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# INTERNATIONAL STANDARD



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INTERNATIONAL ORGANIZATION FOR STANDARDIZATION • МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ • ORGANISATION INTERNATIONALE DE NORMALISATION

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## 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 institutes (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been set up 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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 3685 was developed by Technical Committee ISO/TC 29, *Small tools*, and was circulated to the member bodies in April 1975.

It has been approved by the member bodies of the following countries :

Australia	Mexico	Switzerland
Belgium	Netherlands	Turkey
Czechoslovakia	Poland	United Kingdom
France	Portugal	U.S.A.
Germany	Romania	U.S.S.R.
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Israel	Spain	
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The member bodies of the following countries expressed disapproval of the document on technical grounds :

Austria  
Japan

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# Tool-life testing with single-point turning tools

## 0 INTRODUCTION

Tool-life testing has been carried out for at least 75 years, in tremendously increasing volume, but under a variety of cutting conditions and methods having little in common with each other. Thus, a need exists for standardization of tool-life testing conditions applicable not only in laboratories but also in production plants.

The test conditions have been specified in such a way that the different factors which affect the results of tool-life testing will all be under a reasonable and practical degree of control.

This International Standard has been so framed that it can be directly applied to industrial testing and in research. For research purposes, however, this International Standard should be considered to be only a minimum set of conditions, since greater attention may have to be given to the factors which affect the variability of the tool-life values. Although the test parameters are standardized, any one or more of them may become variables in any given test when they are the quantities being examined.

The limits of the specification of the reference materials are left rather wide for practical reasons. It should be understood that results may vary from batch to batch. If reproducibility is essential, special requirements should be discussed with the supplier of the work material.

The specifications for test conditions given in this International Standard are primarily suited to testing on steel and cast iron work materials. However, with suitable modification they can also be made applicable to testing on other materials.

The specifications for test conditions are also mainly applicable to tool-life testing in which the tool wears at a conventional rate and in a conventional manner. However, it is evident that they may also be applied to some types of accelerated tool-life testing.

If, for some reason, it is necessary to deviate from the specifications given in this International Standard, this shall be reported in detail.

**NOTE** — This International Standard is not an acceptance test and it is not advisable to use it as such.

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## 1 SCOPE AND FIELD OF APPLICATION

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

Further general information is given in annex A.

## 2 REFERENCES

- ISO 3, *Preferred numbers — Series of preferred numbers.*
- ISO 80, *Rockwell hardness test (B and C scales) for steel.*<sup>1)</sup>
- ISO 81, *Vickers hardness test for steel (load 5 to 100 kgf).*<sup>1)</sup>
- ISO/R 185, *Classification of grey cast iron.*
- ISO 229, *Machine tools — Speeds and feeds.*
- ISO/R 468, *Surface roughness.*
- ISO 513, *Application of carbides for machining by chip removal — Designation of the main groups of chip removal and groups of application.*
- ISO 525, *Bonded abrasive products — General features — Designation, ranges of dimensions, and profiles.*

1) In preparation. (Revision of ISO/R 80-1968 and ISO/R 81-1967.)

ISO/R 643, *Micrographic determination of the austenitic grain size of steels.*

ISO/R 683/III, *Heat-treated steels, alloy steels and free-cutting steels – Part III : Wrought quenched and tempered unalloyed steels with controlled sulphur content.*

ISO 1832, *Indexable (throwaway) inserts for cutting tools – Designation – Code of symbolization.*<sup>1)</sup>

ISO 2854, *Statistical interpretation of data – Techniques of estimation and tests relating to means and variances.*

ISO 3002/1, *Geometry of the active part of cutting tools – General terms, reference systems, tool and working angles.*

ISO 3534, *Statistics – Vocabulary and symbols.*

ISO 5479, *Statistical interpretation of data – Test for departure from normality.*<sup>2)</sup>

### 3 WORKPIECE

#### 3.1 Work material

In all cutting tests in which the work material is not itself the test variable or is not itself an important parameter, the investigation shall be conducted on the appropriate one of the reference materials indicated in 3.1.1, 3.1.2 and 3.1.3. In the exceptions quoted, however, it is desirable to conduct tests on a reference material for comparative purposes.

The provision of a well-defined reference work material shall be discussed with the manufacturer.

