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Tool life testing in milling —

Part 1 : Face milling

Essai de durée de vie des outils de fraisage —

Partie 1 : Surfaçage

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Foreword

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International Standard ISO 8668-1 was prepared by Technical Committee ISO/TC 29, *Small tools.*

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

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Tool life testing in milling —

Part 1 : Face milling

0 Introduction

Procedures and conditions for tool-life testing with single-point turning tools are the subject of ISO 3685. Successful application of ISO 3685 resulted in requests for similar documents relating to other commonly used cutting methods.

This part of ISO 8688 has been developed on the initiative of the International Institution for Production Engineering Research (CIRP) and applies to face milling operations with carbide tools, as illustrated in figure 1, which represent a major manufacturing activity.

The recommendations contained in this part of ISO 8688 are applicable in both laboratories and factories. They are intended to unify procedures in order to increase the reliability and comparability of test results when making comparison of cutting tools, work materials, cutting parameters or cutting fluids. In order to achieve as far as possible 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 establishing recommendable 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 part of ISO 8688 have been designed for face milling tests using steel and cast iron workpieces of normal microstructure. However, with suitable modifications, this part of ISO 8688 can be applied to face milling tests on, for example, other work materials or with cutting tools developed for specific applications.

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

NOTE — This part of ISO 8688 does not constitute acceptance tests and should not be used as such.

1 Scope and field of application

This part of ISO 8688 specifies recommended procedures for tool-life testing with cemented carbide tools used for face milling of steel and cast iron workpieces. It can be applied to laboratory as well as to production practice.

The cutting conditions in face milling may be considered under two categories as follows :

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 part of ISO 8688 considers only those recommendations concerned with testing which results predominantly in tool wear.

Testing for the second group of conditions given above is currently under study.

This part of ISO 8688 establishes specifications for the following factors of tool-life testing with face milling tools in accordance with figure 1: workpiece, tool, cutting fluid, cutting conditions, equipment, assessment of tool deterioration and tool life, test procedures, recording, evaluation and presentation of results.

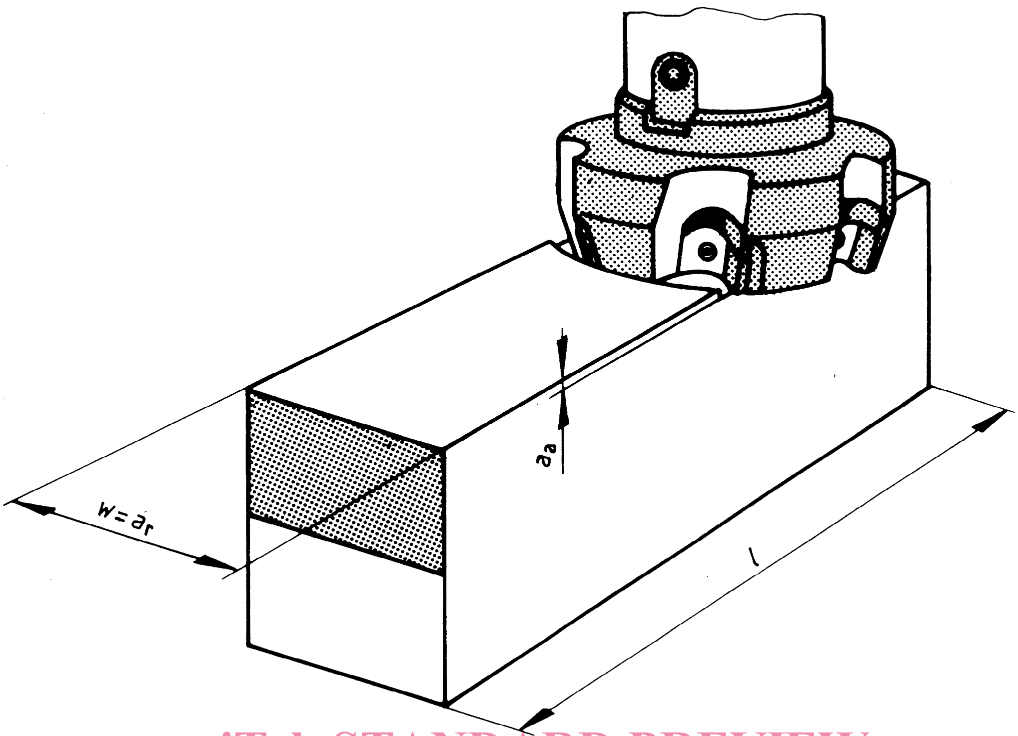


Figure 1 — Face milling — Milling operation

2 References

ISO/R 185, *Classification of grey cast iron.*

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

ISO 513, *Application of carbides for machining by chip removal — Designation of the main groups of chip removal and groups of application.*

