INTERNATIONAL STANDARD

ISO 2818

Fourth edition
2018-12

Plastics — Preparation of test specimens by machining

Plastiques — Préparation des éprouvettes par usinage

Reference number
ISO 2818:2018(E)

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Published in Switzerland

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

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 fourth edition cancels and replaces the third edition (ISO 2818:1994), of which it constitutes a minor revision to update the references in Clause 2. It also incorporates the Technical Corrigendum ISO 2818:1994/Cor 1:2007.

Introduction

The preparation of test specimens by machining influences the finished surfaces and, in some cases, even the internal structure of the specimens. Since test results are strongly dependent on both of these parameters, exact definitions of tools and machining conditions are required for reproducible test results with machined specimens.

Plastics — Preparation of test specimens by machining

1 Scope

This document establishes the general principles and procedures to be followed when machining and notching test specimens from compression-moulded and injection-moulded plastics, extruded sheets, plates and partially finished or wholly finished products.

In order to establish a basis for reproducible machining and notching conditions, the following general standardized conditions are applied. It is assumed, however, that the exact procedures used are selected or specified by the relevant material specification or by the standards on the particular test methods. If sufficiently detailed procedures are not thus specified, the interested parties agree upon the conditions to be used.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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 Milling

NOTE In this machining operation, the tool has a circular primary motion and the workpiece a suitable feed motion. The axis of rotation of the primary motion retains its position with respect to the tool, independently of the feed motion (see ISO 3855). Complete dumb-bell and rectangular test specimens, as well as notches in finished specimens, may be prepared by milling.

3.1.1 Geometry (see ISO 3002-1 and Figure 1)

NOTE Only a few details of the exact geometrical conditions of the milling tool and its position with respect to the workpiece given in ISO 3002-1 are relevant to this document.

3.1.1.1
tool-cutting-edge angle
α_r
angle between the tool-cutting-edge plane, P_s, and the assumed working plane, P_f, measured in the tool back plane, P_r

3.1.1.2
tool back clearance
α_p
angle between the flank, A_α, of the cutter and the tool-cutting-edge plane, P_s, measured in the tool back plane, P_p

3.1.1.3
tool side clearance
α_f
angle between the flank A_α of the cutter and the tool-cutting-edge plane P_s, measured in the assumed working plane, P_f

3.1.1.4
tool radius
R
distance between the axis of the circular primary motion of the tool and its cutting edge

3.1.1.5
number of cutting teeth
z
number of cutting edges on the outer periphery of the rotating milling tool

3.1.2 Tool and workpiece motions (see ISO 3002-1 and Figure 2)

3.1.2.1
rotational speed of tool
n
speed of the circular primary motion of the tool

Note 1 to entry: The rotational speed of tool is expressed in revolutions per minute (r/min).

3.1.2.2
cutting speed
v_c
instantaneous velocity of the primary motion of a selected point on the cutting edge relative to the workpiece

Note 1 to entry: The relationship between v_c and n is given by the formula $v_c = n \cdot 2\pi R$.

Note 2 to entry: The cutting speed is expressed in metres per minute.

3.1.2.3
feed speed
v_f
instantaneous velocity of the feed motion of a selected point on the cutting edge relative to the workpiece

Note 1 to entry: The feed speed is expressed in metres per minute.

3.1.2.4
feed path
λ
distance at any given point on the surface of the workpiece covered during the time between two successive cutting operations

Note 1 to entry: The feed path is given by the formula $\lambda = v_f / z \cdot n$.

Note 2 to entry: The feed path is expressed in millimetres.

3.1.2.5
cutting depth
a
<mean> distance between the surfaces of the workpiece before and after one complete milling run

Note 1 to entry: The cutting depth is expressed in millimetres.

3.2 Cutting of rectangular test specimens

NOTE In this machining operation, rectangular test specimens are cut by means of a circular or band saw, made from hardened steel or coated with diamond or cubic boron nitride powder, or cut with the aid of an abrasive disc of which the cutting edge may be coated with diamond or boron nitride powder. For further details on abrasive discs and abrasive products, see ISO 21950 and ISO 6104.

