

INTERNATIONAL STANDARD

**ISO
3685**

Second edition
1993-11-15

Tool-life testing with single-point turning tools

Essais de durée de vie des outils de tournage à partie active unique

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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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 3685 was prepared by Technical Committee ISO/TC 29, *Small tools*.

This second edition cancels and replaces the first edition (ISO 3685:1977), of which it constitutes a technical revision.

Annexes A, B, C, D, E, F and G form an integral part of this International Standard. Annex H is for information only.

Introduction

The adoption by both industry and testing bodies of the recommendations contained in ISO 3685:1977 created a demand for the publication of similar recommendations for other commonly used cutting processes.

Tool-life testing in milling is covered in ISO 8688-1:1989 and ISO 8688-2:1989. During the final stages of their preparation, it was recognized that there was a need to update the recommendations for single-point turning tools.

This International Standard contains recommendations which are applicable in both laboratories and manufacturing units. These recommendations are intended to unify procedures in order to increase reliability and comparability of test results when making comparisons of cutting tools, work materials, cutting parameters or cutting fluids. In order to come as close as possible to these aims, recommended reference materials and conditions are included and should be used as far as is practical.

In addition, the recommendations can be used to assist in finding recommended cutting data or to determine limiting factors and machining characteristics such as cutting forces, machined surface characteristics, chip form etc. For these purposes in particular, certain parameters, which have been given recommended values, may have to be used as variables.

The test conditions recommended in this International Standard have been designed for turning tests using steel and cast iron workpieces of normal microstructure, with solid high-speed steel tools or tools with cemented carbide or ceramic indexable inserts. However, with suitable modifications, this International Standard can be applied, for example, to turning tests on other work materials or with cutting tools developed for specific applications.

The specified accuracy given in the recommendations should be considered as a minimum requirement. Any deviation from the recommendations should be indicated in detail in the test report.

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Tool-life testing with single-point turning tools

1 Scope

This International Standard specifies recommended procedures for tool-life testing with high-speed steel, cemented carbide and ceramic single-point turning tools used for turning steel and cast iron workpieces. It can be applied in laboratory testing as well as in production practice.

In turning, cutting conditions may be considered under two categories:

- a) conditions as a result of which tool deterioration is due predominantly to wear;
- b) conditions under which tool deterioration is due mainly to other phenomena such as edge fracture or plastic deformation.

This International Standard is solely concerned with recommendations for testing which results predominantly in tool wear.

Testing for the second category of conditions above is to be subject to further study.

This International Standard establishes specifications for the following factors of tool-life testing with single-point turning tools: workpiece, tools, cutting fluid, cutting conditions, equipment, assessment of tool deterioration and tool life, test procedures and the recording, evaluation and presentation of results.

Further general information is given in annex A.

NOTE 1 This International Standard does not constitute an acceptance test and should not be used as such.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements

based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 185:1988, *Grey cast iron — Classification*.

ISO 229:1973, *Machine tools — Speeds and feeds*.

ISO 468:1982, *Surface roughness — Parameters, their values and general rules for specifying requirements*.

ISO 513:1991, *Application of hard cutting materials for machining by chip removal — Designation of the main groups of chip removal and groups of application*.

ISO 683-1:1987, *Heat-treatable steels, alloy steels and free-cutting steels — Part 1: Direct-hardening unalloyed and low-alloyed wrought steel in form of different black products*.

ISO 841:1974, *Numerical control of machines — Axis and motion nomenclature*.

ISO 883:1985, *Indexable hardmetal (carbide) inserts with rounded corners, without fixing hole — Dimensions*.

ISO 1940-1:1986, *Mechanical vibration — Balance quality requirements of rigid rotors — Part 1: Determination of permissible residual unbalance*.

ISO 2540:1973, *Centre drills for centre holes with protecting chamfer — Type B*.

ISO 3002-1:1982, *Basic quantities in cutting and grinding — Part 1: Geometry of the active part of cutting tools — General terms, reference systems, tool and working angles, chip breakers*.

ISO 4957:1980, *Tool steels*.

ISO 5610:1989, *Single-point tool holders for turning and copying, for indexable inserts — Dimensions*.

ISO 9361-1:1991, *Indexable inserts for cutting tools — Ceramic inserts with rounded corners — Part 1: Dimensions of inserts without fixing hole.*

ISO 9361-2:1991, *Indexable inserts for cutting tools — Ceramic inserts with rounded corners — Part 2: Dimensions of inserts with cylindrical fixing hole.*

3 Definitions

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

3.1 tool wear: The change of shape of the tool from its original shape, during cutting, resulting from the gradual loss of tool material or deformation.