ISO/R 683-3, *Heat-treated steels, alloy steels and free-cutting steels — Part 3 : Wrought quenched and tempered unalloyed steels with controlled sulphur content.*

ISO 1701, *Test conditions for milling machines with table of variable height, with horizontal or vertical spindle — Testing of the accuracy.*

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

ISO 3002-1, *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 3365, *Indexable hardmetal (carbide) inserts with wiper edges, without fixing hole — Dimensions.*

ISO 3685, *Tool-life testing with single-point turning tools.*

ISO 6462, *Face milling cutters with indexable inserts — Dimensions.*

3 Workpiece

3.1 Work material

In principle, testing bodies are free to select the work 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, steel C45 according to ISO/R 683-3 or cast iron grade 25 according to ISO/R 185, is recommended. More detailed specifications of these materials are given in annex A.

Within the specification, materials may vary with a resulting affect on machinability. To minimize such problems, the provision of a work material in compliance with stricter specifications shall be discussed with the supplier.

Information concerning the work material such as grade, chemical composition, physical properties, microstructure, complete details of the processing route of the work material (e.g. hot rolled, forged, cast or cold drawn) and any heat treatment should be reported in the test report (see 9.3.1 and annex A).

The hardness of the prepared workpiece shall be determined on one end of each test piece over the testing zone on the cross-section (see 9.3.1). For the recommended workpiece sections, the hardness indentations shall be placed along the centre-line of the zone parallel to the longest edge. The minimum number of test points shall be five; one on the centre, one near each edge and one on either side of the centre point between the centre and the edge points (see figure 2).

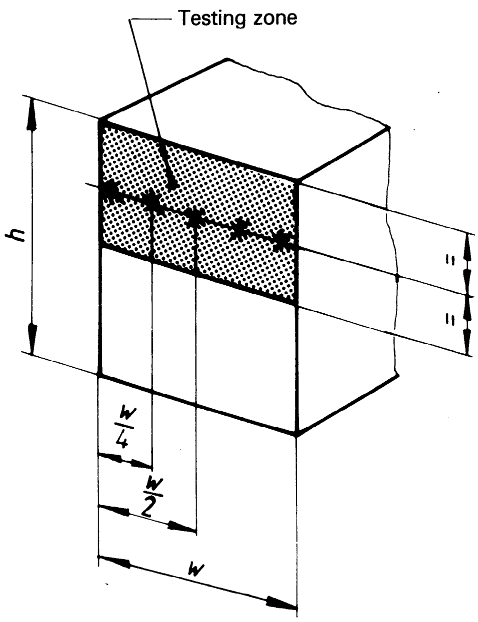


Figure 2 — Hardness testing

For workpieces which are cut from larger billets or for which hardness variation might be expected to be significant, additional hardness measurements should be taken to ascertain that the hardness values fall within the prescribed limits. The location of such measurement points and the method of measuring should be reported in the test report.

The deviation in hardness within one batch of material should be as small as possible. A realistic value for the reference materials given in annex A and similar materials is ± 5 % of the arithmetic mean value.

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 materials to cover their needs.

3.2 Dimensions

3.2.1 The recommended workpiece for face milling (see 9.3.1) shall be a bar or billet of rectangular cross-section with a width of 0,6 times the cutter diameter (75 mm for D = 125 mm), see 6.3, and a minimum length of 3 times the cutter diameter (375 mm for D = 125 mm).

The maximum and minimum heights of a workpiece may be determined according to the number of tests to be made and the need for uniform material properties. These dimensions should be restricted to ensure adequate stability during machining. The actual dimensions shall be reported.