3.2.1 Geometry

3.2.1.1
tool radius
R
distance between the rotary axis of a circular saw or an abrasive disc and the cutting edges of the tool

Note 1 to entry: The tool radius is expressed in millimetres.

3.2.1.2
number of cutting teeth
z
number of cutting teeth on the periphery of a circular saw

3.2.2 Tool and workpiece motions

3.2.2.1
rotational speed of tool
n
speed of rotation of a circular saw or an abrasive disc

Note 1 to entry: Rotational speed of tool is expressed in revolutions per minute (r/min).

3.2.2.2
cutting speed
v_c
instantaneous velocity of the cutting tip of a saw tooth, or of a selected point on the cutting edge of an abrasive disc, relative to the workpiece

Note 1 to entry: For a circular saw or an abrasive disc, the relationship between v_c and n is given by the formula $v_c = n \cdot 2\pi R$.

Note 2 to entry: The cutting speed is expressed in metres per minute.

3.2.2.3
feed speed
v_f
instantaneous velocity of the tool feed parallel to the saw or disc plane and perpendicular to the cutting direction relative to the workpiece

Note 1 to entry: The feed speed is expressed in metres per minute.

3.3 Cutting of disc-shaped test specimens (see Figure 4)

NOTE In this machining operation, disc-shaped test specimens are cut from sheet material with the aid of a circular cutter with a saw-toothed edge of hardened steel or which may be coated with diamond or cubic boron nitride powder. The test specimens may also be cut by means of a milling cutter with one or more teeth, as described in 3.1, which moves in a circular orbit. Furthermore, the test specimens may also be cut from a roughly preshaped pack of individual sheets with the aid of a turning lathe.

3.3.1 Geometry

3.3.1.1
tool radius
R
distance between the rotary axis of the circular cutter and the inner limit of the cutting edge

Note 1 to entry: The tool radius is equal to the radius of the finished test specimen. It is expressed in millimetres.

3.3.1.2
number of cutting teeth
z
number of teeth on the sawtooth cutting edge of a circular cutter

Note 1 to entry: If a lathe is used for cutting circular test specimens, the geometrical definitions of the cutting tool are the same as those given in 3.1.

3.3.2 Tool and workpiece motions

3.3.2.1
rotational speed of tool
n
speed of rotation of a circular cutter

Note 1 to entry: The rotational speed of tool is expressed in revolutions per minute.

3.3.2.2
cutting speed
v_c
instantaneous velocity of a selected point on the cutting edge relative to the workpiece.

Note 1 to entry: The relationship between v_c and n is given by the formula $v_c = n \cdot 2\pi R$.

Note 2 to entry: The cutting speed is expressed in metres per minute.

3.3.2.3
feed speed
v_f
instantaneous velocity, in metres per minute, of the tool feed parallel to the rotary axis of the circular cutter and perpendicular to the cutting direction relative to the workpiece

3.4 Planing of rectangular bars and planing or broaching of notches in finished test specimens

NOTE In this machining operation, sawed or sliced rectangular bars are finished by planing. Also, notches in finished specimens can be cut by planing or broaching.

3.4.1 Geometry

NOTE For this machining operation, the geometry of the *tool-cutting-edge angle*, *the tool back clearance* and the *tool side clearance* is defined, respectively, in 3.1.1.1, 3.1.1.2 and 3.1.1.3.

3.4.2 Tool and workpiece motions

3.4.2.1
cutting speed
v_c
instantaneous velocity of the primary motion of a selected point on the cutting edge relative to the workpiece

Note 1 to entry: The cutting speed is expressed in metres per minute.

3.4.2.2
cutting depth
a
<mean> distance between the surfaces of the workpiece before and after one planing run

Note 1 to entry: The cutting depth is expressed in millimetres.

3.5 Stamping of arbitrarily shaped test specimens fabricated from thin sheets

NOTE In this operation, arbitrarily shaped test specimens are stamped under high pressure from thin sheets by means of a tool with a sharp edge made from hardened steel and located in a plane parallel to the plane of the sheet.