3.2 tool wear measure: A dimension to be measured to indicate the amount of tool wear.

3.3 tool-life criterion: A predetermined threshold value of a tool wear measure or the occurrence of a phenomenon.

3.4 tool life: The cutting time required to reach a tool-life criterion.

4 Workpiece

4.1 Work material

In principle, testing bodies are free to select the work materials according to their own interests. However, in order to increase the comparability of results between testing bodies, the use of one of the reference materials, steel C 45 in accordance with ISO 683-1 or cast iron grade 25 in accordance with ISO 185, is recommended. Detailed specifications of these materials are given in annex B. Within these specifications, materials may vary with a resulting effect on machinability. To minimize such problems the provision of a closer specified work material should be discussed with the supplier.

It is recommended that information concerning the work material such as grade, chemical composition, physical properties, microstructure, hardness, complete details of the processing route of the work material (e.g. hot rolled, forged, cast or cold drawn) and any heat treatment be given in the test report (see 4.2 and annex B).

In order to be able to compare results over reasonably long periods of time, it is recommended that testing bodies procure sufficiently large quantities of reference work material to cover their long term needs.

4.2 Standard conditions for the workpiece

All mill scale or casting skin shall be removed by clean-up cuts before testing, except when the effect of the scale is being tested.

The plastic formed surface of the shoulder, i.e. "the transient surface", and any other burnished or abnormally work-hardened surface on the workpiece which can come in contact with the test tool shall be removed with a sharp clean-up tool prior to testing in order to reduce as much as possible the residual sub-surface deformations due to the previous test. However, this does not include removal of the normally work-hardened surface on the test bar produced by the previous passes of the tool.

The length/diameter ratio of the workpiece shall be not more than the minimum ratio at which chatter occurs. The test shall be stopped when chatter occurs. A length/diameter ratio greater than 10 is not recommended.

The hardness of the work material shall be determined over the complete cross-section of one end of each test bar or tube.

Where hardness variations are expected to be significant, measurements shall be taken to ascertain that values fall within the prescribed limits.

The locations of measurement points and the method of measurement should be noted in the test report. It is recommended that the deviation within one batch of material be as small as possible. A realistic hardness value for the reference materials and similar materials is $\pm 5\%$ of the mean value.

The cutting test shall be conducted only in the range of diameters where the hardness lies within the limits given by the original hardness specification.

Quantitative metallography (as regards microstructure, grain size, inclusion count, etc.) of the work material is recommended but when this is not practical, photomicrographs shall be included in the test report. The magnification shall be in the range $\times 100$ to $\times 500$.

In machining tests carried out on production components, the fixing devices normally employed in the process shall be utilized.

The chuck and the spindle shall be stable and well balanced (for a method of evaluating the balance, see ISO 1940-1). When fixing the workpiece between a chuck or a faceplate and a centre, special care shall be taken to prevent any bending loads on the workpiece.

For diameters above 90 mm, the use of a faceplate is recommended.

A centre hole of 6,3 mm diameter with 120° protecting chamfer, in accordance with ISO 2540, is recommended.

5 Tools

In principle, testing bodies are free to select testing tools according to their own interests. However, in order to increase the comparability of results between testing bodies, the use of one of the reference tool shapes and tool materials, as specified hereafter, is recommended.

5.1 Tool materials

In all cutting tests in which the tool material is not itself the test variable, the investigation shall be conducted with an appropriate reference tool material to be defined by the testing body.

In principle, testing bodies are free to select the tool materials according to their own interest. However, in order to increase the comparability of results between testing bodies, the use of one of the reference materials, specified in this subclause, is recommended.

Within these specifications, tool materials may vary with a resulting effect on performance. To minimize such problems, the provision of a closely specified tool material should be discussed with the supplier to ensure as much uniformity as is practical.

In order to be able to compare results over reasonably long periods of time, it is recommended that testing bodies procure sufficiently large quantities of reference tool materials to cover their long term needs.

Reference tool materials should not have any coating or surface treatment.

If the tool material itself, coating or surface treatment is the test variable then the material classification, physical properties, microstructure hardness and processing route should be reported in detail.

5.1.1 High-speed steel

The high-speed steel reference tool material should be uncoated non-cobalt alloyed (S 2 and S 4) or cobalt alloyed (S 8 and S 11) all of which conform to ISO 4957.

5.1.2 Sintered carbide

The sintered carbide reference tool material shall belong to the ISO groups of application P 10 for machining steel or K 10 for machining cast iron in accordance with ISO 513.