3.2.2 For cast material, the dimensions of the parallelepiped shall be chosen to obtain the required metallographic structure.

4 Tool : Cutter

In principle, testing bodies are free to select the cutter according to their own interests. However, in order to increase the comparability of results between testing bodies, the use of a face milling cutter 125 mm in diameter and with 6 equispaced inserts is recommended. Any deviation from the recommended cutter should be reported.

4.1 Dimensions and tolerances

The dimensions of the recommended cutter shall be in accordance with ISO 6462. The main dimensions of the recommended cutter body are given in figure 3.

Although testing bodies are free to select inserts according to their own interests, it is recommended that indexable carbide inserts mounted in the recommended body are SPAN1203 EDR according to ISO 3365. The dimensions of the recommended inserts are given in figure 4. The deviation between individual inserts used in the same testing sequence should be kept to a minimum (see also 4.2).

The tolerances of the recommended tool complete with recommended inserts are given in figure 3 (see also 4.5 concerning the cutting edge runout).

4.2 Tool geometry

It is recommended that all cutting tests in which the tool geometry is not the test variable be conducted using the cutting tool geometry shown in figures 3 and 4.

The cutting tool angular geometry designations are in accordance with ISO 3002-1.

The deviation between the geometry of individual inserts used in the same testing sequence should be kept to a minimum.

The provision of tools with closer geometrical tolerances should be discussed with the supplier.

4.3 Cutting edge and insert surface

The form and method of preparing the cutting edges of the insert may significantly affect the results. It is therefore important that the geometric features are accurately measured and recorded together with the configuration and direction of grinding marks.

Where cutting edge preparation is not a test variable, the face of the insert to be used in testing should have a land of 0,2 ± 0,05 mm width, which gives a negative normal rake of 20° ± 2° (measured on the insert). The wiper edge of the insert, which in use will be parallel to the machined surface, should be as sharp as possible and there should not be a land on the tool face associated with this wiper edge (see 9.3.2).

Dimensions in millimetres

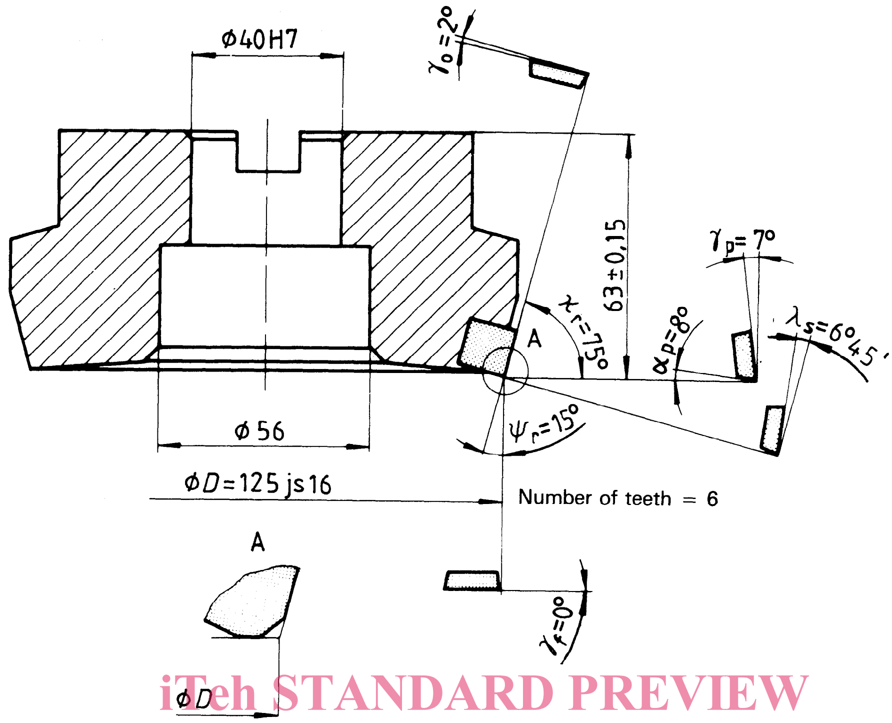


Figure 3 — Face milling cutter with hardmetal indexable inserts
(see ISO 6462, style B, ϕ D = 125 mm)

