (cavity depth, gate size, etc.);

f) details of the injection-moulding machine used (manufacturer, maximum stroke volume, mould-locking force, control systems);

g) the moulding conditions:

— melt temperature T_M, in degrees Celsius,

— mould temperature T_C, in degrees Celsius,

— injection velocity v_I, in millimetres per second,

— injection time t_I, in seconds,

— hold pressure p_H, in megapascals,

— hold time t_H, in seconds,

— cooling time t_C, in seconds,

— cycle time t_T, in seconds,

— mass of the moulding, in grams;

h) any other relevant details (e.g. the number of mouldings initially discarded, the number retained, any post-moulding treatment);

i) the specimen type and the number of specimens obtained from the plate produced, the preparation method used (machined or die-cut) and the locations of the specimens within the plate.