Since carbide grades for the same group of application can vary between producers and are unlikely to be comparable, it is recommended to select a particular supplier's grade as a reference grade.

5.1.3 Ceramics

These shall be of commercially available grades and the composition and physical properties shall be noted in the test report in as much detail as possible.

The reference ceramics shall be

- Al₂O₃-based, with min. 70 % Al₂O₃ and additions of other hard materials such as ZrO₂, titanium carbide (TiC) or titanium nitride (TiN);
- Si₃N₄-based, with min. 90 % Si₃N₄ and additions of Y₂O₃ and/or Al₂O₃.

5.1.4 Other tool materials

When the tool material is the test variable, the material classification and, if possible, the chemical composition, hardness and microstructure shall be noted in the test report.

5.2 Tool geometry

5.2.1 Cutting tool geometry

The cutting tool geometry is defined in accordance with ISO 3002-1.

Figure 1 illustrates those angles which are necessary to define the orientation of the cutting edges, face and flank of a single-point cutting tool.

5.2.2 Standard tool geometry

All cutting tests in which the tool geometry is not the test variable shall be conducted using one of the tool geometries given in table 1. In the case of sintered carbide and ceramic tools, these shall be of the clamped insert type. Brazed or adhesive-bonded insert tools shall not be used as reference tools.

The tool shall be set on the machine correctly. This is accomplished by setting the corner on centre and setting the tool shank perpendicular to the axis of rotation of the workpiece. For carbide cutting tools used for machining steel and similar alloys only, the cutting edge shall have a radius r_n such that,

if $r_e = 0,4$ mm, then $r_n = 0,02$ mm to 0,03 mm;

if $r_e > 0,4$ mm, then $r_n = 0,03$ mm to 0,05 mm.

The conditions of the cutting edge for ceramics shall be in accordance with the magnified view in figure 1. r_n values shall be those obtained by grinding and shall be noted in the test report.

All other cutting tools shall be used with the normally sharp edge produced by the grinding or finishing operations indicated in 5.3.5.