Dimensions in millimetres

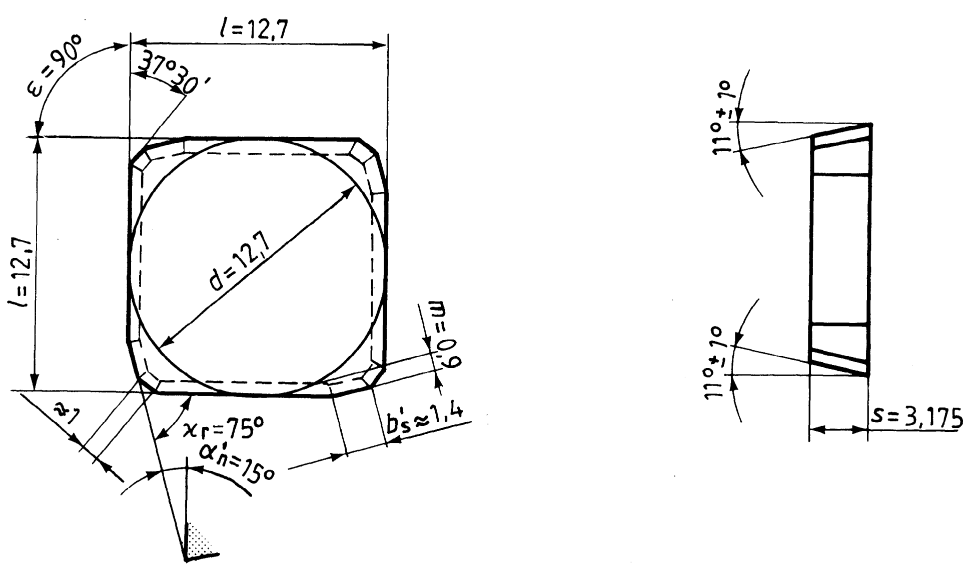


Figure 4 — Square indexable hardmetal inserts
(see ISO 3365, designation SPAN1203 EDR)

The land, if any, on the tool face associated with the major cutting edge may be parallel to the cutting edge or tapered, i.e. with a width increasing with the distance from the tool corner. If the land is tapered, the maximum width within the active part of the major cutting edge should not exceed 0,2 mm and the amount of taper should be reported. The grinding direction used for producing the land should be reported.

The surface roughness R_a of the insert surfaces should not exceed 0,25 µm (measured in accordance with ISO 468).

The deviation in flatness of the supporting surface of an insert should not exceed 0,004 mm.

4.4 Tool material

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 interests. However, in order to increase the comparability of results between testing bodies, the use of one of the following reference tool materials is recommended : uncoated hardmetal grade for group of application P25 for milling steel and K10 for milling cast iron in accordance with ISO 513. In addition, the use of hardmetal from a reference stock is recommended in order to cover the need for comparison of results over a sufficiently long period of time. It is recommended that a sufficient stock of tool material be kept.

The provision of a reference tool material of stricter specifications for machining tests should be discussed with the supplier in order to guarantee as much uniformity of the cutting edges as is practical.

Since hardmetal grades for the same ISO group of application vary between producers and to a lesser extent between batches, the performance of newly bought inserts should be calibrated against that of inserts for which the characteristics are known.

If the tool material is the test variable, the material classification and as many characteristics as possible shall be reported.

The presence of any coating or surface treatment shall be reported in detail.

4.5 Mounting of the tool

The cutter used for face milling tests shall be mounted directly in the machine spindle. The cutter and spindle mounting surfaces shall be cleaned and free from all burrs. The cutter shall be securely fastened to the spindle and the runout of the cutter shall be carefully checked at the cutting edges.

The maximum values of runout shall be as follows :

— radial runout : 100 µm

— axial runout : 50 µm

Between consecutive cutting edges the values of radial runout should not exceed 50 µm. The actual runout for each cutting edge considered should be measured and recorded.

