AN AMERICAN NATIONAL STANDARD

Tool Life Testing With Single-Point Turning Tools

ANSI/ASME B94.55M - 1985

[REVISION OF ANSI B94.34-1946 (R1971) AND B94.36-1956 (R1971)]

REAFFIRMED 1995

FOR CURRENT COMMITTEE PERSONNEL
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FOREWORD

(This Foreword is not part of ANSI/ASME B94.55M-1985.)

This Standard is a slightly modified version of ISO 3685-1977, Tool Life Testing With Single-Point Turning Tools. Only several small changes have been made, such as replacing referenced ISO materials specifications with ASTM and ANSI specifications. It was felt that U.S. users of the Standard would be more familiar with the ASTM and ANSI specifications and have easier access to them.

Following approval by the B94 Standards Committee and ASME, this Standard was submitted to ANSI and approved as an American National Standard on November 27, 1985.

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AN AMERICAN NATIONAL STANDARD

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 Standard has been so framed that it can be directly applied to industrial testing and in research. For research purposes, however, this 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 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 Standard, this shall be reported in detail.

NOTE: This Standard is not an acceptable test and it is not advisable to use it as such.

1 SCOPE AND FIELD OF APPLICATION

This 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 Appendix A.

2 REFERENCES

The latest issues of the following documents form a part of this Standard to the extent specified herein.

American Society for Testing and Materials

ASTM A 159-83, Standard Specification for Automotive Gray Iron Castings (Grade G 3000)
ASTM A 576-81, Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality (Grade G 10450)
ASTM E 18-79, Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
ASTM E 92-82, Standard Test Method for Vickers Hardness of Metallic Materials
ASTM E 112-82, Standard Methods for Determining Average Grain Size

American National Standards

ANSI B46.1-1978, Surface Texture
ANSI B74.3-1982, Markings for Identifying Grinding Wheels and Other Bonded Abrasives
ANSI B94.4-1976, Identification System for Indexable Inserts for Cutting Tools
ANSI B94.50-1975, Basic Nomenclature and Definitions for Single-Point Cutting Tools

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 paras. 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 corresponding nominally to ASTM 1045 (A 576-81) but of the following controlled composition.

C%	Si%	Mn%	S%	P%
0.42 to 0.50	0.15 to 0.40	0.50 to 0.80	0.02 to 0.035	0.035 max.

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 aluminum and the minimum aluminum 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 converters	0.003 to 0.006
Arc, single slag	0.004 to 0.008

It will be necessary to analyze the steel for nitrogen. The steel should be purchased to ASTM A 576-81 specifications, but special quality bars meeting the above criteria should be specified. The limits of the elements and deoxidation practice shall be discussed with the steelmaker 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 correspond nominally to ASTM A 48, Class 25 (ASTM A 159-81), 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.

3.2 Standard Conditions for the Workpiece

All mill scale or casting skin shall be removed by cleanup 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 cleanup tool prior to testing in order to reduce as much as possible the residual subsurface 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.

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×.

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 center, special care shall be taken to prevent any bending loads on the workpiece.

A center hole of 6.3 mm diameter with 120 deg. 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 paras. 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 preground toolbits shall be as follows.

(a) 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).

(b) Preheating. Preheat at 850 °C. When desired, a prior preheat at 650 °C is permitted.

(c) 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.

(d) Quenching. The toolbits shall be quenched in oil or in a salt bath followed by air cooling.

(e) 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 ASTM E 18-79 and ASTM E 92-82.

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 ASTM E 112-82. The actual value shall be recorded.

4.1.2 Sintered Carbide. The use of sintered carbide from "tool material banks"[1] is recommended. If this is not possible, the carbide grades to be used shall belong to USA application groups C-7 or C-6 for machining steel and C-3 or C-2 for machining cast iron.

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

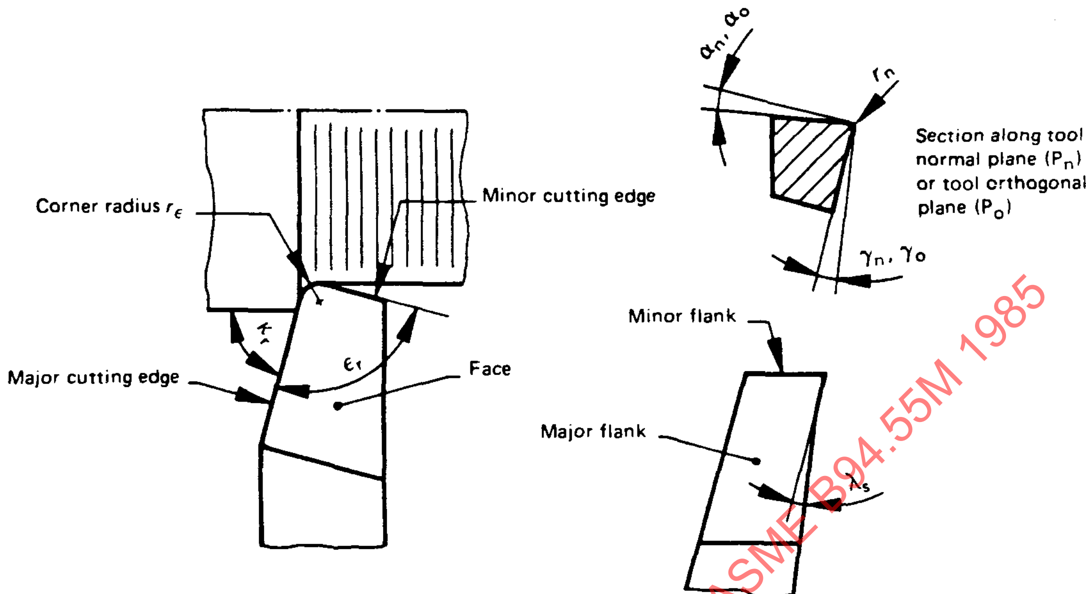


FIG. 1 TOOL ANGLES

TABLE 1
STANDARD TOOL ANGLES, deg.

Cutting Tool Material	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

NOTE:
(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.

Since carbide grades of the same application group vary between producers 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 ANSI B94.50-1975.

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.

The tool shall be set on the machine correctly. This is accomplished by setting the corner on center 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 $r_\epsilon = 0.4$ mm, then $r_n = 0.02$ to 0.03 mm;
if $r_\epsilon > 0.4$ 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 para. 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:

(a) 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);

(b) 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).

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 ±0.5 deg. (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 deg. (See Fig. 2.)

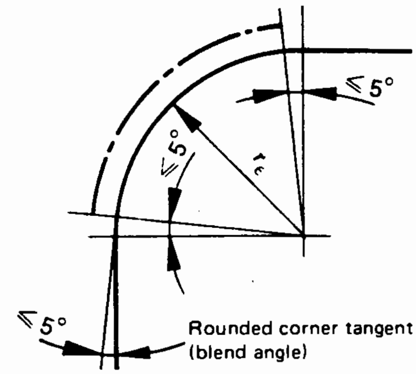


FIG. 2 DETAILS OF ROUNDED CORNER

The tolerance for the corner radius (r_ϵ) shall be $\pm 0.1 \times r_\epsilon$.

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 ANSI B94.50-1975) shall be ±0.5 deg. In practice, this requirement is met when the corner is on center within ±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 ±0.4 mm per 50 mm of infeed motion.

The tolerances of sintered carbide and ceramic inserts shall correspond to ANSI B94.4-1976, 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 μm (measured according to ANSI B46.1-1978).

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× 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.

(a) The geometry shall be as indicated in Table 1.

(b) The tolerance on the angles for toolholder plus inserts shall be ±0.5 deg. (30′) and for the toolholder alone ±0.2 deg. (12′).

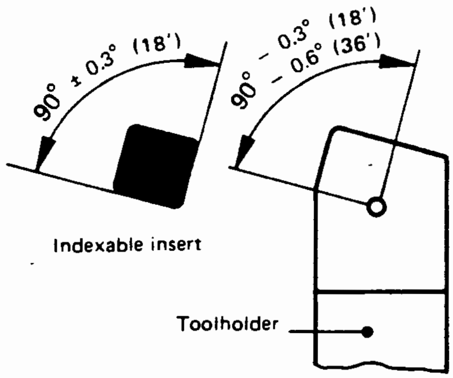


FIG. 3 TOLERANCES ON SQUARENESS OF INSERT AND TOOLHOLDER LOCATION

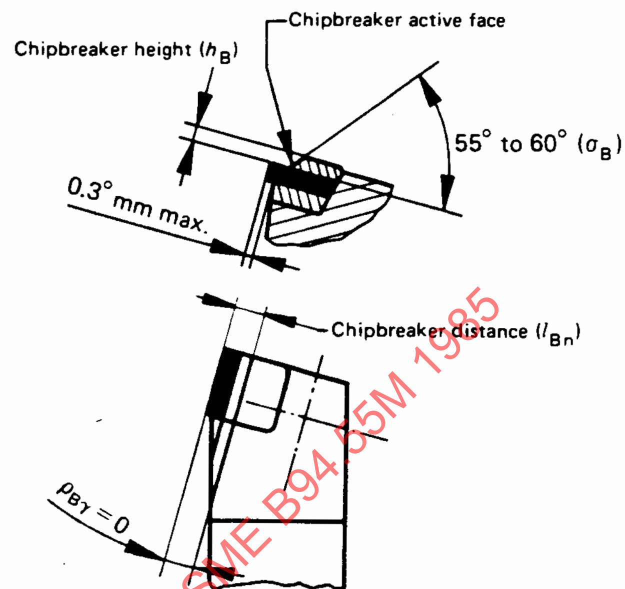


FIG. 4 INSERT OVERHANG AND CHIPBREAKER

(c) The angle for locating the indexable insert in the toolholder shall be as specified in Fig. 3.

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

(e) The flatness of the base of the toolholder shall be within 0.1 mm over the length and width of the toolholder.

(f) The faces on the toolholder or the shim supporting the insert shall be flat to within 0.01 mm.

(g) The underside of the indexable insert shall not project over the supporting face of the toolholder by more than 0.3 mm (see Fig. 4).

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

4.3.5 Tool Grinding of High-Speed Steel. The sequence of operations for original grinding and regrinding prior to testing is given in Appendix B.

The profile of the tool shall be restored after testing as shown in Figs. 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 Fig. 5. The tool geometry has to be maintained as specified in Figs. 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 overheating, especially when the grinding machine does not permit a perfect control of depth setting and feed. Overheating is usually followed by oxidation colors but when colors are not obvious, overheating 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

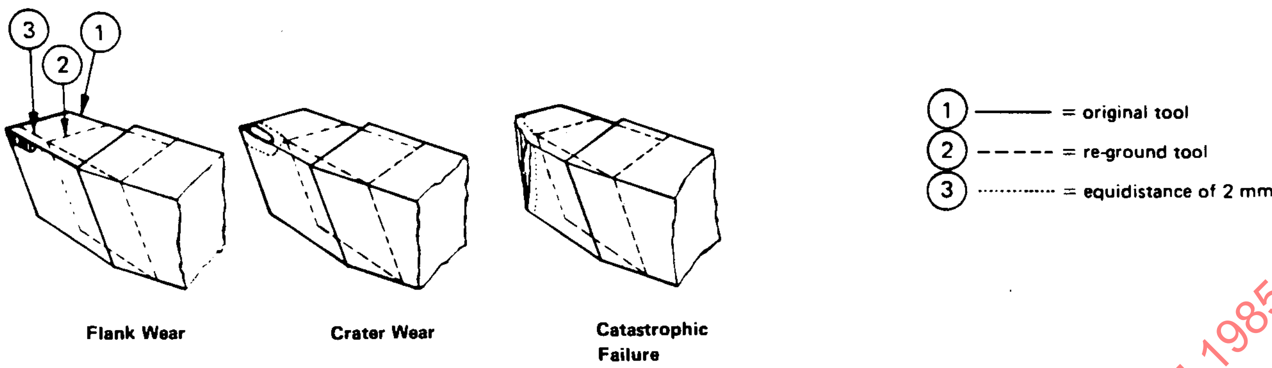


FIG. 5 REGRINDING TOOL AFTER TESTING

face is parallel to the straight portion of the major cutting edge. The chipbreaker wedge angle (σ_B), i.e., the angle between the active face of the chipbreaker and the tool face, shall be between 55 and 60 deg.