##### 3.1.1 Steel

The steel reference material shall be a hot-rolled medium carbon steel of the following composition corresponding to steel C 45 ea, in conformity with ISO/R 683/III.

C %	Si %	Mn %	S %	P %
0,42	0,15	0,50	0,02	0,035 max.
to	to	to	to	
0,50	0,40	0,80	0,035	

The presence of the following elements in excess of the maximum values given below shall disqualify the steel as a reference test material.

- Ni = 0,20 %
- Cr = 0,15 %
- Mo = 0,05 %
- V = 0,02 %
- Cu = 0,20 %

The steel shall be deoxidized with aluminium and the minimum aluminium content shall be 0,01 %. Special deoxidants shall not be used.

The nitrogen content, being to some extent dependent on the steelmaking source, shall be as follows :

Source	Nitrogen content
Open hearth or Oxygen convertors	0,003 to 0,006 %
Arc, single slag	0,004 to 0,008 %

It will be necessary to analyse the steel for nitrogen. The steel shall be purchased to ISO/R 683/III delivery condition 1 (chemical analysis only). The limits of the elements and deoxidation practice shall be discussed with the steel-maker and analyses of C, Si, Mn, Ni, Cr, Mo, P, S, V, Cu, Al and N requested at the time of the order.

The minimum initial test bar diameter shall be 100 mm, but the actual initial diameter shall be reported.

The test bars, after being cut to length, shall be normalized to a Brinell hardness of 180 to 200 HB. The actual hardness shall be reported.

##### 3.1.2 Cast iron

The cast iron reference material shall be supplied to ISO/R 185, grade 25, with a Brinell hardness of 200 to 220 HB.

If available, the following material shall be used.

The microstructure throughout the entire volume of each cast iron test bar shall consist essentially of a matrix of 100 % pearlite with flake graphite within the following specification :

– pearlite	100 %
– free iron carbide	0 %
– free ferrite	5 % max.
– steadite (iron-iron phosphide eutectic)	5 % max.
– graphite	flake graphite only

##### 3.1.3 Other work materials

Where the work material is not one of the reference materials, if possible the grade, chemical composition, physical properties, microstructure and complete details of the processing route of the work material (for example hot-rolled, forged, cast or cold drawn) and any heat treatment shall be reported.

1) At present at the stage of draft. (Revision of ISO/R 1832-1971.)

2) At present at the stage of draft proposal.

### 3.2 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 metal forming the 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 chatters 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.

The cutting test shall be conducted only on the bar 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 report. The magnification shall be in the range 100 to 500 X.

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. When fixing the workpiece between a chuck or a face-plate and a centre, special care shall be taken to prevent any bending loads on the workpiece.

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

## 4 TOOL

### 4.1 Tool material

In all cutting tests in which the tool material is not itself the test variable or is not itself an important parameter, the investigation shall be conducted with the appropriate one of the reference tool materials indicated in 4.1.1, 4.1.2, 4.1.3 and 4.1.4. In the exception quoted, however, it is desirable to conduct tests with a reference tool material for comparative purposes.

#### 4.1.1 High-speed steel

The composition of the reference tool material shall be as follows :

C %	Si %	Mn %
0,80 to 0,85	0,10 to 0,40	0,10 to 0,40

Cr %	Mo %	W %
4,0 to 4,25	4,75 to 5,25	6,0 to 6,5

V %	P %	S %
1,7 to 2,1	0,03 max.	0,03 max.

The heat treatment of the pre-ground toolbits shall be as follows :

**Annealing :** The tool material shall be annealed from a temperature not exceeding 850 °C, followed by furnace cooling (where possible the cooling rate should not exceed 30 °C/h).

**Pre-heating :** Pre-heat at 850 °C. When desired, a prior pre-heat at 650 °C is permitted.

**Hardening :** Harden between 1 220 and 1 240 °C. The holding time shall be adjusted according to batch size and furnace size. Where possible, neutral salt-baths should be used as the heating media. The approximate time at temperature shall be 2 min.

**Quenching :** The toolbits shall be quenched in oil or in a salt-bath followed by air cooling.

**Tempering :** Temper between 550 and 560 °C for two periods of 1 h each at full temperature. Following a hardness test, the material shall be tempered a third time at a temperature suitable to obtain a hardness of 65 ± 1 HRC corresponding to 846 ± 23 HV and shall be checked according to ISO/R 80 and ISO/R 81.