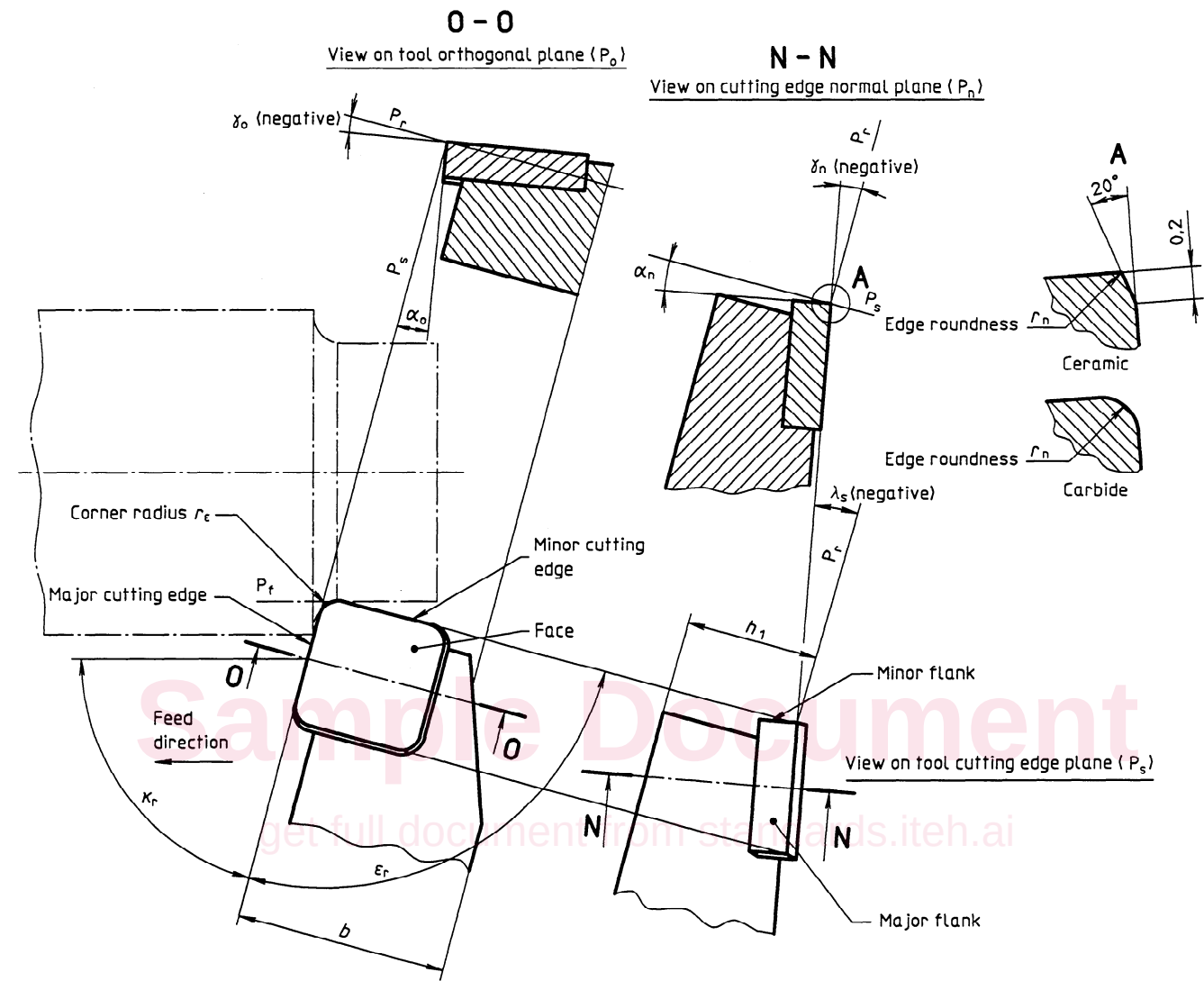


Figure 1 — Illustration of tool angles

Table 1 — Standard tool angles

Cutting tool material	Angles in degrees				
	Rake ¹⁾ γ	Clearance ¹⁾ α	Cutting edge inclination λ_s	Cutting edge angle κ_r	Included angle ϵ_r
High-speed steel	25	8	0	75	90
Sintered carbide	+6	5	0	75	90
	-6	6	-6	75	90
Ceramic	-6	6	-6	75	90

1) The tool rake and tool clearance angles may be measured in either the cutting edge normal plane (P_n) or the tool orthogonal plane (P_o). The appropriate subscript shall be added to γ and α to denote the plane of measurement, i.e. γ_n or γ_o and α_n or α_o .

5.2.3 Other tool geometries

Alloys unusually difficult to machine, such as nickel base and refractory materials, may require a departure from the standard tool geometry, but such a departure shall only be made when it is impossible to employ the standard tool geometry. In such a case or where tool geometry is the test variable, the following information shall be indicated in the test report:

- values of the tool angles and the corresponding working angles (specified for the condition where the feed speed is zero as shown in table 1);
- condition of the cutting edge: normally sharp, rounded to a specified radius or chamfered (the widths and angles of any lands on the face or flank).

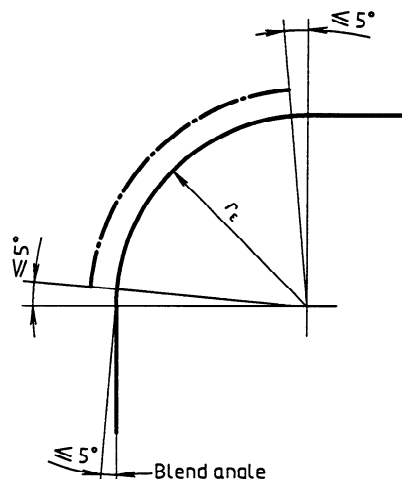


Figure 2 — Details of rounded corner

5.3 Standard conditions for the tool

5.3.1 Tool type and size

A straight roughing tool shall be used.

The shank cross-section $h_1 \times b$ for tool holders, in accordance with ISO 5610, shall be

25 mm $\times$ 16 mm for solid high-speed steel tools;

25 mm $\times$ 25 mm for carbides; and

32 mm $\times$ 25 mm for ceramics.

The distance from the corner of the tool to the front of the lathe tool post holder (overhang) shall be 25 mm.

Sintered carbide inserts shall be 12,7 mm square and with a thickness of 4,76 mm for negative rake and 3,18 mm for positive rake (see ISO 883).

Ceramic inserts, in accordance with ISO 9361-1 and ISO 9361-2, shall be 12,7 mm square and with a thickness of 4,76 mm.

5.3.2 Tolerances

Tolerances for all tool angles shall be $\pm 0,5^\circ$ ($30'$) for the complete cutting tool.

The angle between a tangent to the rounded corner and the major or minor cutting edges at the point where these blend shall not be greater than 5° (see figure 2).

The tolerance for the corner radius (r_e) shall be $\pm 0,1 \times r_e$.