The chipbreaker distance shall be chosen so that an acceptable chip form is achieved (see Fig. 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.

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 ($NaNO_2$) 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 para. 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.

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_ϵ, mm	0.4	0.8	0.8	1.2

5.3 Standard Conditions for the Cutting Fluid

The flow rate of the cutting fluid shall be not less than 3L/min, or 0.1L/min for each cubic centimeter 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_ϵ are not the prime test variables shall be one or more of the combinations listed in Table 2.

The tolerance on feed shall be $^{+3}_{-2}$ %.

The tolerance on depth of cut shall be 5%.

The tolerance on corner radius is defined in para. 4.3.2.

TABLE 3
LIMITS OF OTHER CUTTING CONDITIONS

Minimum depth of cut	2 times corner radius [Note (1)]
Maximum depth of cut	10 times feed
Maximum feed	0.8 times corner radius

NOTE:
(1) A smaller depth of cut may make measurements of tool wear more difficult and less accurate.

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 Fig. 6. The limits of the triangular areas are defined in Table 3.

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.

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

TABLE 4
GEOMETRIC SERIES OF PREFERRED NUMBERS FOR CUTTING SPEEDS (m/min)

High-Speed Steel (R40)	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

(a) 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.

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

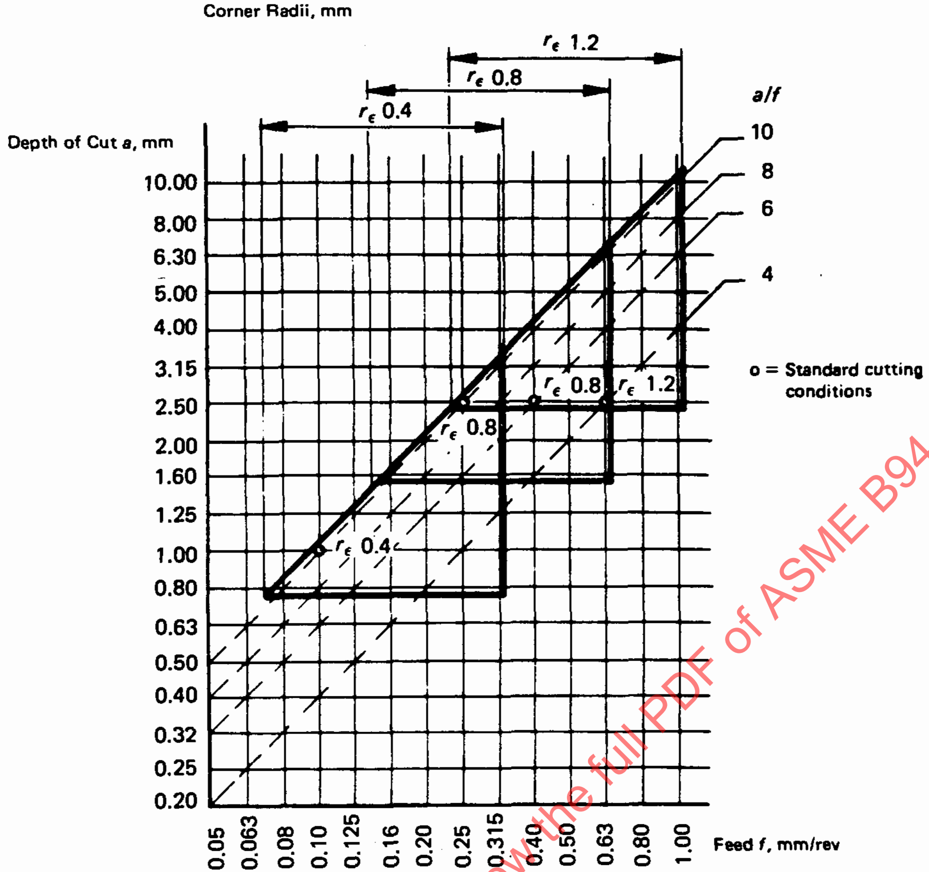


FIG. 6 LIMITS OF CUTTING CONDITIONS

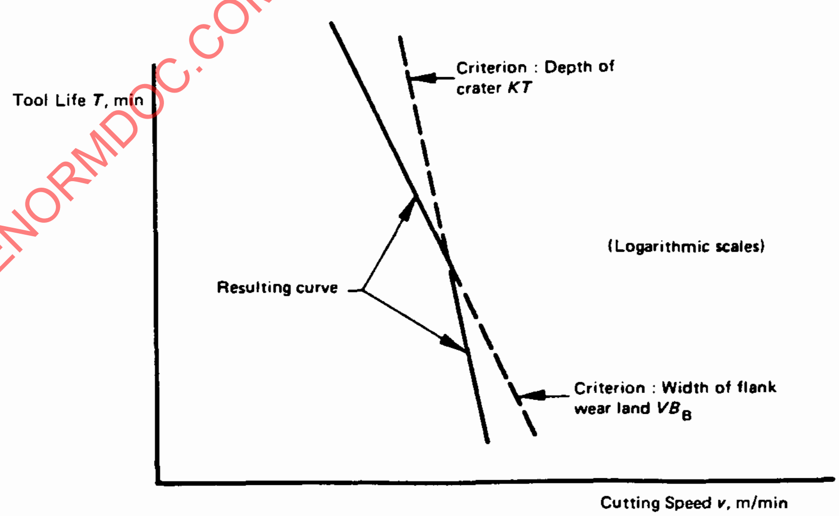


FIG. 7 BROKEN *v-T* CURVE, COMBINED FLANK AND CRATER WEAR

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 Fig. 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.

7.1.1 Common Criteria for High-Speed Steel Tools. (See Fig. 8.) The criteria most commonly used for high-speed steel tools are as follows:

(a) catastrophic failure;

(b) the average width of the flank wear land VB_B = 0.3 mm, if the flank wear land is considered to be regularly worn in Zone B;

(c) the maximum width of the flank wear land VB_B max. = 0.6 mm, if the flank wear is irregularly worn, scratched, chipped, or badly grooved in Zone B.

7.1.2 Common Criteria for Sintered Carbide Tools. (See Fig. 8.) The criteria most commonly used for sintered carbide tools are as follows:

(a) the average width of the flank wear land VB_B = 0.3 mm, if the flank wear land is considered to be regularly worn in Zone B;

(b) the maximum width of the flank wear land VB_B max. = 0.6 mm, if the flank wear land is not regularly worn in Zone B;

(c) the depth of the crater KT given, in millimeters, by the formula

$$KT = 0.06 + 0.3f$$

where f is the feed in millimeters per revolution. This leads to the following values of KT for the feeds specified in the recommendation where KT applies as a criterion.

Feed f, mm/rev	0.25	0.4	0.63
Crater depth KT, mm	0.14	0.18	0.25

7.1.3 Common Criteria for Ceramic Tools. (See Fig. 8.) The criteria most commonly used for ceramic tools are as follows:

(a) the average width of the flank wear land VB_B = 0.3 mm, if the flank wear land is considered to be regularly worn in Zone B;

(b) the maximum width of the flank wear land VB_B max. = 0.6 mm, if the flank wear land is not regularly worn in Zone B;

(c) catastrophic failure.

7.1.4 Common Criterion for Finish Turning. Surface roughness is a common criterion for finish turning and the following R_a values, according to ANSI B46.1-1978, are preferred:

$$0.4 - 0.8 - 1.6 - 3.2 - 6.3 - 12.5\,\mu m$$

7.1.5 Other Criteria. The criteria specified in para. 7.1 are usually sufficient when turning steel and cast iron.

The reasons for the selection and choice of other criteria for special cases are discussed in Appendix C.

7.2 Tool Wear Measurements

Particles adhering to the flank directly under the wear land can give the appearance of a larger width of the wear land. Also, a deposit in the crater results in lower values of the crater depth. Loose material shall be removed carefully but chemical etchants shall not be used except at the end of the test.

For the purpose of the wear measurements, the major cutting edge is considered to be divided into the following three zones (as shown in Fig. 8).

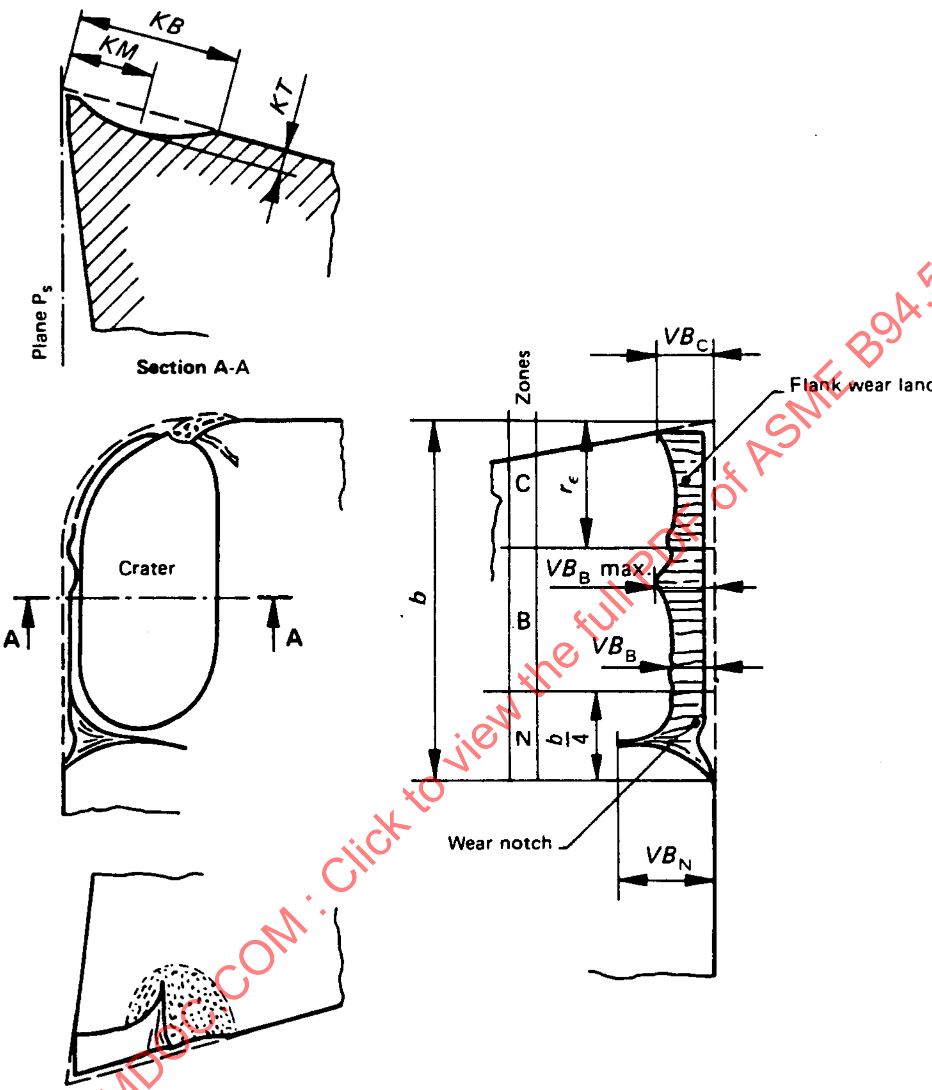
(a) Zone C is the curved part of the cutting edge at the tool corner.