If the required hardness is achieved after the second temper, then the third temper shall be carried out at 550 °C.

After heat treatment, the grain size shall be approximately intercept No. 12 (ISO/R 643). The actual value shall be recorded.

#### 4.1.2 Sintered carbide

The use of sintered carbide from "Tool Material Banks"<sup>1)</sup> is recommended. If this is not possible, the carbide grades to be used shall belong to the ISO groups of application P 10 or P 30 for machining steel and K 10 or K 20 for machining cast iron in accordance with ISO 513.

1) For example, indexable inserts manufactured especially for testing purposes.

Since carbide grades of the same ISO group of application vary between producers (and were therefore not comparable at the time of drafting this International Standard) and to a lesser extent between batches, the performance of inserts should be calibrated against inserts from a "Tool Material Bank" if possible.

4.1.3 Ceramics

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

4.1.4 Other tool materials

Where the tool material is the test variable, the material classification, and, if possible, chemical composition, hardness and microstructure shall be reported.

4.2 Tool geometry

4.2.1 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.

4.2.2 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.

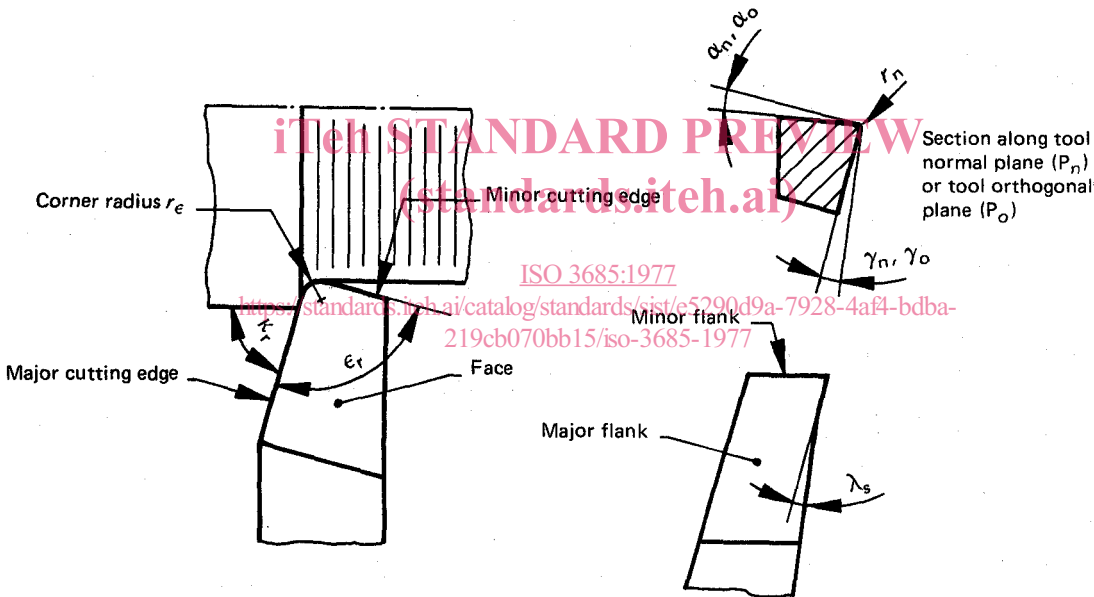


FIGURE 1 – Illustration of tool angles

TABLE 1 – Standard tool angles, in degrees

Cutting tool material	Rake <sup>1)</sup> $\gamma$	Clearance <sup>1)</sup> $\alpha$	Cutting edge inclination $\lambda_s$	Cutting edge angle $\kappa_r$	Included angle $\epsilon_r$
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  $\gamma$  and  $\alpha$  to denote the plane of measurement, i.e.  $\gamma_n$  or  $\gamma_o$  and  $\alpha_n$  or  $\alpha_o$ .



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  $r_n = 0,02$  to  $0,03$  mm;
- if  $r_e > 0,4$  mm, then  $r_n = 0,03$  to  $0,05$  mm.