The tolerance on parallelism between the tool reference plane P_r and the tool back plane P_p (see ISO 3002-1:1982, subclauses 4.1.1 and 4.1.3) and the fixed setting axes X_m and Z_m (see ISO 3002-2:1982, subclause 2.2) of the machine tool, shall be $\pm 0,5^\circ$. In

practice, this requirement is met when the corner is on centre within $\pm 0,25$ mm and the infeed of the tool past a stationary reference point produces a deviation of the top surface (parallel to the supporting plane) and the side surface (parallel to the plane P_p) of the tool shank not in excess of $\pm 0,4$ mm per 50 mm of infeed motion (see figure 3).

The tolerances of sintered carbide and ceramic inserts shall correspond to ISO 1832 class G, except as indicated above.

5.3.3 Tool finish

The roughness, R_a , of the face and flank of the tool shall not exceed $0,25 \mu\text{m}$ (measured in accordance with ISO 468).

The deviation from flatness of the supporting face of an insert, except in the immediate vicinity of its edges, shall not exceed 0,004 mm.

The cutting edge on high-speed steel tools shall have neither burrs nor feather edge. These may be removed by careful light honing of the face and flank surfaces of the tool.

Each cutting edge to be used in testing shall be examined at a minimum magnification of $\times 10$ for visual defects such as chips or cracks. These defects shall be corrected if possible, otherwise the tool shall not be used.

5.3.4 Tool holders for inserts

For cutting tests, tool holders shall meet the following conditions.

The geometry shall be as indicated in table 1.

The tolerance on the angles for tool holder plus inserts shall be $\pm 0,5^\circ$ ($30'$) and for the tool holder alone $\pm 0,2^\circ$ ($12'$).

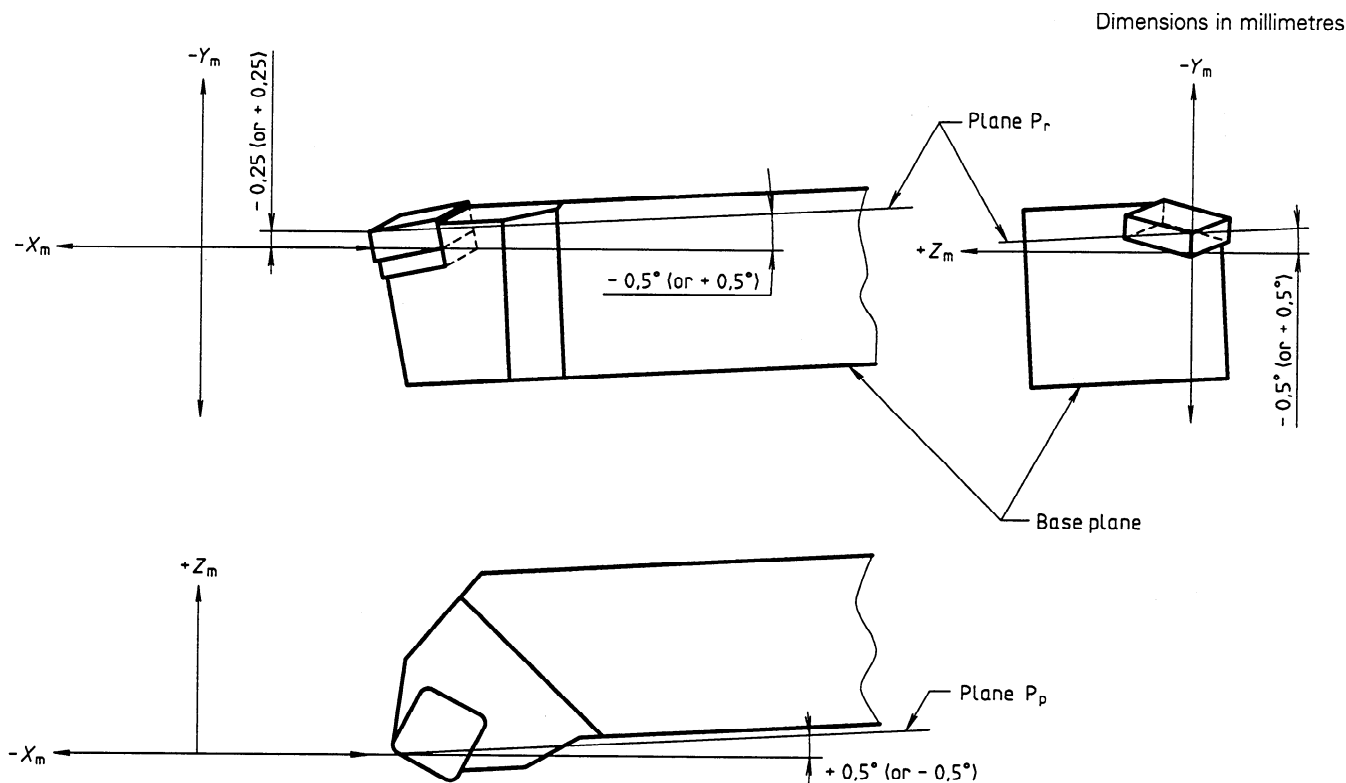


Figure 3 — Tolerance on parallelism

The angle for locating the indexable insert in the tool holder shall be as specified in figure 4.