(b) Zone N is the quarter of the worn cutting edge length b farthest away from the tool corner.

(c) Zone B is the remaining straight part of the cutting edge between Zone C and Zone N.

The width of the flank wear land VB_B shall be measured within Zone B in the tool cutting edge plane P_s [see footnote (2)] perpendicular to the major cutting edge. The width of the flank wear land shall be measured from the position of the original major cutting edge.

[2] The tool cutting edge plane P_s is the plane containing the major cutting edge and the direction of primary motion.



KB = crater width
KM = crater center distance
KT = crater depth
(See para. C.5, Appendix C.)

FIG. 8 SOME TYPES OF WEAR ON TURNING TOOLS

The crater depth *KT* shall be measured as the maximum distance between the crater bottom and the original face in Zone B.

Further details appear in Appendix C.

8 EQUIPMENT

8.1 Machine Tool

The lathe on which the test is carried out shall be of stable design and in such good condition that no tendencies to vibrations or abnormal deflections can be observed under the test conditions.

The machine tool upon which the test is to be made shall be equipped with an infinitely variable speed spindle drive covering the range of spindle speeds to be used.

This is particularly important in turning in order to be able to maintain the same cutting speed as the diameter of the workpiece is reduced by successive cuts.

Furthermore, a variable speed drive allows precise predetermination of cutting speeds and reduces the time required to obtain the data for a complete tool life curve.

8.2 Other Equipment

The following equipment is needed for specific measurements and shall be of sufficient resolution to discriminate the tolerances specified in this Standard:

(a) a device for measuring tool geometry accurately;

(b) a profile projector for inspection of the tool corners;

(c) a stopwatch for recording of cutting time;

(d) a toolmaker's microscope, or a microscope equipped with a filar eyepiece, for measuring flank wear;

(e) a dial indicator with a contact point approximately 0.2 mm in diameter for measuring crater depth;

(f) an X – Y table is recommended to obtain more accurate tool-wear measurements;

(g) a profile recorder if registration of the crater profile is desired;

(h) hardness testing equipment for the determination of hardness of the workpiece and the tool;

(i) a portable roughness measuring apparatus for measuring workpiece roughness while the workpiece is mounted on the lathe;

(j) an instrument for measuring cutting speed;

(k) a slide caliper for measuring workpiece diameter and for setting the chipbreaker distance;

(l) equipment for measuring the flow rate of cutting fluids. (This can be done by measuring the time to fill a barrel of known volume.)

9 TOOL LIFE TEST PROCEDURE

It is only possible to describe tool life test procedure in general terms, as conditions will vary with each situation.

The method to follow is the same as that used for good machine tool operation, except that great care and observation must be exercised and that certain measurements must be taken.

Most details of the measurements and the precautions to be taken have already been covered elsewhere in this Standard.

Before starting the test, it should be ascertained that lathe, workpiece, and tools fulfil all the requirements of this Standard. The data sheet, "General Conditions," as shown in Appendix D shall be completed.

The machine shall be set to the required cutting conditions. If necessary, a preliminary tool life test as described in Appendix E shall be carried out.

Tool wear measurements shall be made at suitable intervals. All data shall be recorded on the data sheet, "Tool Wear Measurements," as shown in Appendix D. The readings shall be plotted on a tool wear (ordinate) versus time (abscissa) diagram (see Figs. 9 and 10).

Such diagrams shall show at least five experimental points for each curve so that the time at which the value that is selected as the tool life criterion is reached can be assessed with sufficient accuracy.

Under no circumstances shall the tool life be determined by extrapolating the tool wear versus time diagram.

Finally, the results of a series of tests shall be recorded on the data sheet, "Cutting Speed Versus Tool Life Diagram," as shown in Appendix D.

The evaluation of the tool life data is dealt with in Section 10.

10 RECORDING AND REPORTING RESULTS

10.1 Tool Life Tests

10.1.1 Tool Life as a Function of Cutting Speed. Flank wear versus time measurements taken at several cutting speeds will provide curves as shown in Fig. 9.

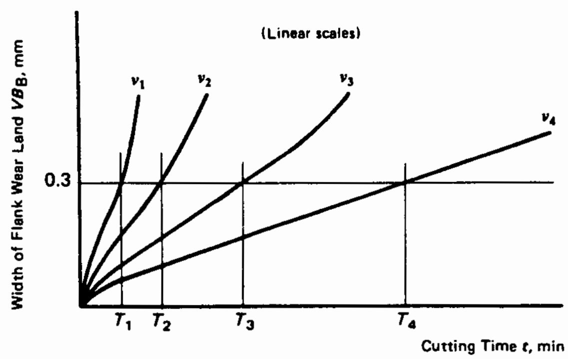


FIG. 9 DEVELOPMENT OF FLANK WEAR FOR DIFFERENT CUTTING SPEEDS

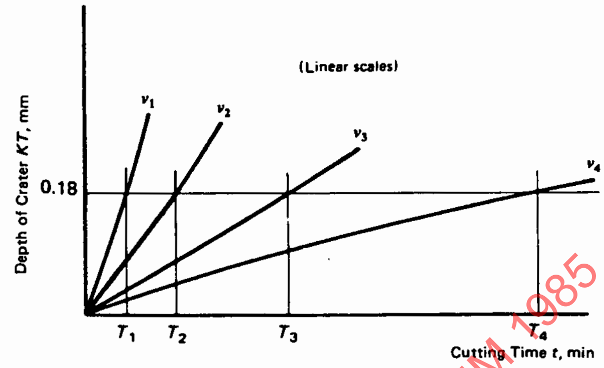


FIG. 10 DEVELOPMENT OF CRATER DEPTH FOR DIFFERENT CUTTING SPEEDS

Corresponding curves will be obtained in measuring cratering as shown in Fig. 10, surface roughness, etc.

If catastrophic failure is used as a criterion, the tool life T is plotted directly against the cutting speed v, which will provide tool life curves.

Plotting the coordinates (v_1, T_1), (v_2, T_2), etc., obtained from Figs. 9 and 10 on a double logarithmic cutting speed versus tool life diagram (same module along both axes) will produce a v-T curve as shown in Figs. 11 and 12.

These v-T curves may be considered linear within a certain speed range. The equation for this linear portion of the curves is written

$$v \times T^{-1/k} = C$$

where

v = the cutting speed in meters per minute
T = the tool life in minutes
k = tg α (as shown in Figs. 11 and 12) defines the slope of the tool life curve
C = constant

The values of k and C in the above equation shall be reported. Methods for the determination of k and C are given in para 10.3.

If the flank wear criterion is reached before that of the crater wear or vice versa, a v-T curve may be drawn according to Fig. 7. It should be observed that usually the v-T curve determined by cratering is steeper than the curve determined by flank wear.

10.1.2 Tool Life as a Function of Spindle Speed. In production it is sometimes suitable to plot the combinations of revolutions and number of workpieces produced for a specific criterion of tool wear on a double logarithmic diagram as shown in Fig. 13. This diagram can be used in the same way as a v-T diagram.

10.1.3 Tool Life Tests at a Single Speed. In certain circumstances, tests at a number of cutting speeds cannot be carried out. In such a case the tool life is expressed in minutes or alternatively as the number of workpieces produced at a single chosen speed.

The evaluation of such tests is explained in Appendix F.

Further information is given in Appendix E.

10.2 Data Sheets and Diagrams

10.2.1 General. No standard data sheets are specified. However, suggested layouts are given in Appendix D, but these are not suitable for computer evaluation.

Three different data sheets are suggested:

(a) General Conditions, which covers all the basic data for a complete series of tests;

(b) Wear Versus Time Measurements, which covers all the details of a single tool life test;

(c) Cutting Speed Versus Tool Life, for recording the results of a number of tool life tests carried out at a range of cutting speeds.

All information shown on the sample data sheets shall be included in any other data sheet compiled.

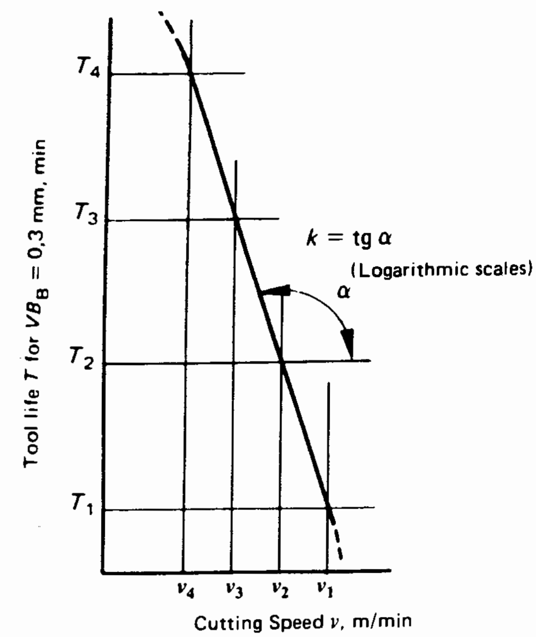


FIG. 11 *v-T* CURVE FOR VB_B = 0.3 mm

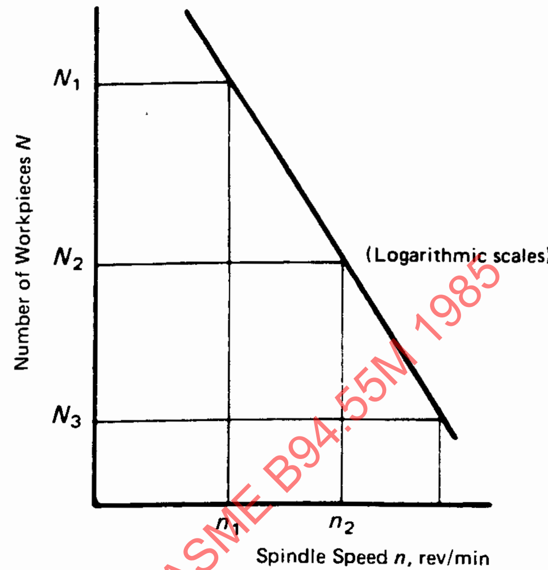


FIG. 13 NUMBER OF WORKPIECES PRODUCED AS A FUNCTION OF SPINDLE SPEED

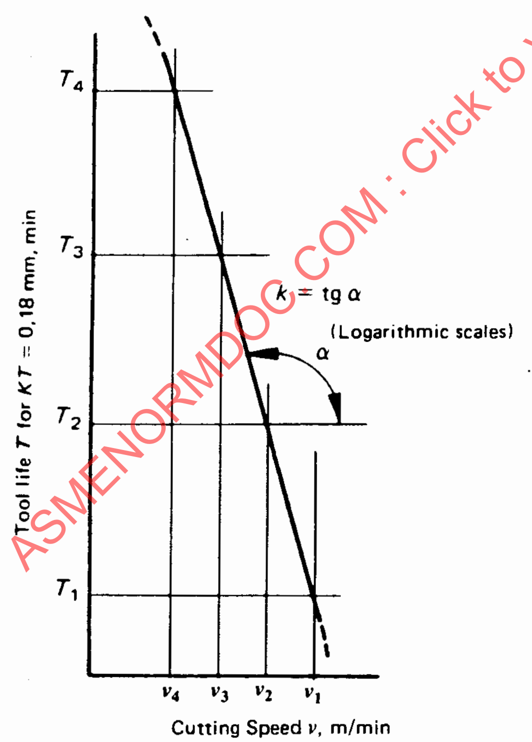


FIG. 12 *v-T* CURVE FOR *KT* = 0.18 mm

10.2.2 Data Sheet, Wear Versus Time. Information recorded in the "remarks" column on the data sheet (b) in para. 10.2.1 shall include the following:

(a) the chipforms obtained (see Appendix G);

(b) the progressive readings of Brinell hardness of the workpiece as its diameter is reduced by successive cuts;

(c) the orifice diameter, flow rate, and reservoir temperature of the cutting fluid supply and fluid pressure if possible.