For ceramic tools the condition of the cutting edge shall be reported. All other cutting tools shall be used with the normally sharp edge produced by the grinding or finishing operations indicated in 4.3.5.

#### 4.2.3 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 reported.

- 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 width and angles of any lands on the face or flank).

### 4.3 Standard conditions for the tool

#### 4.3.1 Tool type and size

A straight roughing tool shall be used.

The shank cross-section for toolholders shall be 25 mm × 25 mm and for solid high-speed steel tools 25 mm × 16 mm.

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.

#### 4.3.2 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  $5^\circ$ . (See figure 2.)

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

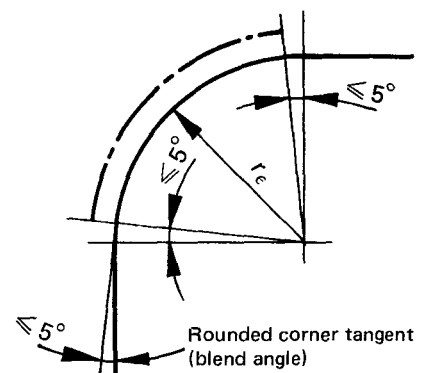


FIGURE 2 – Details of rounded corner

The tolerance on parallelism between the axis of the tool shank and both the tool reference plane  $P_r$  and the tool black plane  $P_p$  (see ISO 3002/1) 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 and side surfaces of the tool shank not in excess of  $\pm 0,4$  mm per 50 mm of infeed motion.

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

#### 4.3.3 Tool finish

The roughness  $R_a$  of the face and flank of the tool shall not exceed  $0,25 \mu\text{m}$  (measured according to ISO/R 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 10 X for visual defects such as chips or cracks. The defect shall be corrected if possible, otherwise the tool shall not be used.

#### 4.3.4 Toolholders for inserts

For cutting tests, toolholders shall meet the following conditions :

The geometry shall be as indicated in table 1.

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

The angle for locating the indexable insert in the toolholder shall be as specified in figure 3.

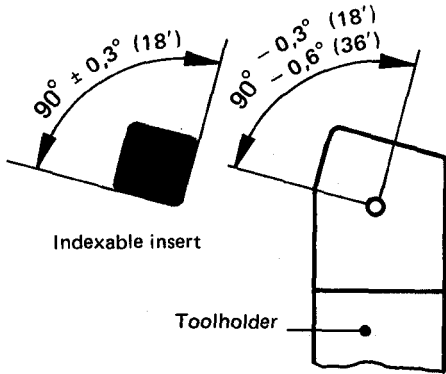


FIGURE 3 – Tolerances on squareness of insert and toolholder location

The toolholders shall be steel with a tensile strength not less than 1 200 N/mm<sup>2</sup> (1 200 MPa).

The flatness of the base of the toolholder shall be within 0,1 mm over the length and width of the toolholder.

The faces on the toolholder or the shim supporting the insert shall be flat to within 0,01 mm.

The underside of the indexable insert shall not project over the supporting face of the toolholder by more than 0,3 mm (see figure 4).

The chipbreaker height and chipbreaker distance and the method of clamping the insert shall be reported.

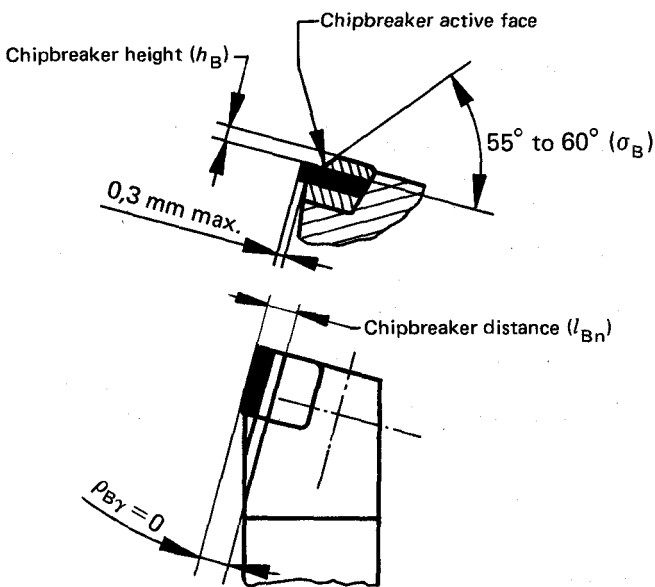


FIGURE 4 – Illustration of insert overhang and chipbreaker

#### 4.3.5 Tool grinding of high-speed steel

The sequence of operations for original grinding and regrinding prior to testing is given in annex B.