3.5.1 Geometry

3.5.1.1
shape of the stamping tool
geometric shape of the stamping edge in a plane parallel to the sheet plane

Note 1 to entry: The shape of the stamping tool depends on the shape of the test specimen to be stamped, along with its required dimensions and tolerances.

3.5.2 Forces on the tool and tool motion

3.5.2.1
contact force
F_c
force applied to the stamping tool in the direction perpendicular to the sheet plane

Note 1 to entry: Contact force is expressed in newtons.

3.5.2.2
feed speed
v_f
instantaneous velocity of the feed motion of the edge plane of the stamping tool in a direction perpendicular to the sheet plane

Note 1 to entry: The feed speed is expressed in metres per minute.

4 Test specimens

4.1 Shape and state of the test specimens

The following types of test specimen can be prepared by the machining processes described in this document:

— rectangular bars;

— notched rectangular bars;

— rectangular plates;

— curvilinear test specimens (e.g. dumb-bells);

— discs.

The exact shape, dimensions and tolerances of the test specimens shall conform to the standard for the particular test method in question. The machined surfaces and edges of the finished specimens shall be free of visible flaws, scratches or other imperfections when viewed with a low-power magnifying glass (approximately ×5 magnification).

Rectangular bars shall be free of twist and shall have perpendicular pairs of parallel surfaces. The surfaces and edges shall be free from scratches, pits, sink marks and flashes. Each specimen shall be checked for conformity with these requirements by visual observation against straight-edges, squares and flat plates, and by measuring with micrometer callipers.

The requirements on the quality of the edges of disc-shaped specimens used for impact-penetration tests are less rigorous than those for tensile-test specimens.

Any specimen showing a measurable or observable departure from the requirements given above shall be rejected or machined to proper size and shape before testing.

4.2 Preparation of test specimens

The test specimens shall be machined from plates or sheets made from the material to be tested by compression moulding, injection moulding, casting, polymerizing *in situ,* extrusion or other processing operations to produce semi-finished products. Plates may also be obtained in an appropriate manner from finished products. If the sample from which the specimens are prepared is not isotropic, prepare test specimens with their main axis parallel to and perpendicular to the main orientation axis. In all cases, the exact conditions for producing the test specimens, and the position and orientation of the specimens within the samples, shall be agreed upon by the interested parties, and such details shall be described in the test report.

NOTE The room temperature and the temperature of the material during the machining can influence the properties of the specimen.

5 Machinery and tools

5.1 General

For preparing test specimens from plastics materials and for notching of finished specimens, the machines mentioned in 5.2 to 5.6 can be used (see also Clause 3). Recommended machining conditions for various specimen shapes and specimen materials are given in Table 1. Any required conditions for preparation of test specimens by machining will be specified for each material in the specifications for preparation of test specimens and determination of properties of the appropriate ISO material standard. The conditions given in Table 1 for machining notches have also been found to give satisfactory results for numerous materials; however, because of the wide variety of materials tested, other conditions may also be appropriate.

5.2 Milling cutters

These can be used to prepare dumb-bell test specimens and rectangular bars. They may contain one tooth or a number of teeth arranged in a manner described in ISO 3855 and may cut at variable speeds (at high speeds, for instance, in the case of copy milling machines). They can also be used to cut notches in rectangular specimens. In this case, more than one tooth shall be used only if the notches can be made with the same quality as with one tooth.

5.3 Slicing or sawing machines

These may be used to prepare rectangular bar or plate test specimens. They can be equipped with a circular or a band saw, or with a circular disc, the edge of which is coated with an abrasive material such as diamond or cubic boron nitride.

5.4 Tubular cutting machines

These are used to prepare disc test specimens from flat plates or sheet material. The cutting edge of this kind of tool may be saw-toothed or coated with an abrasive material.

5.5 Lathes

These can be used for the same purpose as indicated in 5.4, i.e. for cutting disc test specimens from roughly pre-shaped packs of individual sheets.