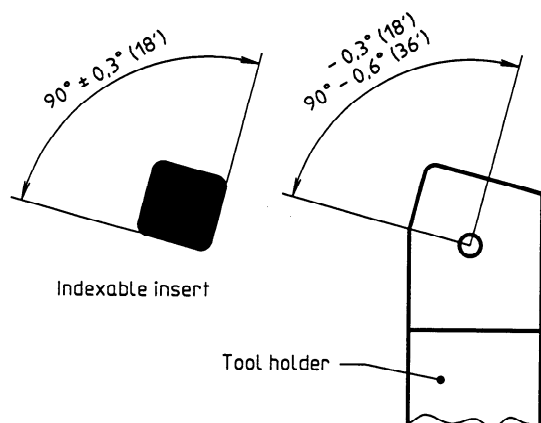


Figure 4 — Tolerances on squareness of insert and tool holder location

The tool holder material shall be steel with a tensile strength not less than $1\,200\text{ N/mm}^2$ ($1\,200\text{ MPa}$).

The flatness of the base of the tool holder shall be within $0,1\text{ mm}$ over the length and width of the tool holder.

The faces on the tool holder or the shim supporting the insert shall be flat to within $0,01\text{ mm}$.

The underside of the indexable insert shall not project over the supporting face of the tool holder by more than $0,3\text{ mm}$ (see figure 5).

The chip breaker height and chip breaker distance and the method of clamping the insert shall be noted in the test report. (See 5.3.7.)

5.3.5 Tool grinding of high-speed steel

The sequence of operations, types of grinding wheel, cutting data and recommended procedures should be obtained from the grinding wheel manufacturers.

For tools having a positive rake, each subsequent corner shall be lower than the preceding one. The decrease in tool corner height shall not exceed 5 mm , otherwise a new rake face shall be ground at the original height.

The cutting direction of the active periphery of the grinding wheel should be approximately perpendicular to the tool major cutting edge and in a direction away from the major cutting edge across the tool surface being ground.