The values of runout specified above can be achieved using standard inserts and cutters mounted on conventional machines. However, since runout of cutting edges may influence the wear of individual edges, especially for testing conditions using the two lower values of recommended feed per tooth (see table 1), efforts should be made to reduce the actual values of runout as much as possible by selective mounting of the inserts in the body.

5 Cutting fluid

Normally, tests should be carried out without the application of a cutting fluid. However, if circumstances require the use of a cutting fluid, the fluid used should be clearly specified. This specification should include, for example, the trade-mark or composition of the active elements, the actual concentration, the hardness of the water (when used as a diluent), or the pH value of the solution or emulsion.

In these cases, the flow of cutting fluid 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, the flow-rate and the reservoir temperature should be reported.

6 Cutting conditions

6.1 Recommended cutting conditions

The cutting conditions for all tests in which the feed per tooth f_z, the axial depth of cut a_a or the radial depth of cut a_r are not the prime test variables, shall be selected from table 1.

Table 1 — Recommended cutting conditions

Cutting condition		I	II	III	IV
Axial depth of cut a_a	mm	2,5	2,5	2,5	4
Radial depth of cut[1] a_r	mm	0,6 D[2]			
Feed f_z	mm/tooth	0,125	0,2	0,315	0,5

1) In this particular case, the depth is equal to the width of the workpiece.

2) D = diameter of the milling cutter.

The tolerance on the axial depth of cut and the radial depth of cut shall be ± 5 %.

6.2 Other cutting conditions

In those cases where the indicated feed values are not practical, other values as close as possible to those indicated may be used. In such cases the axial depth of cut should be

either $a_a = 2{,}5$ mm

or $a_a = 8f_z$

whichever is the larger.

In cases where the feed, the depth of cut or the width of workpiece are the test variables, all data shall be clearly specified. It should be noted, however, that the cutting conditions shall be chosen to be compatible with the cutting tool, the machine tool, the clamping device, etc. in order to obtain reliable test data.

It should be noted that feeds of less than 0,1 mm per tooth or greater than 0,8 mm per tooth and depths of cut smaller than 2 mm or greater than 8 mm may result in modes of tool deterioration other than those recommended as criteria in this part of ISO 8688 and should therefore not be used.

6.3 Location of the cutter

For face milling tests, the cutter axis should preferably travel along the centre-line of the workpiece. In order to avoid the danger of edge fracture as the insert exits from the workpiece, it is permitted to alter the cutter position in relation to the centre-line of the workpiece in the direction away from the exit edge of the workpiece. If it is desired to locate the axis of the cutter to give a predominantly down-mill condition or a predominantly up-mill condition, the location of the cutter axis with respect to the workpiece centre-line should be recorded. However, it should be recognized that certain conditions of predominantly up-milling may result in adverse insert exit from the workpiece with significant cutting edge fracture and associated short tool life (see clause 1, second condition). The actual location of the cutter relative to the workpiece should be reported (see annex C).

6.4 Cutting speed

The cutting speed is the peripheral speed of the cutting tool determined at the nominal diameter (see figure 3). The average cutting speed should be measured with the tool under load at cutting conditions representative of the test conditions to take account of any losses resulting from the cutting action.

It is suggested that the desired cutting speed be established from a preliminary test (see 9.2). An appropriate cutting speed can be found in machining data handbooks. For the reference workpiece materials and the reference cutting tool this speed will be approximately 180 m/min.

A relatively small change in cutting speed will significantly affect tool life, e.g. a change of ± 10 % may result in an approximate doubling or halving of tool life.

7 Tool deterioration and tool-life criteria

7.1 Introduction

In practical workshop situations the time at which a tool ceases to produce workpieces of the desired size or 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 the useful tool life. However, the reasons for which tools may be considered to have reached the end of their useful tool life will be different in each case depending on the cutting conditions, etc.

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

In order to produce test values which are reliable and comparable with test values produced from a variety of sources, it is necessary to identify and classify tool deterioration phenomena in accordance with 7.3 and to recommend those, together with their limiting values, which should be used to determine the end of useful tool life in accordance with 7.4.

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

This part of ISO 8688 recommends that tool deterioration in the form of wear be used for determining tool life. Since other modes of tool deterioration may determine the end of useful tool life, the definitions given in 7.2 take into account cracks, chipping and deformation.