10.2.3 Data Sheet, Cutting Speed Versus Tool Life. The tool life curve shall be plotted on standard log-log graph paper with the same module in both directions (83.33 mm modules if possible).

The abscissa shall be the cutting speed v expressed in meters per minute.

The ordinate shall be the tool life T in minutes or the number of workpieces N.

The following pertinent data shall be shown in the heading of the graph:

(a) date

(b) work material specification

(c) hardness or physical properties of work material

(d) tool material used and hardness in the case of high-speed steel

(e) tool geometry (data given in the following order γ, α, λ_s, κ_r, ϵ_r and r_ϵ and chipbreaker)
(f) cutting fluid
(g) feed
(h) depth of cut
(i) criterion of end-point of tool life
(j) all other data pertinent to the test

10.3 Evaluation of Tool Life Data

10.3.1 General. Any evaluation of tool life test data becomes useless if precautions are not taken during the experiment to ensure that the observations obtained are really independent of all factors other than that which is being investigated, and that the tests are carried out in a random sequence.

The constants of the Taylor tool life equation

$$v \times T^{-1/k} = C$$

can be estimated from tool life tests either by a simple graphic method, described in para. 10.3.2 or by a mathematical method, described in para. 10.3.3. If the latter is used, it is possible to obtain a measure for the dispersion as well as for the significance and the confidence interval limits, as described in paras. 10.3.4 and 10.3.5.

10.3.2 Evaluation "By Eye". With evaluation "by eye" it is possible to estimate the constants C and k quickly with an accuracy that is acceptable in many cases. However, it should be borne in mind that evaluation "by eye" is not objective, as it is unlikely that two individuals would arrive at exactly the same result. Further details are given in Appendix F.

10.3.3 Evaluation by Calculation. Linear regression analysis is an objective method of fitting a straight line through a number of observations. The line is fitted by the method of least squares which requires that the sum of the squares of the deviations between the observation points and the line be minimized. The method is described in Appendix F.

10.3.4 Statistical Considerations on the Goodness of Fit of the *v-T* Curve

(a) Dispersion. All experimental observations are concerned with dispersion. One way of indicating the dispersion is by the determination of residual variation about the regression line, which is the mean-square deviation of the observed log T values from the value according to the regression line. Further details are given in Appendix F.

(b) Significance. If the observed relation between the variables T and v is not to be considered as only a result of chance, the residual variation should be small in relation to the total variation of the T values due to regression. Further calculation methods are shown in Appendix F.

10.3.5 Confidence Interval Limits for the *v-T* Curve

(a) Confidence Interval Limits for the Complete Line. The confidence interval limits form an area around the calculated regression line within which, if the tool life tests were repeated several times, a certain percentage of the corresponding regression lines would fall. The method of calculation is given in Appendix F.

(b) Confidence Intervals for the Constants a, C, and k. The confidence intervals for the coefficients a, C, and k form an interval within which the coefficients would lie in a certain number of cases if the tests were repeated. The calculations are explained in Appendix F.

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APPENDIX A
GENERAL INFORMATION

(This Appendix, which is placed after the main text for convenience, is an integral part of ANSI/ASME B94.55M-1985.)

The objective of this Standard is to provide standard conditions and procedures for conducting tool life tests with single-point tools in turning so that:

(a) results from different sources can be compared;

(b) dispersion of the test results will be kept to a minimum.

Aims of such tests may be:

(a) determination of machining properties of work materials;

(b) comparison of tools (material, geometry, etc.);

(c) comparison of cutting fluids;

(d) determination of recommendable cutting data.

In this Standard, certain items are standardized (for example, standard tool geometries and standard cutting conditions). The term "standard" is used for quantities the values of which can be measured and expressed in physical units, one or more of the values being chosen as standard. In tool life testing there are also variables like work material, tool material, and type of cutting fluid the properties of which may be important for machining but cannot be easily expressed in physical units. Here, a detailed description containing chemical composition, manufacturing procedure, etc., is needed. Therefore, the term "reference" is introduced. The tool life criteria are divided into "common" criteria and "other" criteria, as it is impossible to standardize them all. For practical reasons and for reasons of comparability, the "common" criteria specified in this Standard are preferred, but in some situations "other" criteria may be more appropriate. In such cases Appendix C should serve as a guide.

Although the reference materials are described in detail, differences in behavior in cutting may be noticed when another batch is taken of the same nominal material. The only real solution for this problem would be an international "material bank" in which very large amounts of very rigidly controlled materials would be kept for calibration purposes. This idea has been considered but cannot be realized. Such banks exist on a national level and in a few countries only.

A major problem in drafting this Standard was that a standard with only one or very few conditions gives very good comparability but little freedom to adopt the test circumstances to wider use.

If more conditions (for example, feeds and tool geometries) are standardized, a greater chance exists that a case comparable with a particular type of production is covered, but it would be unlikely that data of this case are available for comparison. If, for instance, it is required to test the machining properties of work materials in order to obtain information for the purchasing, work preparations, and other departments, this can be done in most cases by the use of one of the standard cutting conditions, standard tool geometries, common tool life criteria, the reference tools, and the reference cutting fluid. Then the results will be comparable with those obtained elsewhere. In many cases it will be necessary to deviate from this Standard. For instance, work materials very different from the non-alloyed steels and cast irons, which are the work materials most commonly used in the tests described in this Standard, may make it necessary to use a non-reference tool material, and perhaps the standard tool geometry will also not be the best choice. If deviations are necessary, it is advisable to follow this Standard when possible.

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APPENDIX B
GRINDING OF HIGH-SPEED STEEL

(This Appendix, which is placed after the main text for convenience, is an integral part of ANSI/ASME B94.55M-1985.)

In Table 5 are listed grinding data which, it is suggested, will ensure a production of a satisfactory high-speed steel tool. The type of wheel, choice of speed, and dressing conditions are not, however, obligatory.

The cutting direction of the active periphery of the wheel is to be approximately perpendicular to the major cutting edge and towards the wedge of the tool as indicated in Figs. 14 and 15.

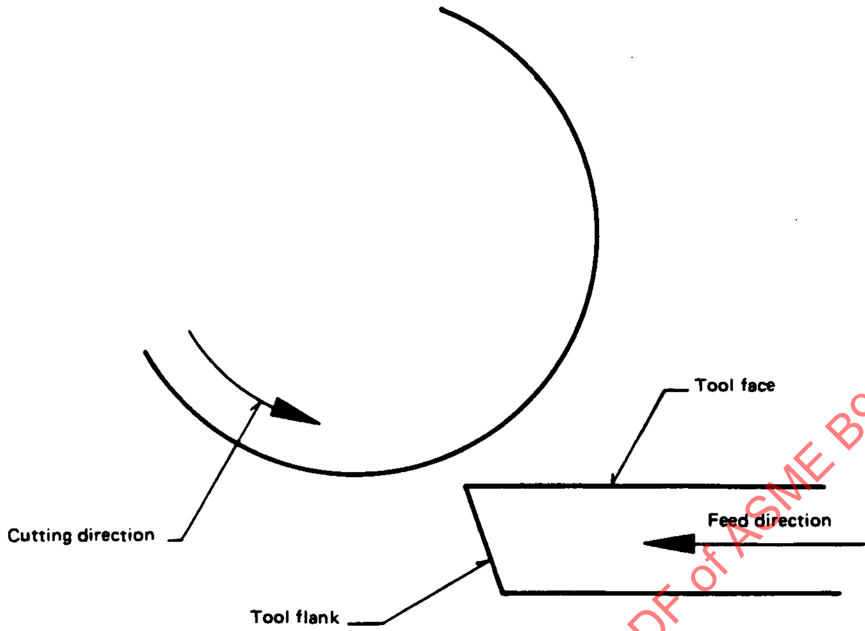
When using a plain grinding wheel, the cutting direction may be opposite or equal to the feed direction. (See Fig. 14.)

When using a cup grinding wheel, the cutting direction is approximately perpendicular to the feed direction. (See Fig. 15.)

TABLE 5
GRINDING RECOMMENDATIONS

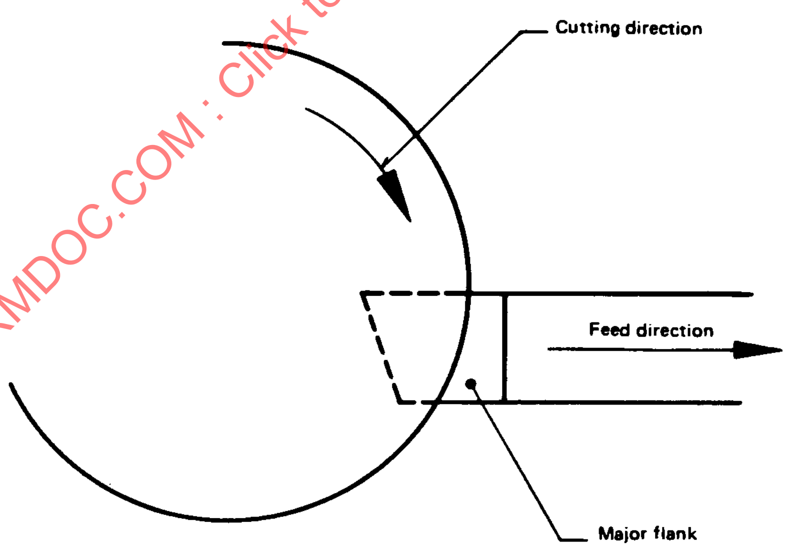
Operation	No.	Surface	Grinding Data					Notes
			Grinding Wheel Type	Grinding Wheel Marking According to ANSI B74.13	Cutting Speed m/s	Depth Setting mm/stroke	Table Feed m/min	
Original Grinding								
Cutting off	1	Minor flank	Cut-off wheel	A80P4B	50 to 70		approx. 3	
Rough-grinding[1]	2	Minor and major flank	Cup grinding wheel	A46I8V or A60H8V	25	0.01 to 0.02	approx. 3	Wheel to be dressed after the regrinding each tool
	3	Face	Plain grinding wheel		25	0.02	approx. 3	
Fine-grinding[1]	4	Minor and major flank	Cup grinding wheel		25	0.01 to 0.02	approx. 3	Before fine grinding, the wheel is to be carefully dressed with a single-point diamond
	5	Face	Cup grinding wheel	A120G8V	25	0.005 to 0.01	approx. 3	
Regrinding								
Rough-grinding[1] Fine-grinding according to (1) above	4–5	Minor and major flank	Cup grinding wheel	A46I8V	25	0.01 to 0.02	approx. 3	

NOTE:
(1) All grinding operations are to be performed with an adequate flow of coolant. Grinding shall be done perpendicular to the major cutting edge and with grinding direction away from the edge.