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 as indicated in figure 5. 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.

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

After regrinding, 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 regrinding, further grinding or cutting back shall be performed until the desired hardness is achieved.

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

#### 4.3.6 Carbide and ceramic inserts

These inserts shall be machined all over and, where grinding is employed, diamond shall be the grinding medium. These inserts shall not be reground.

#### 4.3.7 Chipbreaker

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

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

The chipbreaker angle ( $\rho_{B\gamma}$ ) shall be zero such that the line of intersection of the chipbreaker and the tool face is parallel to the straight portion of the major cutting edge. The chipbreaker wedge angle ( $\sigma_B$ ), i.e. the angle between the active face of the chipbreaker and the tool face shall be between 55 and 60 degrees.

The chipbreaker distance shall be chosen so that an acceptable chip form is achieved (see figure 4). The actual chipbreaker distance shall be reported.

NOTE – Particular attention shall be paid to the fact that the crater can be different when turning with or without a chipbreaker.

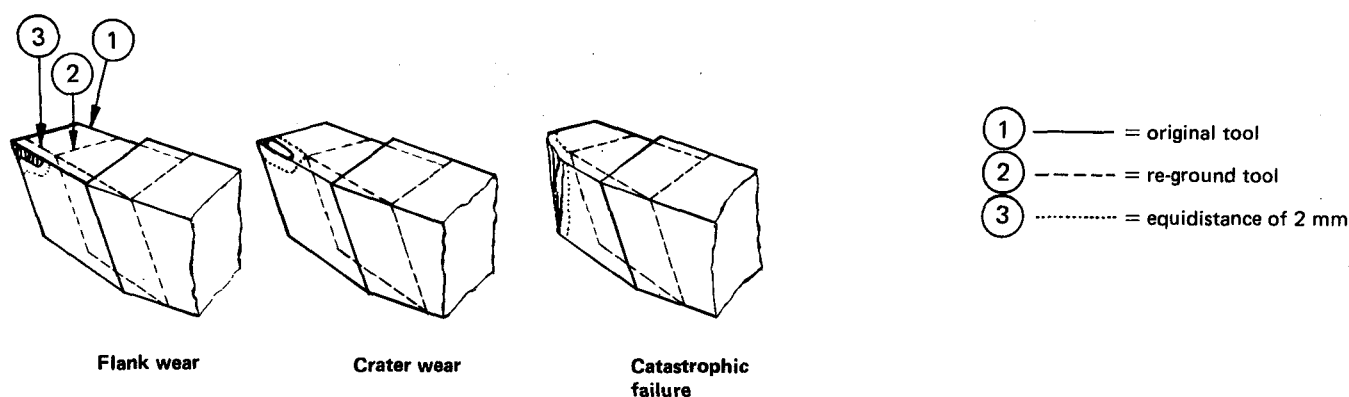


FIGURE 5 — Regrinding tool after testing

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### 5 CUTTING FLUID

#### 5.1 Reference cutting fluid

All cutting tests in which the cutting fluid is not the test variable shall be conducted either dry or using the reference cutting fluid specified below.

5.1.1 High-speed steel tools shall be used dry when catastrophic failure is desired as the tool-life criterion.

When flank wear is to be the tool-life criterion, testing shall be done with an aqueous solution containing 0,5 % triethanolamine and 0,2 % sodium nitrite ( $\text{NaNO}_2$ ) by mass.

5.1.2 Sintered carbide and ceramic tools shall be used without application of a cutting fluid. If circumstances require the use of a cutting fluid, the reference fluid indicated in 5.1.1 is preferred.

#### 5.2 Other cutting fluids

In all cases, where the cutting fluid is not the reference fluid, all known data shall be reported, in particular the diluent and the concentrations of materials present.

#### 5.3 Standard conditions for the cutting fluid

The flow rate of the cutting fluid shall be not 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 flow of cutting fluid shall be directed at the face of the cutting tool and completely surround the active part of the tool.