Each type of deterioration will progress or occur in a variety of ways depending on the cutting conditions. To aid both test reporting and the interpretation of test reports, a coded classification system is recommended to give a detailed description of the form of deterioration (see 7.3).

Many types of tool deterioration phenomena are listed in this clause and in table 2. Some of them may occur only occasionally under the testing conditions recommended in this part of ISO 8688.

7.2 Definitions

For the purposes of this part of ISO 8688, the following definitions apply.

7.2.1 tool deterioration : All changes in a cutting part of a tool caused by the cutting process.

Three major classes of tool deterioration are distinguished, i.e. tool wear, brittle fracture and plastic deformation.

7.2.1.1 tool wear : Change in shape of the cutting part of a tool from its original shape, resulting from the progressive loss of tool material during cutting.

7.2.1.2 brittle fracture : Occurrence of cracks in the cutting part of a tool followed by the loss of small fragments of tool material, resulting from crack initiation during cutting.

7.2.1.3 plastic deformation : Distortion of the cutting part of a tool from its original shape without initial loss of the tool material during cutting (see 7.3.7).

7.2.2 tool deterioration measure : Quantity used to express the magnitude of a certain aspect of tool deterioration by a numerical value.

Examples :

— The width of a uniform flank wear land VB 1 (see 7.3.2.1).

— The number of comb cracks CR 1 (see 7.3.5.1 and 7.5.4).

7.2.3 tool-life criterion : Predetermined value of a specified tool deterioration measure or the occurrence of a specified phenomenon.

Examples :

— The width of a uniform flank wear land VB 1 = 0,35 mm (see 7.4.1).

— Cracking becomes visible.

7.2.4 tool life T_c : Total cutting time of the tool required to reach a specified tool-life criterion.

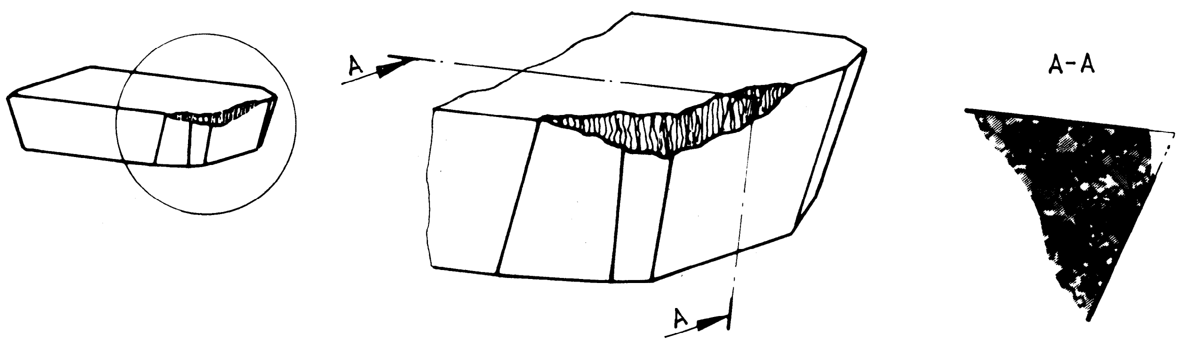
7.3 Tool deterioration phenomena

7.3.1 Coding system for tool deterioration and tool wear

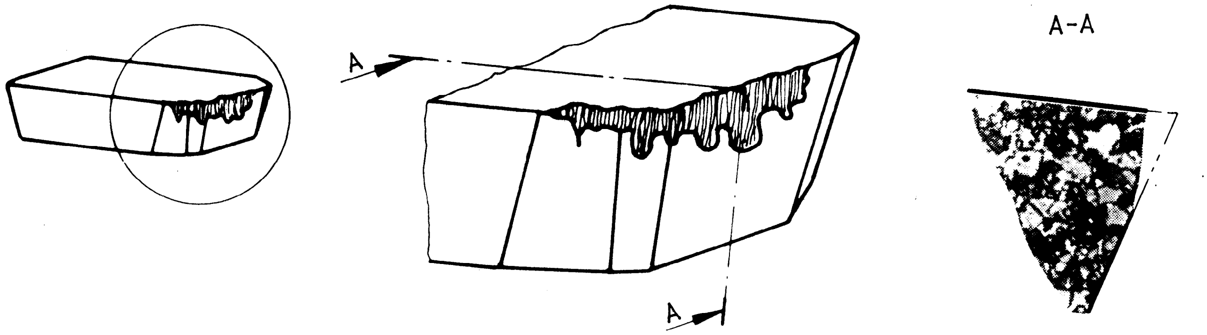
In practice, different types of deterioration will occur together during machining. It is desirable, therefore, to be able to give information concerning deterioration in a meaningful manner. Table 2 gives recommendations for and illustrations of a coding system to describe deterioration phenomena observed at each stage of measurement during testing, thus reducing the risk of misinterpretation of lengthy written descriptions and minimizing the number of illustrations required in a test report.