Tool face
Feed direction
Cutting direction
Tool flank

FIG. 14



Cutting direction
Feed direction
Major flank

FIG. 15

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APPENDIX C
TOOL WEAR AND TOOL LIFE CRITERIA

(This Appendix, which is placed after the main text for convenience, is an integral part of ANSI/ASME B94.55M-1985.)

C1 INTRODUCTION

The aim of tool life testing is to determine experimentally how one or more factors affect the useful life of cutting tools.

The reason why the useful life of a cutting tool should be considered to be ended is often different in different machining operations. The most simple case that may occur is that the tool becomes completely useless.

In most cases the tool wears gradually, and the work done by the tool becomes less satisfactory, for instance the roughness of the machined surfaces becomes too high, cutting forces rise and cause intolerable deflections or vibrations, the tool wear rate increases so that dimensional tolerances cannot be maintained, etc.

For reasons of comparability the determination of the end of tool life has been established.

C2 DEFINITIONS

For the purposes of this Standard the following definitions apply.

tool wear — the change of shape of the tool from its original shape, during cutting, resulting from the gradual loss of tool material

tool wear measure — a dimension to be measured to indicate the amount of tool wear

tool life criterion — a predetermined threshold value of a tool wear measure or the occurrence of a phenomenon

tool life — the cutting time required to reach a tool life criterion

C3 GENERAL REMARK

The numerical values in this Appendix and in para. 7.1 are a reasonable compromise and apply to the cutting conditions specified in Section 6 for non-alloyed and low-alloyed steels and cast irons, with tools having the approximate characteristics specified in Section 4. (As an example, the presence of sintered-in chipbreaking grooves or special surface treatments may influence the wear behavior significantly and make the assessment of the amount of wear more difficult.) In circumstances which differ greatly from those specified, it may be necessary to select other values for the tool life criteria. In such cases, values being either 50% lower or 50% higher than the indicated values are recommended. Under no circumstances should the tool life be assessed by extrapolating the wear versus time graph.

C4 WEAR OF THE MAJOR FLANK

C.4.1 Flank Wear

This is the best-known type of tool wear (Fig. 8). In many cases the flank wear land has a rather uniform width along the middle portion of the straight part of the major cutting edge. The width of the flank wear land is relatively easy to measure. The growing width of the flank wear land leads to a reduction in the quality of the tool. All cutting-tool materials normally have a high initial rate of flank wear which usually decreases considerably after a short time of cutting unless excessive cutting speeds are used (Fig. 9). The flank wear of high-speed steel frequently develops differently from the wear of sintered carbide tools.

High-speed steel tools may have prolonged periods of very little measurable increase of flank wear. This phenomenon occurs especially at low cutting speeds when machining ductile materials. At higher cutting speeds the increase of flank wear of all cutting-tool materials is usually approximately uniform (see Fig. 9) subsequent to the initial high wear rate. The final portion of the flank wear versus time graph often shows an accelerated rate of wear which leads to catastrophic failure. The width of the flank wear land VB_B (Fig. 8) is a suitable tool wear measure and a predetermined value of VB_B is regarded as a good tool life criterion.

For reasons of comparability, one value $VB_B = 0.3$ mm is shown in para. 7.1.

A lower value would cause more dispersion of results since the initial high wear rate would have too much influence.

A higher value would be costly and might not be reached in all tests.

An irregularly worn flank is often caused by chipping of the cutting edge and is therefore dealt with in para. C7.2.

C4.2 Notch Wear

This is a special type of flank wear at the spot where the major cutting edge intersects the work surface, which seldom makes the change of tools necessary. The profile and the length of the wear notch VB_N (Fig. 8) depend to a great extent on the accuracy of depth setting.

For these reasons the notch wear is excluded from the evaluation of the width of the flank wear land (see para. 7.2). In special cases where the notch wear is predominant over all other tool wear phenomena, the length of the wear notch may be used as the tool wear measure. In such cases the value $VB_N = 1.0$ mm may be used as the tool life criterion.

C5 WEAR OF THE FACE

Crater wear is the most commonly occurring type of face wear.

The depth of the crater *KT* (Fig. 8) may be used as a tool wear measure and a predetermined value of *KT* may be selected as a tool life criterion. Crater wear is more important for carbide tools than for high-speed steel or ceramic tools. Recommended values are given in para. 7.1.2.

The position of the crater relative to the cutting edge has also some importance. A deep, wide crater far away from the cutting edge may be less dangerous to the tool than a less deep, narrow crater close to the cutting edge.

This is one of the reasons why the values for *KT* as a tool life criterion are given in relation to the feed. For special purposes the crater center distance *KM* and the crater width *KB* may be measured as additional information. However, they should not be used as tool life criteria.

The crater center distance *KM* (the distance between the original major cutting edge and the deepest point of the crater) is measured in Zone B parallel to the face and perpendicular to the major cutting edge (Fig. 8).

The crater width *KB* (the distance between the original major cutting edge and the rear side of the crater) is measured parallel to the face in Zone B and perpendicular to the major cutting edge (Fig. 8). As the crater center distance *KM* depends not only on feed but also on work material and tool material, the crater ratio K ($K = KT/KM$) is sometimes calculated. A chosen value may then be used as the tool life criterion and the value $K = 0.1$ is recommended.

C6 WEAR OF THE MINOR FLANK

In turning, the machined surface is shaped mainly by the tool corner and the minor cutting edge. This means that any change of the tool corner as a result of wear has an effect on the machined surface.

In finish turning with small feeds, one or more grooves are often found in the minor flank after a period of cutting. These grooves cause increased roughness of the machined surface. A direct evaluation of this type of tool wear is difficult but its effect may be assessed by the measurement of the roughness of the machined surface. A certain value of the roughness may be used as the tool life criterion. Recommended values are given in para. 7.1.4.

Oxidation of the minor flank often leads to the destruction of the tool when turning with carbide tools at sufficiently high temperatures caused by high feeds and high cutting speeds. In such cases the tool may become useless because of oxidation of the minor flank before the criteria $VB_B = 0.3$ mm or the recommended value of *KT* are reached. In such cases the sudden deterioration of the machined surface caused by the destruction of the minor flank has to be used as the tool life criterion.

In general, this happens quite suddenly, otherwise a certain deterioration has to be taken as a criterion.

C7 VARIOUS OTHER PHENOMENA

C7.1 Deformation of the Tool Corner

This may lead to destruction of high-speed steel and carbide tools when cutting conditions are severe.

Deformation of the tool corner should not itself be used as a tool life criterion; however, deformation will in most cases lead to a more rapid occurrence of catastrophic failure of high-speed steel tools and it makes the consequences of oxidation of carbide tools more severe. It may happen that cutting conditions are so heavy that deformation starts immediately after the tool starts cutting. In such cases the tool life is usually very short. This is why it is recommended in para. 6.3 that tool life should be not less than 5 min for normal materials or not less than 2 min for expensive materials.

C7.2 Chipping

The chipping of fine particles from the cutting edge and thermal cracking (frequently met in interrupted cuts) is important with brittle tool material. The amount of chipping and thermal cracking is evaluated to a certain extent by the maximum width of the flank wear land VB_B max. (Fig. 8). Therefore, the value VB_B max. = 0.6 mm is indicated in para. 7.1 as a tool life criterion.

C7.3 Premature Failure

All abnormally quick and therefore unreliable and unpredictable modes of tool failure and heavy deformations which end tool life immediately may be caused by a hard spot in the work material or an accident in the operation of the machine tool. One tool of a series may break, chip badly, deform, or may otherwise fail unpredictably. The occurrence of premature failure disqualifies the test, unless special cases arise where premature failure is more frequent than wear and the other criteria are seldom reached.

This may be the case when machining very hard and heterogeneous work materials with brittle tool materials (for example, ceramic tools) and delicate tool shapes. In such cases it is recommended that more experimental points be used to determine the v-T lines.

C7.4 Catastrophic Failure

The rapid deterioration of the cutting edge after a period of successful cutting under the combined action of load and increasing temperature is a reliable criterion for high-speed steel tools and is therefore indicated in para. 7.1.1. It may also be used in case of testing carbide and ceramic tools under severe metal cutting conditions.

C7.5 Preliminary Failure

This phenomenon, sometimes observed prior to the catastrophic failure of high-speed steel tools, is evidenced by a shiny, burnished appearance of the machined surface and the transient surface, usually during a few revolutions of the workpiece. This may occur seconds before catastrophic failure or as early as half of the tool life. Preliminary failure shall not be used as a tool life criterion and cutting shall be continued until one of the preferred tool life criteria is reached. The instant of preliminary failure shall be recorded.

C8 CUTTING FORCES AND TEMPERATURE

A major increase of cutting forces and temperature with cutting time is sometimes used as the basis for a tool life criterion in scientific research and in adaptive control systems.

This is not covered in this Standard. Forces and temperature may be measured as additional information. It should be kept in mind that most dynamometers are less rigid than a standard tool post. Increased vibrations, which affect tool wear, may be the result.

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APPENDIX D
DATA SHEETS

(This Appendix, which is placed after the main text for convenience, is an integral part of ANSI/ASME B94.55M-1985.)

Data sheets follow on the next three pages.

Company	GENERAL CONDITIONS	Reg. No. Order No.
Date	Ordered by	Performed by

AIM OF THE TEST

TEST MATERIAL

Designation	Manufacturer						Country							Charge No.	
Analysis %	C	Si	Mn	P	S	Ni	Cr	Mo	Cu	V				Al_{tot}	%
Standard														O	%
Charge														N	%
Test bars														H_2	%

Slag analysis and inclusions	SiO_2	Al_2O_3	FeO	MnO	Inclusions (Type, size, etc.)
	CaO	MgO	TiO_2	Cr_2O_3	

Treatment of ingot (ingot size, rolling, etc.)	
Heat treatment	Structure

Mechanical properties	$R_{eO.2}$ . . . N/mm²	Brinell hardness	Additional data
	R_{eH} . . . N/mm²	Ball diameter . . . mm	
	R_{eL} . . . N/mm²	Load . . . N	

TOOLS

Manufacturer	Country		Tool material
Sintered carbide and Ceramic	Insert (designation)	Group of application	
	Toolholder (type and designation)		
High-speed steel	Composition		Hardness
	Heat treatment		Designation of tool
	Grinding method		

Tool geometry	γ_n =	α_n =	λ_s =	κ_r =	ϵ_r =	r_ϵ =

LATHE

Manufacturer	Type	No.	Year of manufacture
Rated output . . . kW	Height of centres . . . mm	Maximum distance between centres . . . mm	Machine conditions as for record No. . . .
Machine mounting (bolted down, etc.)		Infinitely variable speed	Yes ☐ No ☐
Miscellaneous			

FIXING DEVICE

The following fixing device is used	Chuck ☐ Chuck-centre ☐ Centres ☐	Other device (description)

CUTTING FLUID

Cutting fluid used	Yes ☐ No ☐	Type	Designation or analysis	Pressure	Temperature	Volume . . . l/min
Miscellaneous						

Company	WEAR VB_B, KT VERSUS TIME t MEASUREMENT		Reg. No. Order No.
Date	Ordered by	Performed by	

TEST BARS, TOOL AND CUTTING DATA

Insert or tool No. . . .	Edge No.	Rough diameter . . . mm	Diameter before machining . . . mm	Length of workpiece . . . mm	Machined zone . . . mm	Chipbreaker	
Feed f . . . mm/rev		Depth of cut a . . . mm		Cutting speed v . . . m/min		height	distance
Miscellaneous							