5.6 Planing machines

These can be used to cut finished sawed or sliced rectangular bars and to cut notches.

5.7 Stamping tools

Stamping tools are suitable for preparing test specimens of any shape from thin sheets made of materials of adequate ductility.

5.8 Broaching tools

These can be used for notching. They may be hand-operated or machine-driven.

6 Procedure

6.1 General

The machining speed is dependent on the material being tested and shall be such that overheating of the material is avoided. This is particularly important in the case of thermoplastic materials. If the use of a cooling agent is necessary, this will be stated in the specifications for preparation of test specimens and determination of properties of the appropriate ISO material standard. The use of a cooling agent shall have no deleterious effect on the material being machined (see also Table 1). Fine abrasives may be used to achieve a smooth finish. In the case of tools with edges coated with diamond, cubic boron nitride or another abrasive material, ISO 21950, ISO 6104, and ISO 6106 should be considered.

When machining specimens, care should be taken to avoid skin contact and inhalation of dust, as dust may cause irritation.

6.2 Preparation of dumb-bell specimens

Prepare such specimens by low-speed milling with a hand-controlled milling tool or, preferably, by high-speed copy milling using the conditions given in Table 1.

Examine the milled surfaces and edges of the finished test specimens with a magnifying glass having an approximately ×5 magnification for the presence of flaws, scratches and other imperfections. After cutting a maximum of 500 specimens, examine the cutting edge with the aid of a microscope or profile projector with a ×50 to ×100 magnification.

6.3 Preparation of rectangular test specimens by sawing or cutting with an abrasive disc

The detailed conditions used in these methods are given in Table 1. Prepare the test specimens by sawing only if there are no particular requirements regarding the quality of the specimen surfaces, or if the surfaces are to be subsequently finished by another method such as milling or planing. In the latter case, examine the surfaces as specified in 6.2.

6.4 Preparation of disc-shaped test specimens

In general, disc specimens are used to perform impact-penetration tests. In such cases, imperfections in the machined surfaces have no serious influence on the test results. Prepare such specimens using the conditions given in Table 1 and ensure that the plane surfaces of the specimens are smooth and free from flaws.

6.5 Stamping out test specimens of any shape

Use this method for the preparation of test specimens only if the material in question is sufficiently soft and the specimens are to be made from sufficiently thin sheets. The specimen is stamped from the sheet using a single stroke of a knife-edged punch of appropriate shape and dimensions. The cutting edge of the punch shall be sufficiently sharp and free from notches. The sheet shall be supported on a slightly yielding material with a smooth surface (for example leather, rubber or good-quality cardboard) on a flat, rigid base.

The criterion for the applicability of this method is the quality of the specimen edges and surfaces as revealed by examination using the method outlined in 6.2.

6.6 Notching finished test specimens by milling or broaching

Notching may be carried out with the aid of a milling or broaching machine or a lathe, preferably with a single-tooth cutter. Use a tool having a cutting edge made of high-speed steel, hardened steel or diamond. Use a multi-tooth cutter only if notches can be prepared having the same quality as notches made with a single-tooth cutter. For specimens prepared by stamping, machine the notch in a secondary operation (i.e. the notch shall not be stamped).

In preparing notches, the use of abrasives is not permissible.

For milling, choose the feed rate so that the thickness d_s of the shavings is from 0,003 mm to 0,07 mm (see Figures 2 and 3). The thickness d_s is given, in millimetres, by Formula (1):

$$d_s = v_f^{\,2} \Big/ \left(n^2 \cdot R\right) \tag{1}$$

where

v_f is the feed speed, in millimetres per minute;

n is the rotary speed of the tool, in revolutions per minute;

R is the distance, in millimetres, between the axis of the milling machine and the tip of the cutter.

It is essential that close tolerances are established on the contour and radius of the notch because these parameters largely determine the degree of stress concentration at the base of the notch. To obtain reproducible results, carefully grind and hone the cutting edge to ensure sharpness and freedom from nicks and burrs.