The orifice diameter, the flow rate, the reservoir temperature, the hardness of the water when used as a diluent and the pH value of the solution or emulsion should be recorded, if possible.

### 6 CUTTING CONDITIONS

#### 6.1 Standard cutting conditions

The cutting conditions for all tests in which feed  $f$ , depth of cut  $a$ , or corner radius  $r_e$  are not the prime test variables 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 $a$ , mm	1,0	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  $\pm \frac{3}{2}$  % (according to ISO 229).

The tolerance on depth of cut shall be 5 %.

The tolerance on corner radius is defined in 4.3.2.

6.2 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 <sup>1)</sup>
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.

6.3 Cutting speed

The cutting speed (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. In general, the cutting speeds shall be so chosen that the tool life at the highest speed is not less than 5 min.

When machining expensive materials, a shorter tool life may be chosen, but this shall be not 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 constant ratio which will result in an approximately double tool life. This is achieved by choosing the cutting speed from a geometrical series of preferred numbers as indicated in table 4.

To extend the table upwards or downwards, divide or multiply the given value by 10 or a power of 10. The values are taken from the series of preferred numbers (see ISO 3).

Where it is considered necessary for a wider range of cutting speeds to be chosen, however, the following series are recommended :

For cutting tests using high-speed steel, the R 20 series may be substituted for the R 40 series, and similarly for carbide tools, the R 10 series may be substituted for R 20.

Alternatively, a narrower speed range may be used if required.

TABLE 4 – Geometric series of preferred numbers for cutting speeds (m/min)

High-speed steel (R 40)	Carbide (R 20)	Ceramic (R 10)
1,00	1,00	1,00
1,06		
1,12	1,12	
1,18		
1,25	1,25	1,25
1,32		
1,40	1,40	
1,50		
1,60	1,60	1,60
1,70		
1,80	1,80	
1,90		
2,00	2,00	2,00
2,12		
2,24	2,24	
2,36		
2,50	2,50	2,50
2,65		
2,80	2,80	
3,00		
3,15	3,15	3,15
3,35		
3,55	3,55	
3,75		
4,00	4,00	4,00
4,25		
4,50	4,50	
4,75		
5,00	5,00	5,00
5,30		
5,60	5,60	
6,00		
6,30	6,30	6,30
6,70		
7,10	7,10	
7,50		
8,00	8,00	8,00
8,50		
9,00	9,00	
9,50		
10,00	10,00	10,00

7 TOOL-LIFE CRITERIA AND TOOL-WEAR MEASUREMENTS

7.1 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 below. The type and value of the criterion used shall be reported. If it is not clear which type of wear will predominate, it is possible to use either two criteria, resulting in two  $v-T$  curves, or a mixed criterion, resulting in a broken  $v-T$  curve, (see figure 7) (for example in a typical case of a feed of 0,4 mm/rev, tool life will be considered to be ended when either  $VB_B = 0,3$  mm or  $KT = 0,18$  mm is reached).