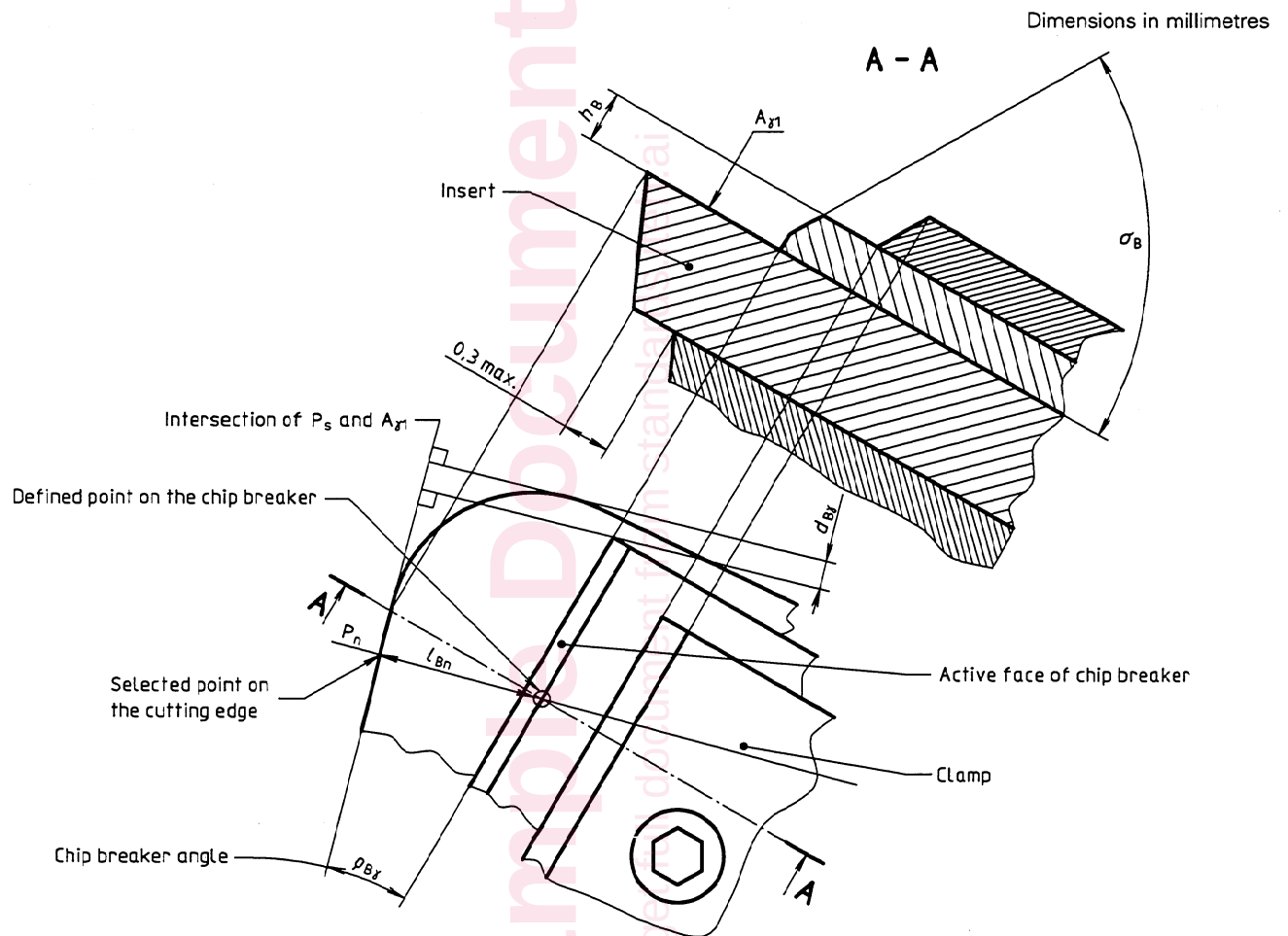


Figure 5 — Illustration of insert overhang and chip breaker

When using a plain grinding wheel the direction of feed motion may be either in the same direction or opposite to the cutting direction of the wheel relative to the surface being ground.

There is a danger of overheating, especially when the grinding machine does not permit a perfect control of depth setting and feed. Overheating is usually followed by oxidation colours but when colours are not obvious, overheating may still influence the hardness. Therefore, a hardness check shall be made.

After grinding, the hardness of the tool shall be measured on the flank or face as near as possible to the cutting edge. The hardness shall correspond to the previously measured hardness of the tool material. If this hardness value is not obtained after grinding, further grinding or cutting back shall be performed until the desired hardness is achieved.

The profile of the tool shall be restored after testing as shown in figures 1 and 2 and table 1.

When regrinding, the tool shall be ground back at least 2 mm beyond the wear marks. The tool geometry has to be maintained as specified in figures 1 and 2 and table 1. Care shall be taken to ensure that the tool corner has not been displaced sideways.

5.3.6 Carbide, ceramic

These inserts shall be used in the manufacturer's delivery condition and shall not be reground.

5.3.7 Chip breaker

A chip breaker shall not be used on high-speed steel tools unless the chip breaker is itself a test variable or if chipbreaking is necessary. The use of a chip breaker is permissible when testing with sintered carbide and ceramic tools. A chip breaker is often required when using these tool materials as a safety factor.

The chip breaker, if used, shall rest flat on the indexable insert. The deviation in flatness of the face of the chip breaker in contact with the insert shall not exceed 0,004 mm.

The chip breaker angle α_{B_y} (see figure 5) is the angle between the line of intersection of the chip breaker and the tool face and the straight portion of the major cutting edge. The angle α_{B_y} can be varied with different work piece materials so that an acceptable chip form is achieved and in order to guide the chip direction to or from the work piece, see ISO 3002-1:1982, subclause 7.5. The chip breaker wedge angle (σ_B), i.e. the angle between the active face of the chip breaker and the tool face shall be between 55° and 60°.

The chip breaker distance l_{Bn} shall be chosen so that an acceptable chip form is achieved (see figure 5). The actual chip breaker distance shall be noted in the test report.

For ceramic tools, the distance l_{Bn} may not be too small with regard to the risk for crushing the edge.

NOTE 2 Particular attention should be paid to the fact that the crater can be different when turning with or without a chip breaker.

6 Cutting fluid

Cutting fluid shall be used when cutting steel workpieces with high-speed steel tools unless the high-speed steel tools are being tested to catastrophic failure (see 8.2.1).