7.3.2 flank wear (VB) : Loss of tool material from the tool flanks during cutting which results in the progressive development of a flank wear land.

7.3.2.1 uniform flank wear (VB 1) : Wear land which is normally of constant width and extends over those portions of the tool flanks adjoining the entire length of the active cutting edge.



7.3.2.2 non-uniform flank wear (VB 2) : Wear land which has an irregular width and for which the profile generated by the intersection of the wear land and the original flank varies at each position of measurement.

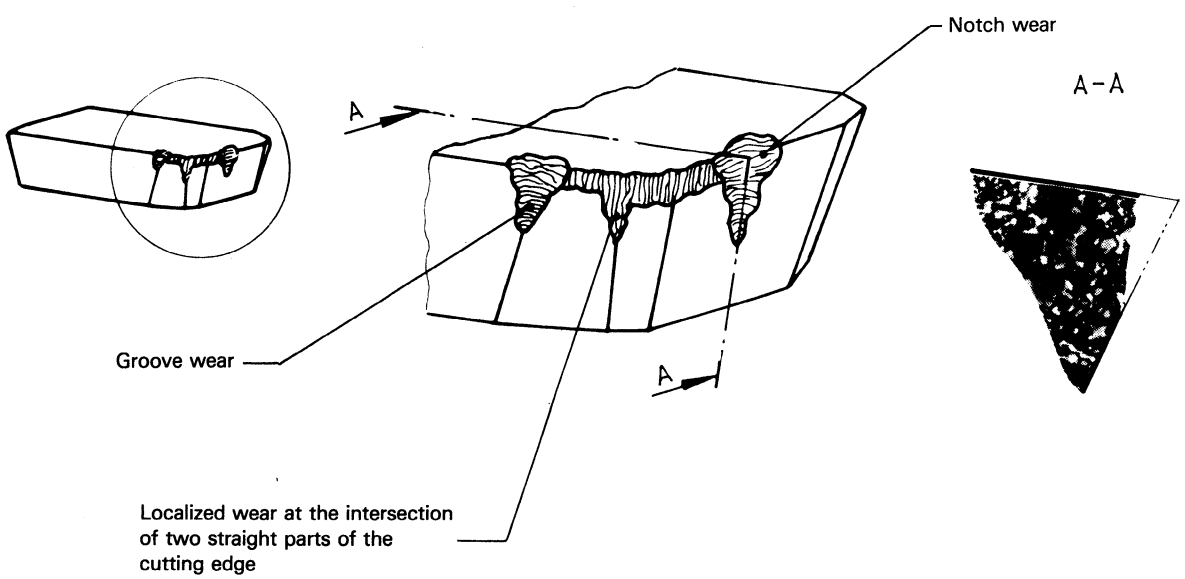


7.3.2.3 localized flank wear (VB 3) : Exaggerated form of flank wear which develops at localized points on the flanks (see figure 5, points P_1 to P_2 and P_f or zone A_1).

One special form of this type of flank wear is **notch wear** which develops on that part of the major flank adjacent to the work surface during cutting.

Another special form of this type of flank wear is **groove wear** which develops on that part of the minor flank adjacent to the machined surface during cutting.

A third special form of localized flank wear occurs sometimes at the point of intersection of two straight parts of the cutting edge.



7.3.3 face wear (KT) : Gradual loss of tool material from the tool face during cutting.