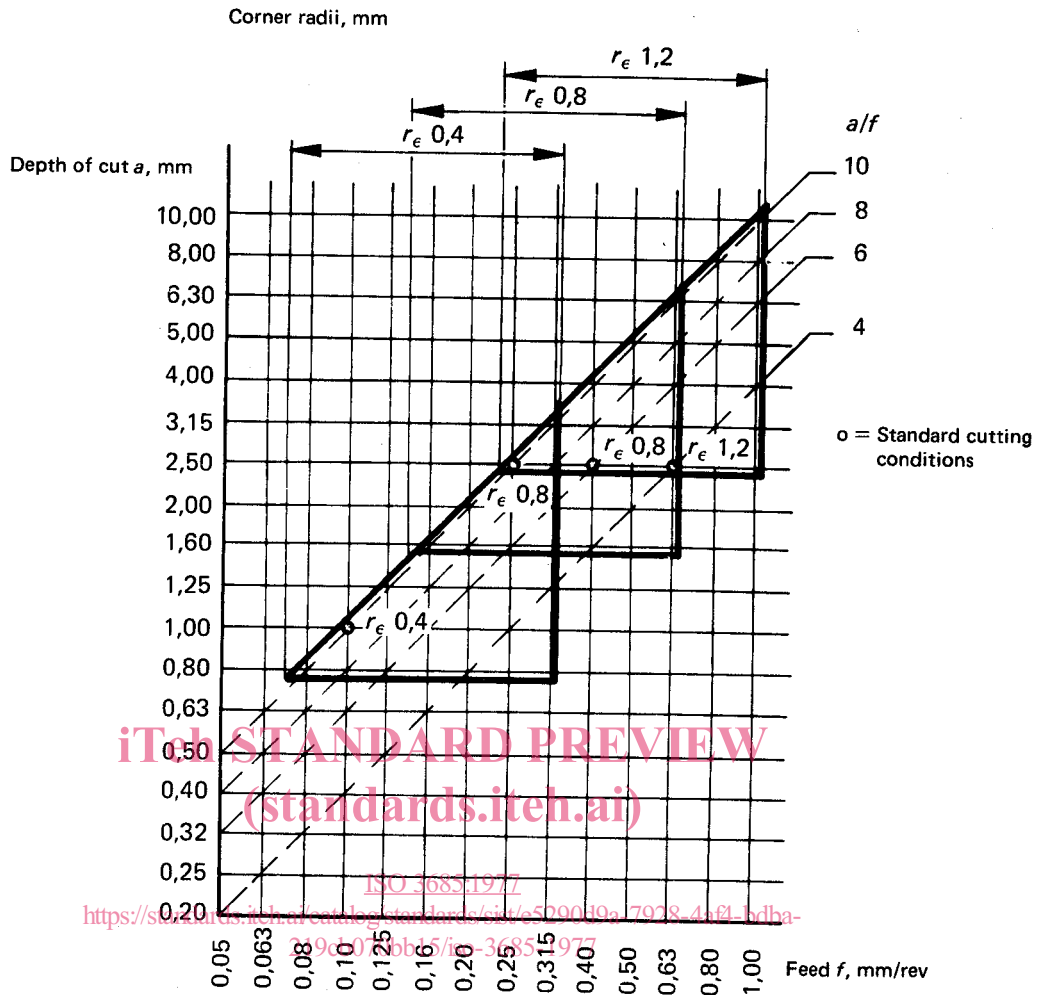


FIGURE 6 – Limits of cutting conditions

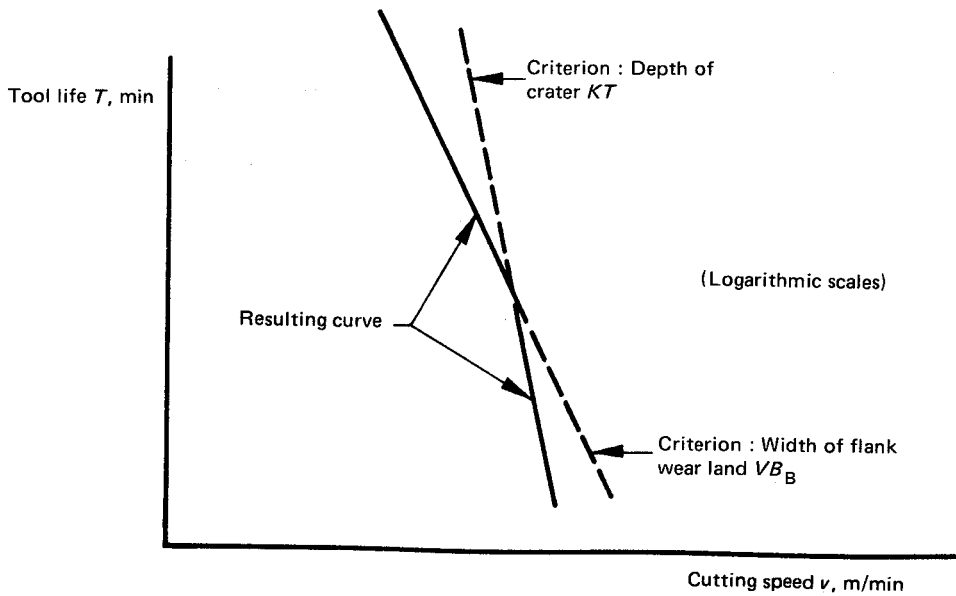


FIGURE 7 – Broken  $v$ - $T$  curve, combined flank and crater wear