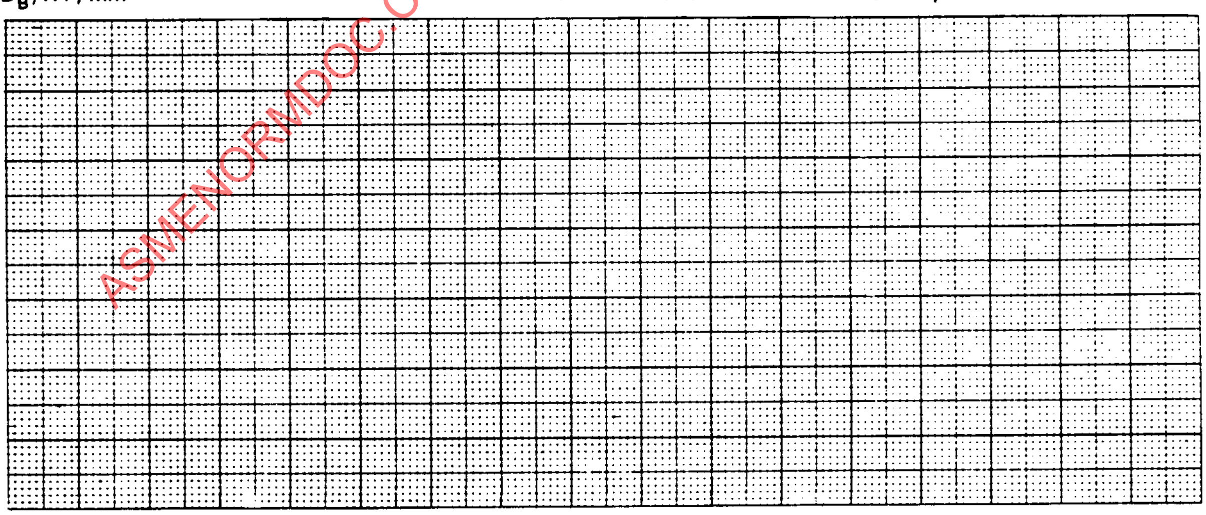
TEST VALUES

Measurement No.	Time t min	Diameter D mm	Flank wear VB_B mm	Flank wear VB_B max. zone	Flank wear VB_B max. mm	Flank wear 1)	Cratering KT mm	Cratering 1)	Chip form	Remarks
0			–	–	–	–	–	–	–	
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										

Tool-life criterion	1) If other wear measure is applied	Is chipforming affected by chipbreaker ? Yes ☐ No ☐

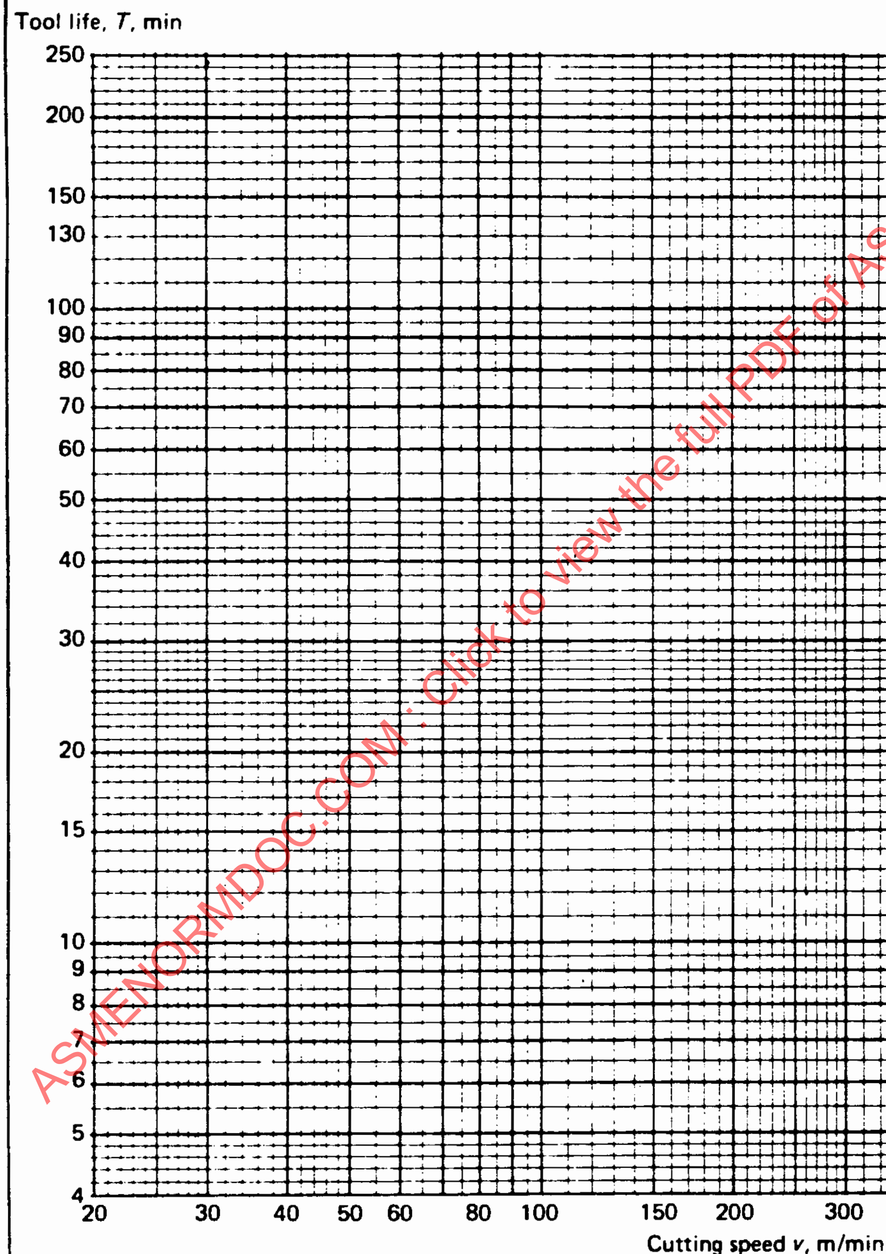
VB_B, KT, mm

The scales of the two axes shall be adapted to the values obtained.



Time t, min

Company	CUTTING SPEED *v* VERSUS TOOL LIFE *T* DIAGRAM					Reg. No. Order No.
Date	Ordered by			Performed by		
MAIN DATA						
Test material	Tool material		Tool designation		Feed *f* . . . mm/rev	Depth of cut *a* . . . mm
Tool geometry	$\gamma_n =$	$\alpha_n =$	$\lambda_s =$	$\kappa_r =$	$\epsilon_r =$	$r_\epsilon =$
Cutting fluid						
Remarks						



Test values

Sheet No.	Tool-life criterion	Cutting speed *v* m/min	Tool life *T* min: Mean value	Tool life *T* min: Standard deviation

Remarks

APPENDIX E
PRELIMINARY TOOL LIFE TEST

(This Appendix, which is placed after the main text for convenience, is an integral part of ANSI/ASME B94.55M-1985.)

It is recommended that a preliminary tool life test be carried out in order to determine a cutting speed which will result in a reasonable tool life and avoid inordinately time-consuming cuts.

A cut should be taken with the machine set at an arbitrarily selected low cutting speed and, if necessary, the chipbreaker distance should be adjusted until an acceptable chip form is obtained. The period of time over which the cut is taken should be short, and will probably vary between individual cases. The tool should then be examined for indications of failure, and if none appear, a further cut should be taken with the cutting speed increased. This procedure should be repeated until the tool has failed.

A tool life point thus obtained should not be recorded as part of the data; however, it is valid in establishing the correct operating level. The cutting time taken during the test at the lower speeds is an insignificant portion of the life of the cutting tool when operating at the speed at which the tool failure occurred.

The cutting speed for the first tool life tests is determined by estimating the slope k of the tool life curve.

Using a log-log graph paper (module 83.33 mm recommended), a line having an estimated slope may be drawn through the tool life point obtained in this preliminary test.

This line can then be used to determine the cutting speed for the first tool life desired. This cutting speed can also be calculated by using the tool life equation in the following formula:

$$V_2 = V_1 \left(\frac{T_1}{T_2}\right)^{-1/k}$$

A reasonable estimate of the slope of the tool life line for flank wear for different cutting-tool materials is given below.

High-speed steel: $k = -7$, but values between -12 and -5 may be obtained.

Carbide: $k = -4$, but values between -6 and -2.5 may be obtained.

Ceramics: $k = -2$, but values between -2.5 and -1.25 may be obtained.

Values near the initial estimated values are frequently found when cutting reference work material with reference tools.

The cutting speed thus chosen will rarely yield the tool life selected; however, it will provide a reasonable cutting speed at which the test may be started. With some experience the preliminary test can be omitted.

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APPENDIX F
EVALUATION OF TOOL LIFE DATA

(This Appendix, which is placed after the main text for convenience, is an integral part of ANSI/ASME B94.55M-1985.)

INTRODUCTION

It should be noted that the symbols N, X, Y, $\overline{X}$, $\overline{Y}$, σ and σ^2 used previously for the work relative to tool life testing with single-point turning tools have been replaced by n, x, y, $\overline{x}$, $\overline{y}$, s and s^2, respectively.

F1 EVALUATION "BY EYE"

F1.1 Procedure and Calculation

A log-log graph paper of equal scale moduli shall be used with the tool life T (dependent variable) on the vertical scale and the cutting speed v (independent variable) on the horizontal scale.

All observations of v and T for the particular tool life criterion shall be plotted with the exception of obviously false data. Errors frequently occur by averaging the results of observations at one speed prior to plotting on the double logarithmic graph.

The best straight line shall be fitted to the graph of log v against log T. Theoretically, the line should be drawn in such a manner that the sum of the squares of the vertical distances between the line and the actual points are estimated, by eye, to be as small as possible.

The constant k can be easily obtained from the slope of the line, or from two sets of observations (v, T) through which the line actually passes.

$$k = \frac{\log T_2 - \log T_1}{\log v_2 - \log v_1}$$

The constant C can be read directly from the graph as the cutting speed for a tool life of 1 min.

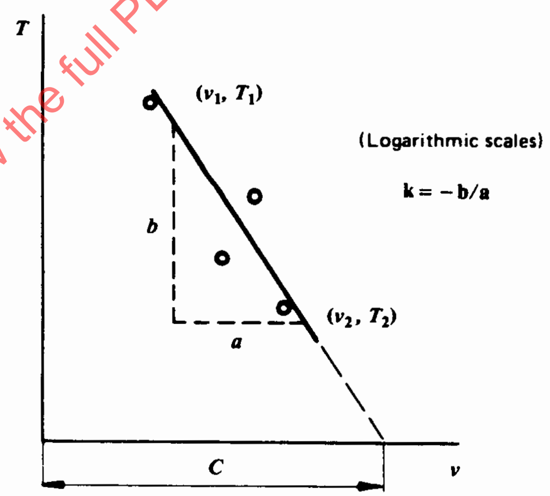


FIG. 16

Alternatively, C may be calculated from

$$C = v_1 \times T_1^{-1/k}$$

Example 1: In a series of tool life tests with carbide P 30 tools on a normalized 0.45% steel with feed

f = 0.25 mm/rev, depth of cut a = 2.5 mm, corner radius r_ϵ = 0.8 mm, and tool orthogonal angle γ_0 = 6 deg., the following results were obtained:

Number of Test	Cutting Speed v m/min	Tool Life T, min	
		Criterion KT = 0.14 mm	Criterion VB_B = 0.3 mm
1	180	10	17.5
2	160	18.5	24
3	140	24	30
4	140	20	26
5	125	36	40
6	160	13	17
7	125	44	51
8	180	8	15.5
9	160	15.5	22
10	125	40	47
11	140	25	36
12	180	6.5	12.5

NOTE: The work material and the tool material were not exactly identical with the reference materials described in this Standard.