Before the first use and after cutting about 500 notches, or more often if the cutter has been used to notch a hard abrasive material, inspect the cutter for sharpness, absence of nicks, correct tip radius and correct tip contour. If the radius and contour do not fall within the specified limits, replace the cutter by a newly sharpened and honed one.

A microscope or profile projector with a ×50 to ×100 magnification is suitable for checking the cutter and the notch. In the case of single-tooth cutters, the contour of the tip of the cutting tool may be checked instead of the contour of the notch in the specimen, provided that, for the type of notch produced, the two correspond or that a definite relationship exists between them. There is some evidence that notches cut by the same cutter in widely differing materials may differ in contour.

In the case of transparent materials, it is often possible to detect undesirable changes in the specimen by means of photoelastic effects. For example, undesirable heating or melting caused by machining, especially of injection-moulded specimens, becomes visible by virtue of distinct changes in coloured interference lines or areas within the zone near the machined surface.

Experience using notched specimens has shown that there are materials (e.g. PMMA, PC) for which the measured values obtained in tests using such specimens decrease gradually in spite of the fact that the cutter is optically satisfactory. In such cases, it is recommended that the cutter be checked using a reference material.

7 Test report

The test report shall include the following information:

a) a reference to this document, i.e. ISO 2818:2018;

b) a description of the material tested and of the sample from which the test specimens were machined (shape, method of preparation, orientation, etc.);

c) a precise description of the position and orientation of the test specimens as taken from a semi-finished or finished product;

d) the dimensions of the test specimens;

e) the method of machining used;

f) the machining conditions used (see Table 1);

g) any other relevant details.

Table 1 — Recommended machining conditions for four types of test specimen and for notches

Material	Method of machining	Rotational speed	Geometry of tool				Number of teeth	Tool motions				Coolant
		n r/min	Diametre $2R$ mm	Cutting edge angle α_r	Back clearance α_p	Side clearance α_f	z	Cutting speed v_c m/min	Feed speed v_f m/min	Feed path λ mm	Cutting depth a mm	
1) Dumb-bell specimen (see 6.2)												
Thermoplastics	Medium-speed milling	180 to 500	125 to 150	5 to 15	5 to 20	—	10 to 16	70 to 250	Slowly	—	1 to 5	None, air or water
Thermosets		—	—	—	—	—	—	70 to 250	Slowly	—	1 to 5	
Thermoplastics	High-speed copy milling	8 000 to 30 000	5 to 20	10 to 15	5 to 20	—	4 to 8	125 to 2 000	Slowly	—	0,2	Air or water
Thermosets		20 000	15 to 20	10 to 15	5 to 20	—	4 to 8	100 to 1 500	Slowly	—	0,5	
2) Rectangular specimen (see 6.3)												
Thermoplastics	Sawing with a circular saw	1 000 to 2 000	50 to 150	—	—	—	30 to 100	150 to 1 000	Medium	—	—	None or air
Thermosets		1 000 to 2 000	50 to 150	—	—	—	50 to 150	150 to 1 000	Medium	—	—	
Thermoplastics	Sawing with a band saw	—	—	—	—	—	as for circular saw	3 to 15	Medium	—	—	None or air
Thermosets		—	—	—	—	—		3 to 15	Medium	—	—	
Thermoplastics	Cutting with an abrasive disc	2 000 to 13 000	50 to 150	—	—	—	—	1 000 to 2 000	Slowly	—	—	Air or water
Thermosets		2 000 to 13 000	50 to 150	—	—	—	—	1 000 to 2 000	Slowly	—	—	
3) Disc-shaped specimen (see 6.4)												
Thermoplastics	Cutting with a circular-saw-like cutter	100 to 200	40 to 100	—	—	—	30 to 100	10 to 100	Medium	—	—	None or air
Thermosets		100 to 200	40 to 100	—	—	—	30 to 100	10 to 100	Medium	—	—	

NOTE — These machining conditions vary depending on the specific materials and tools used. The machining conditions used are those which provide specimens conforming to the specified dimensions and free of flaws when examined under the specified magnification.