When cutting steel workpieces with carbides or ceramics cutting fluid normally should not be used.

When cutting cast iron the use of cutting fluids is not recommended.

The cutting fluid shall be clearly specified either by trademark or composition of the active elements, the actual concentration, hardness of water (when used as a diluent) and the pH value of the solution or emulsion.

When using cutting fluid the flow should "flood" the active part of the tool. The flow-rate should not be less than 3 l/min or 0,1 l/min for each cubic centimetre per minute of metal removal rate, whichever is the larger. The orifice diameter, flow-rate and reservoir temperature should be noted in the test report.

7 Cutting conditions

7.1 Standard cutting conditions

For all tests in which feed, f , depth of cut, a_p , or corner radius, r_e , are not the prime test variables, the cutting conditions shall be one or more of the combinations listed in table 2.

Table 2 — Standard cutting conditions

Cutting condition	A	B	C	D
Feed, f , mm/rev	0,1	0,25	0,4	0,63
Depth of cut, a_p , mm	1	2,5	2,5	2,5
Corner radius, r_e , mm	0,4	0,8	0,8	1,2

The tolerance on feed shall be $^{+3}_{-2}$ % (in accordance with ISO 229).

The tolerance on depth of cut shall be ± 5 %.

The edge geometry on corner radius is defined in 5.3.2.

NOTE 3 Designations in accordance with ISO 3002-3 have been used.

7.2 Other cutting conditions

When it is not possible to choose one of the standard cutting conditions, or when the feed, the depth of cut or the corner radius is the test variable, it is recommended that only one parameter be altered at a time and that the values chosen be at the intersection of designated feeds and depths of cut within the triangular areas shown in figure 6. The limits of the triangular areas are defined in table 3.

Table 3 — Limits of other cutting conditions

Minimum depth of cut	2 times corner radius ¹⁾
Maximum depth of cut	10 times feed
Maximum feed	0,8 times corner radius
1) A smaller depth of cut may make measurements of tool wear more difficult and less accurate.	

7.3 Cutting speed

The cutting speed, in metres per minute (m/min), shall be determined on the surface of the workpiece to be cut, i.e. the work surface and NOT on the diameter resulting from the cut, i.e. the machined surface. Furthermore, the cutting speed shall be measured after the tool has engaged the workpiece to take into account any loss of cutting speed resulting from the cutting action.

At least four different cutting speeds shall be chosen for each cutting condition, except for ceramics, when a limitation to three speeds is practical with regard to the material consumption. In general, the cutting speeds shall be chosen such that the tool life at the highest speed is not less than 5 min, for ceramics not less than 2 min.

When machining expensive materials, a shorter tool life may be chosen, but shall not be less than 2 min.

In order to obtain adequately spaced points on the cutting speed tool-life curve, it is recommended that successive cutting speeds bear a ratio which will result in an approximately double tool life. The ratios can be chosen from a geometrical series of preferred numbers given in ISO 3 and/or ISO 229.

As a guideline, the following speed ratios can be used:

high-speed steel tool: 1,06

carbide tools: 1,12

ceramic: 1,25

8 Tool-life criteria and tool wear measurements

8.1 Introduction

In practical/workshop situations, the time at which a tool ceases to produce workpieces of the desired size and surface quality usually determines the end of useful tool life. The period up to the instant when the tool is incapable of further cutting may also be considered as useful tool life. However, the reasons for which tools may be considered to have reached the end of useful tool life will be different in each case depending upon cutting conditions etc.

To increase reliability and comparison of test results, it is essential that tool life is defined as the total cutting time of the tool to reach a specified value of tool-life criterion.

Depending on where at the cutting edges the deterioration occurs different values can be accepted.

This International Standard recommends that tool deterioration in the form of wear shall be used for determining tool life.

Where more than one type of wear becomes measurable, each type should be recorded and when any one of the wear phenomena limits has been attained, then the end of tool life has been reached.

The numerical value of tool wear used to determine tool life governs the quantity of testing materials required and the costs of testing. If the limiting value is too high, the cost of establishing results may exceed the worth of these results. If the limiting value is too low, the established result may be unreliable since it may be determined during the initial stages of wear development under the test conditions.

8.2 Tool-life criteria

The type of wear that is believed to contribute most to the end of useful tool life in a specific series of tests shall be used as a guide to the selection of one of the tool-life criteria specified hereafter. The type and value of the criterion used shall be noted in the test report. If it is not clear which type of wear will predominate, it is possible to use either two criteria, resulting in two v_c-T_c curves, or a mixed criterion, resulting in a broken v_c-T_c curve (see figure 7).