Determine the constants of the tool life equation.

Solution: The experimental points are plotted as shown in Fig. 17. One line is plotted for the criterion VB_B = 0.3 mm and another line for the criterion KT = 0.14 mm. The constants are obtained graphically and are indicated in the figure.

F2 EVALUATION BY CALCULATION

F2.1 Regression Analysis

Regression analysis is a statistical method which helps to fit the best line to a given set of data, instead of simply drawing a line by eye. This method determines the equation of that straight line from which the sum of the squared distances, or deviations, of all plotted points in a particular direction becomes a minimum.

In this particular work it is assumed that log T is a linear function of an independent variable log v; the deviations are thus measured in the log T or vertical direction.

The logarithmic transformation from T and v to log T and log v results in the regression analysis being calculated for deviations from log T instead of T. This distinction leads to a small underestimation of the level of the line, as shown in Fig. 18.

In practice, the difference between a tool life calculated for T and a curve calculated for log T is very small in comparison with the scatter about the curve.

F2.2 Calculations

For the calculations the computation schedule shown in Table 6 may be used. Columns 1, 2, and 3 are completed initially by the insertion of the observed v and T values for all the experimental results taken. Only undoubtedly false results should be omitted.

The following notation is used:

n = number of experimental observations
x = log v
y = log T

Columns 4 and 5 of Table 6 are completed by simply taking logarithms of v and T. The summation of both the x and y values is then obtained and their mean values $\bar{x}$, $\bar{y}$ computed from:

$$\bar{x} = \frac{\Sigma x}{n} \quad \text{and} \quad \bar{y} = \frac{\Sigma y}{n}$$

Transformation of the Taylor tool life equation together with suitable choice of axes gives the following formula:

$$y = a + k(x - \bar{x})$$

where

$$a = k(\bar{x} - \log C) = \bar{y}$$

and

$(\bar{x}, \bar{y})$ are the coordinates of the centroidal point.

It is necessary to find the values of C and k such that the sum of the squares of the y residuals is a minimum. An outline for the calculation is given in Table 6.

The constant k, which is the tangent of the angle between the regression line and the X-axis, is given by

$$k = \frac{\Sigma xy - [(\Sigma x \cdot \Sigma y)/n]}{\Sigma x^2 - (\Sigma x)^2/n}$$

The products xy are tabulated in column 6 of Table 6 and their summation obtained. The separate values of Σx and Σy are obtained from columns 4 and 5, respectively. The product $\Sigma x \cdot \Sigma y$ is then divided by n.

In column 7 the sum of squares Σx^2 is calculated. Then from column 4 the sum Σx is obtained, squared, and divided by n.

Finally, the constant C is calculated from

$$\log C = \bar{x} - \bar{y}/k$$

NOTE: Σx^2 is not the same as $(\Sigma x)^2$.

Example 2: Calculate the constants k and C in the Taylor tool life equation for the observations presented in Example 1.

Solution: A simple graph of tool life against cutting speed is made on log-log paper as indicated in Fig. 17. The graph shows that there is good reason to assume that the tool life follows the Taylor equation. Thus, it is reasonable to compute the constants k and C by means of regression analysis.

The calculations are shown in Table 9 for the criterion $KT = 0.14$ mm. The results are shown in Fig. 18.

F3 STATISTICAL CONSIDERATIONS ON THE GOODNESS OF FIT OF THE v-T CURVE

F3.1 Dispersion

The residual variation is calculated according to

$$s_r^2 = \frac{\Sigma y^2 - \bar{y}\Sigma y - k\left(\Sigma xy - \dfrac{\Sigma x \cdot \Sigma y}{n}\right)}{n-2}$$

For the computation, the computation schedules shown in Tables 6 and 7 are used. Begin with the computation of the square sum Σy^2 in Table 6. Transfer this square sum from Table 6 to part 1 of Table 7, as well as $\bar{y}$, Σy, k, Σxy, $\Sigma x \cdot \Sigma y/n$. Continue with computation of s_r^2 according to the formula given in part 1 of Table 7.

F3.2 Significance

Calculations: For the calculations, use the computing scheme shown in Table 7. The following have to be calculated:

(a) the mean-square sum due to deviation from the regression line (= residual variation) as described in F3.1 (use part 1 of Table 7);

(b) the mean-square sum due to variation explained by regression

$$s_R^2 = k(\Sigma xy - \Sigma x \cdot \Sigma y/n)$$

This quantity has already been calculated as a partial result in part 1 of Table 7.

(c) the ratio s_R^2/s_r^2.

Choose the confidence level necessary (for example, 90%) and read from Fischer's F-Table the F-value for the number of degrees of freedom (d.f.) equal to 1 and $n - 2$. The ratio s_R^2/s_r^2 should be greater than the F-value in the F-table. If this is not the case, the observed relationship should be regarded as a chance result.

F4 CONFIDENCE INTERVAL LIMITS FOR THE v-T CURVE

F4.1 Confidence Interval Limits for the Complete Line

Calculations: Use the computation schedule shown in Table 8. Proceed as follows.

(a) Write in the head of Table 8 the quantities obtained in Tables 6 and 7. Choose the desired level of confidence. Read in Student's t-Table the two-sided t-value for the number of degrees of freedom equal to $n - 2$.

(b) The confidence interval for the complete line is calculated from the following formula:

$$y = \bar{y} + k(x - \bar{x}) \pm ts_r\sqrt{\frac{1}{n} + \frac{(x - \bar{x})^2}{\Sigma x^2 - (\Sigma x)^2/n}}$$

The first two terms of this formula represent the regression line itself. The last term is an expression for the size of the confidence interval, that is, the complete range between the confidence limits.

Table 8, part 2 indicates the order of the calculations required. Values for ts_r (column 1) and $1/n$ (column 2) are first obtained. A series of x values is then chosen (column 3) followed by the completion of columns 4, 5, and 6.

Column 6 gives the confidence interval on either side of the regression line for the chosen confidence level.

F4.2 Confidence Intervals for the Constants *a, C,* and *k*

Calculation: The confidence interval for k is obtained from

$$k_m = k \pm \frac{ts_r}{\sqrt{\Sigma x^2 - (\Sigma x)^2/n}}$$

Table 8 suggests a method for recording the values obtained. Input data may be obtained from part 1 of Table 8.

The confidence interval for the constant a is obtained from

$$a = \bar{y} \pm \frac{ts_r}{\sqrt{n}}$$

and a substitution in equation

$$\log C = \bar{x} - \bar{y}/k$$

Corresponding limit values for log C and finally C may be obtained. Again, Table 8 suggests a method for recording the values obtained.

Example 3: Obtain a measure for the dispersion about the regression line treated in Example 2 (F2.2). Also, carry out a test of significance and set up confidence interval limits.

(a) Dispersion. The calculations are shown in Table 10, part 1.

(b) Significance. The calculations are shown in Table 10, parts 2 and 3. When the F-value is taken from the table of the F-distribution, note that the degree of freedom is $n - 2$ for the smaller sum of squares and 1 for the greater sum of squares and thus the correct F-value is taken from the $n - 2$ row and the first column.

As the variance ratio = 131 and $F = 4.96$, there exists a high degree of significance.

(c) Confidence interval limits

(1) Confidence Interval Limits for the Line as a Whole. The calculations are shown in Table 11. The results can be shown graphically. Note that if a log-log paper with scale modulus 100 mm is used, then $x = 2.25$ corresponds to a distance of 225.5 mm from $x = 0.0$ ($v = 1$ m/min). Thus, a confidence interval width of $\Delta y = 0.082$ corresponds to a distance (above or below the mean regression line) of 8.2 mm.

In Fig. 18 the regression line with confidence intervals limits corresponding to a confidence level of 95% is shown.

(2) Confidence Interval for k. The calculations are shown in part 3 of Table 11.

(3) Confidence Interval for C. In part 4 of Table 11 the minimum and maximum values are shown.

F5 EVALUATION OF TOOL LIFE TESTS AT A SINGLE SPEED

Calculation: From the observed number n of T-values, the mean value $\bar{T}$ should be calculated as:

$$\bar{T} = \Sigma T/n = \frac{T_1 + T_2 + T_3 + T_4 + \ldots + T_n}{n}$$

Moreover, if:

(a) the observations are statistically independent;

(b) randomization has been carried out;

(c) the sample of the observed T-values may be regarded as drawn from a population with normally distributed T-values. (Sometimes a normal distribution[1] may be obtained by taking log T instead of the T values.)

The confidence interval for the calculated mean tool life $\bar{T}$ can be obtained from:

$$T = \bar{T} \pm s \frac{t}{\sqrt{n}}$$

where s is the standard deviation of the n observed values of tool life.

$$s = \sqrt{\frac{\Sigma(T - \bar{T})^2}{n - 1}}$$

and t denotes Student's t-value for $n - 1$ degrees of freedom for the desired level of confidence $1 - \alpha\%$ (Table 12).

Example 4: The difference between the wear resistance of two tool materials was investigated by practical industrial tests in a machine tool group, where three machine tools of the same model and year of manufacture were in use under identical cutting conditions.

As the material for the workpieces was delivered from more than one stock, it was decided to divide the material up in 20 lots. The order of the machining of each lot was determined by means of a table of random numbers. The workpieces where then machined with toolbits made of materials A and B, and the number of workpieces that could be machined by each tool edge was recorded. (The tool life criterion was $VB_B = 0.8$ mm.)

[1]A test of normality should be used for confirmation.

The following tool life data were obtained:

Tool Life (Number of Workpieces for Each Tool Edge)	Number of Observed Tool Lives	
	Material A	Material B
14	4	
15	5	
16	6	1
17	15	6
18	10	18
19	16	20
20	18	20
21	10	14
22	8	8
23	5	8
24	2	4
25	1	2
Sum $n =$	100	101

Solution and discussion: The mean tool life for tool material A is

$$\overline{T}_A = \frac{14 \times 4 + 15 \times 5 + 16 \times 6 + \ldots}{4 + 5 + 6 + \ldots} = 19.0$$

The mean tool life for tool material B is

$$\overline{T}_B = 20.0$$

The standard deviation for material A is

$$s_A = \sqrt{\frac{4(14 - 19)^2 + 5(15 - 19)^2 + \ldots}{4 + 5 + 6 + \ldots - 1}} = 2.5$$

and for steel B

$$s_B = 2.0$$

The confidence interval for material A is (with a confidence level of 95%)

$$T_A = 19.0 \pm 1.984 \times 2.5/\sqrt{100} = 19.0 \pm 0.5$$

For material B the corresponding interval is

$$T_B = 20.0 \pm 0.4$$

The confidence interval is less than the difference between the mean tool lives for the tested materials. Thus, the mean tool life for material B is greater than that for material A under the test conditions. If there is no factor other than tool material that might explain the test result, it is justified to generalize that the tool material B has a greater wear resistance than material A, under conditions similar to those of the test.

However, in this case the formulation of the text of the problem indicates that there exist some factors (besides tool material) that might result in a difference in tool life in the two sets of observations. These factors are the machine tools involved, their operators, and the order of testing A and B. If the influence of these factors had been controlled, for example by randomization, the above conclusion could have been drawn.