Particular machining conditions are reported in the appropriate designation standard for the material concerned.

Table 1 *(continued)*

Material	Method of machining	Rotational speed n r/min	Geometry of tool: Diametre $2R$ mm	Geometry of tool: Cutting edge angle α_r	Geometry of tool: Back clearance α_p	Geometry of tool: Side clearance α_f	Number of teeth z	Tool motions: Cutting speed v_c m/min	Tool motions: Feed speed v_f m/min	Tool motions: Feed path λ mm	Tool motions: Cutting depth a mm	Coolant
Thermoplastics	Cutting with a circular abrasive cutter	300 to 1 500	40 to 100	—	—	—	—	100 to 200	Slowly	—	—	Air or water
Thermosets		300 to 1 500	40 to 100	—	—	—	—	100 to 200	Slowly	—	—	
Thermoplastics	Cutting with a single-tooth milling cutter	100 to 200	40 to 100	5 to 15	5 to 20	—	1	10 to 100	Slowly	—	—	None or air
Thermosets		100 to 200	40 to 100	5 to 15	5 to 20	—	1	10 to 100	Slowly	—	—	
Thermoplastics	Turning with a lathe	500 to 1 000	20 to 100	5 to 15	5 to 20	—	1	30 to 300	Slowly	—	—	None or air
Thermosets		500 to 1 000	20 to 100	5 to 15	5 to 20	—	1	30 to 300	Slowly	—	—	
4) Stamped specimens of any shape (see 6.5)												
Thermoplastics	Stamping from thin sheets	—	—	—	—	—	—	—	Slowly by pressure	—	—	None
Thermosets		—	—	—	—	—	—	—		—	—	
5) Cutting notches (see 6.6)												
Thermoplastics	Medium-speed milling	200 to 1 000	60 to 80	2 to 7	2 to 7	2 to 7	1	50 to 250	0,07 to 2	1 to 2	0,2 to 2	Air or water
Thermosets		200 to 1 000	60 to 80	2 to 7	2 to 7	2 to 7	1	50 to 250	0,07 to 2	1 to 2	0,2 to 2	
Thermoplastics	Broaching	—	—	2 to 7	—	—	1	8 to 20	Slowly	—	0,01 to 0,3	Air or water
Thermosets		—	—	2 to 7	—	—	1	8 to 20	Slowly	—	0,01 to 0,3	

NOTE — These machining conditions vary depending on the specific materials and tools used. The machining conditions used are those which provide specimens conforming to the specified dimensions and free of flaws when examined under the specified magnification.

Particular machining conditions are reported in the appropriate designation standard for the material concerned.