Example 5: The difference in the wear resistance of two kinds of high-speed steel tool materials was investigated. For this purpose, the number of workpieces produced by one tool until tool failure occurred was recorded for a number of tools made from both kinds of high-speed steel.

All workpieces were identical and made from cold-drawn steel bars from one delivery. As there might be some influence of variation of the properties of the work material between the bars, tools were changed in a random sequence each time a workpiece was finished. All tests were carried out by the same operator on a semiautomatic lathe with a constant spindle speed.

This means that these results do not necessarily apply when cutting conditions, tool geometry, or work material are changed.

In order to achieve reasonably safe production, tools made of material A should be changed after 12 products have been made. For tool material B this number is 15. Approximately 20% of the tools will fail before this number is reached.

If tools are changed after 11 and 14 products respectively, the risk of early failure is reduced to about 10%.

Tool Material A			
Tool Number	Tool Life T	$T - \bar{T}$	$(T - \bar{T})^2$
1	15	1.5	2.25
2	10	− 3.5	12.25
3	17	3.5	12.25
4	14	0.5	0.25
5	13	− 0.5	0.25
6	11	− 2.5	6.25
7	14	0.5	0.25
8	12	− 1.5	2.25
9	16	2.5	6.25
10	13	− 0.5	0.25
11	12	− 1.5	2.25
12	14	0.5	0.25
13	15	1.5	2.25
14	13	− 0.5	0.25
$n = 14$	$\Sigma T = 189$	$\Sigma(T - \bar{T})^2 = 47.50$	

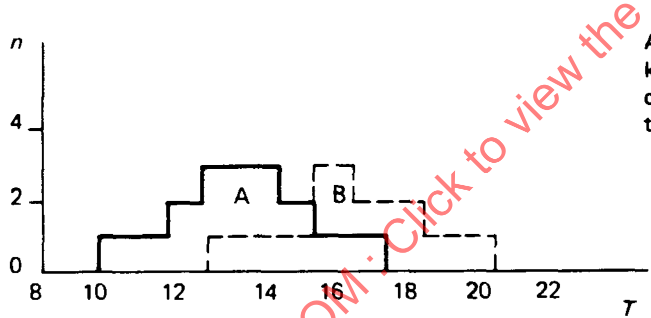
$$\bar{T} = \frac{\Sigma T}{n} = \frac{189}{14} = 13.5$$

$$s = \sqrt{\frac{\Sigma(T - \bar{T})^2}{n - 1}} = \sqrt{\frac{47.50}{13}} = 1.97$$

Tool Material B			
Tool Number	Tool Life T	$T - \bar{T}$	$(T - \bar{T})^2$
1	14	− 2.6	6.76
2	18	1.4	1.96
3	17	0.4	0.16
4	13	− 3.6	12.96
5	16	− 0.6	0.36
6	18	1.4	1.96
7	17	0.4	0.16
8	20	3.4	11.56
9	16	− 0.6	0.36
10	16	− 0.6	0.36
11	15	− 1.6	2.56
12	19	2.4	5.76
$n = 12$	$\Sigma T = 199$	$\Sigma(T - \bar{T})^2 = 44.92$	

$$\bar{T} = \frac{\Sigma T}{n} = \frac{199}{12} = 16.6$$

$$s = \sqrt{\frac{\Sigma(T - \bar{T})^2}{n - 1}} = \sqrt{\frac{44.92}{11}} = 2.02$$



As it is felt that all factors which may affect tool life were kept under a reasonable degree of control, it is justified to conclude that tool material B has a greater wear resistance than tool material A for the conditions of these tests.

Confidence level : 95 %

Number of degrees of freedom : $n - 1$

Material A : $n - 1 = 13$, t value = 2.160

Material B : $n - 1 = 11$, t value = 2.201

$$T = \bar{T} \pm \frac{ts}{\sqrt{n}}$$

$$T_A = 13.5 \pm \frac{2.16 \times 1.97}{\sqrt{14}} = 13.5 \pm 1.1$$

$$T_B = 16.6 \pm \frac{2.2 \times 2.02}{\sqrt{12}} = 16.6 \pm 1.3$$

Difference significant   Yes [X]   No [ ]

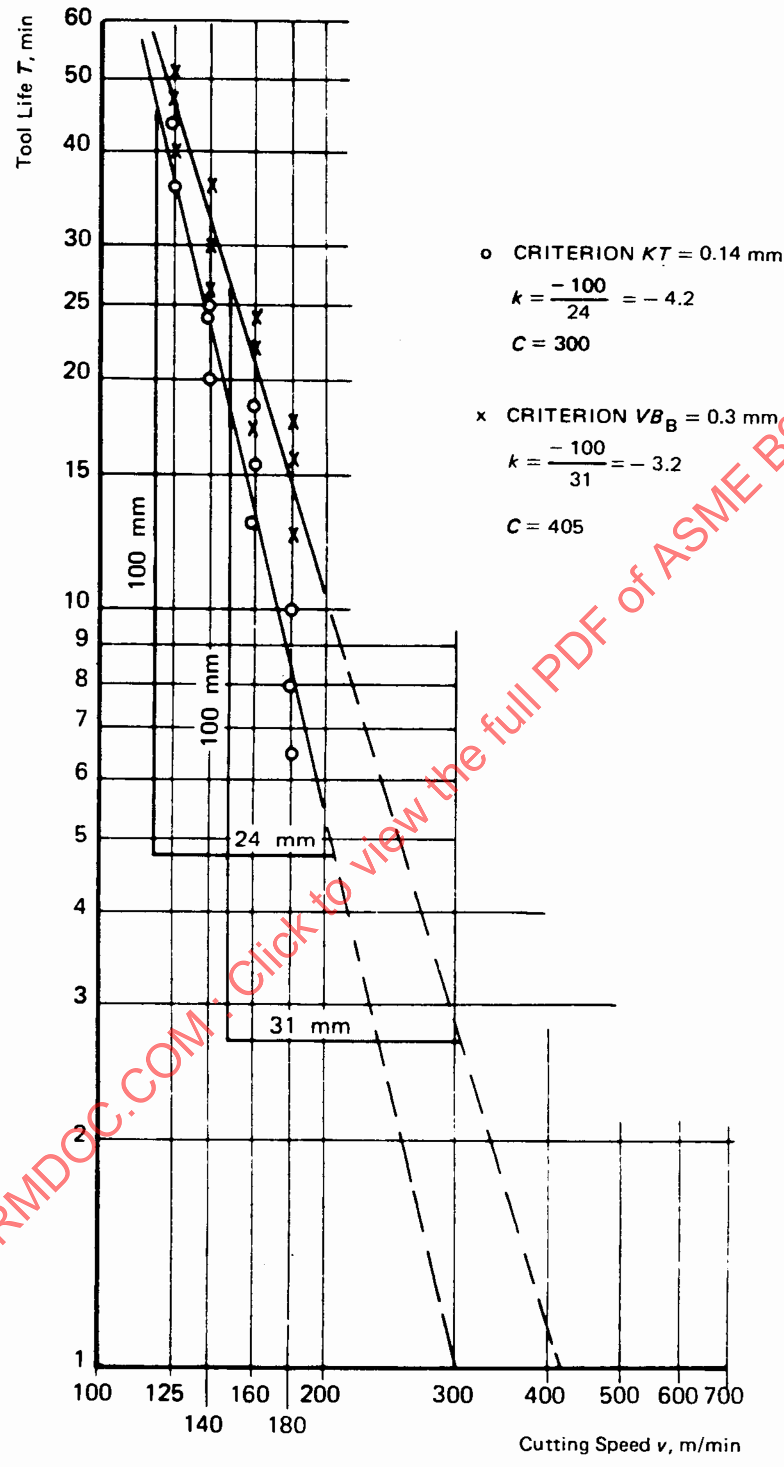


FIG. 17 LINES FITTED "BY EYE"

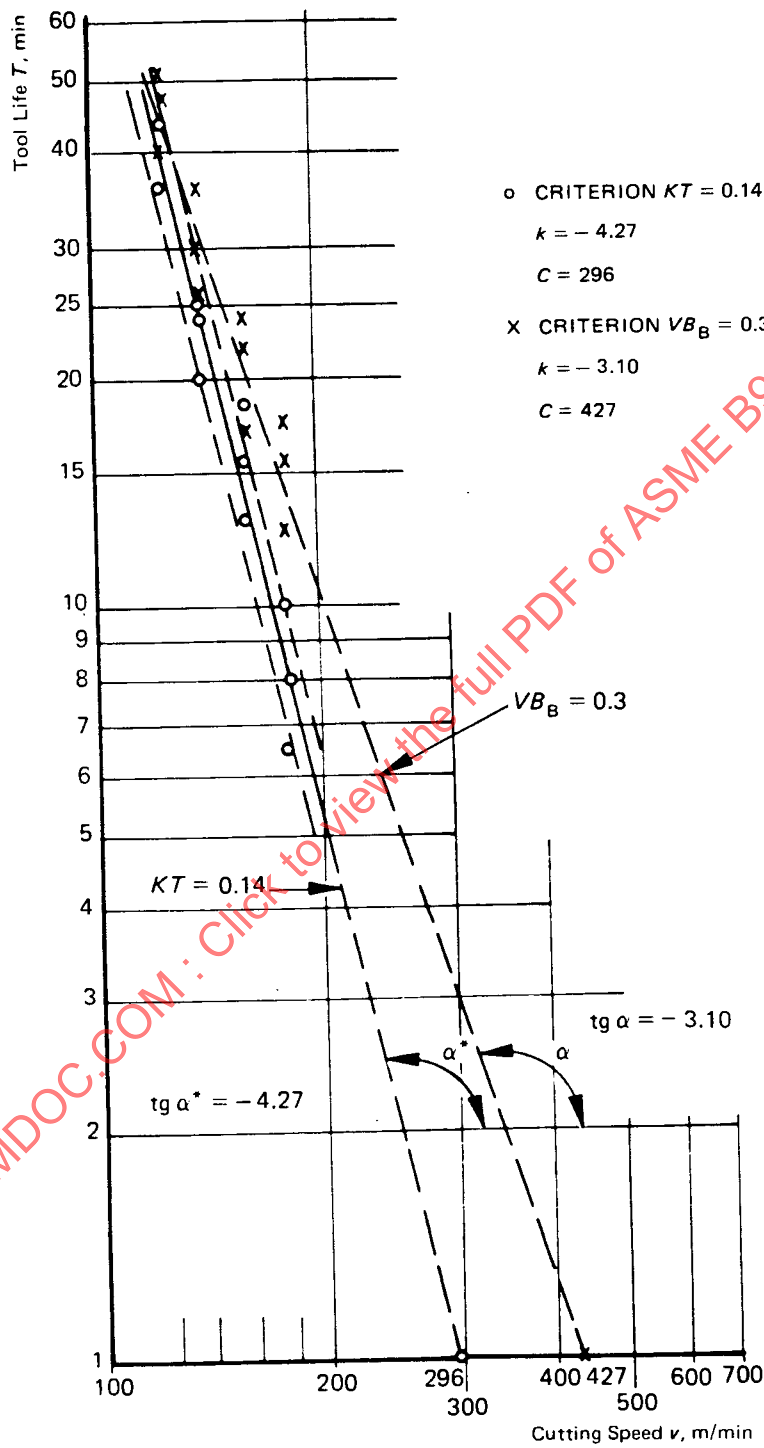


FIG. 18 LINES WITH CONFIDENCE INTERVAL FITTED BY CALCULATION