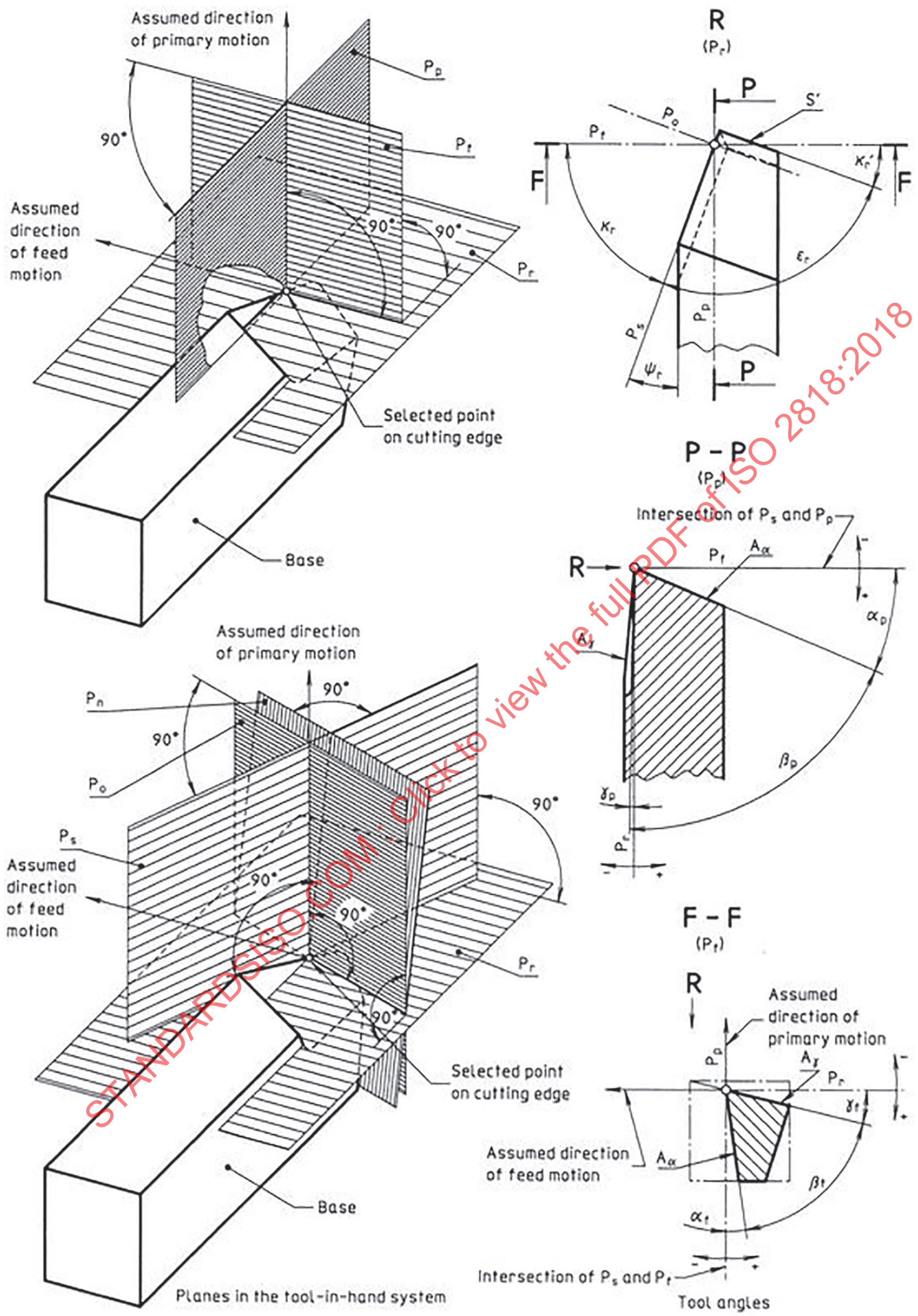
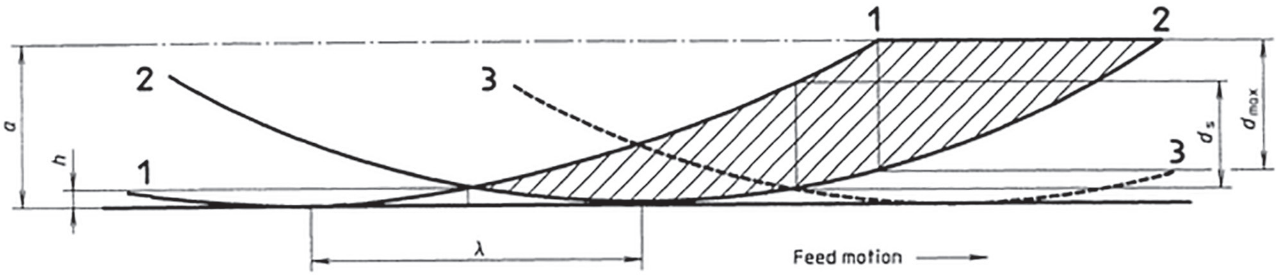


Figure 1 — Geometry of the active part of cutting tools



Key

1, 2, 3 successive cuts

a cutting depth

λ feed path

h roughness

d_s thickness of chip

d_{max} maximum thickness of chip

Figure 2 — Shape of milling chips