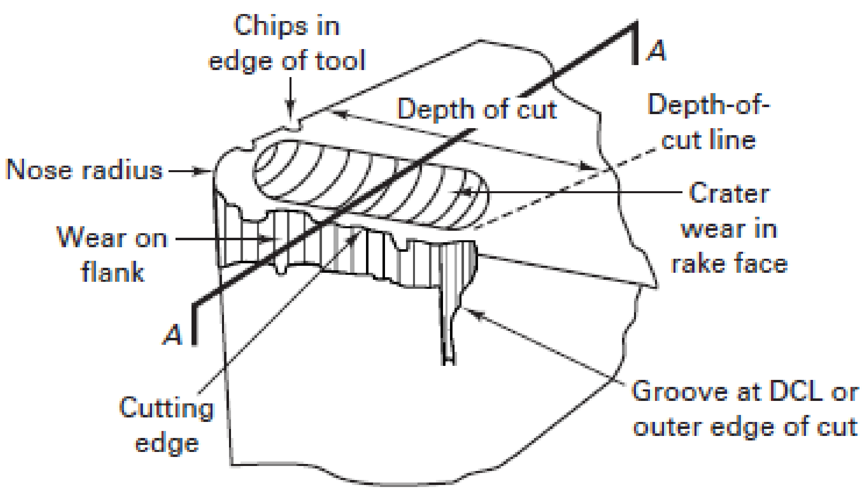
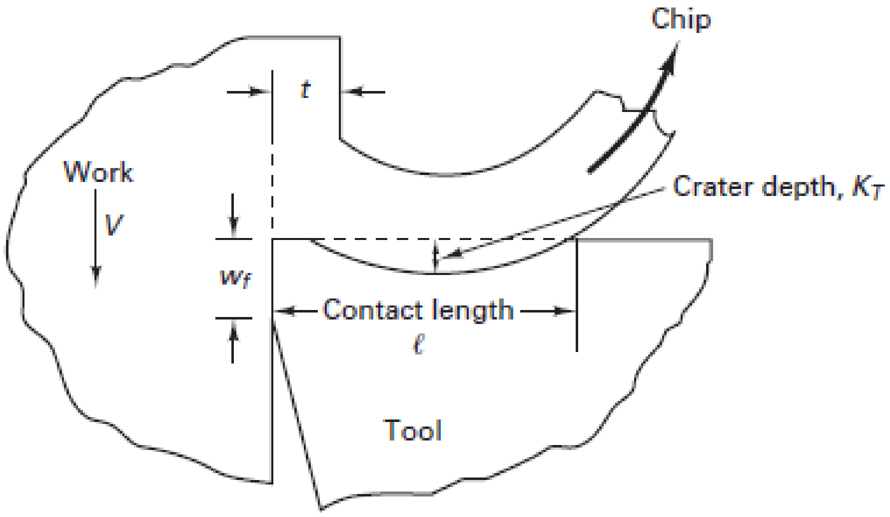
Tool Failure and Tool life

Tool Failure and Too Life

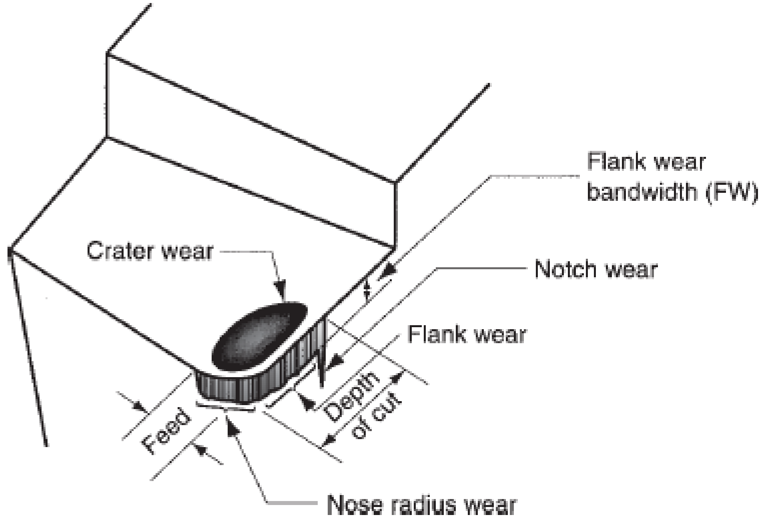
1. *Physical failures* mainly include gradual tool wear on the flank(s) of the tool below the cutting edge (called flank wear) or wear on the rake face of the tool (called *crater wear*) or both.
2. *Chemical failures*, which include wear on the rake face of the tool (called *crater wear)* are rapid, usually unpredictable, and often catastrophic failures resulting from abrupt, premature death of a tool.





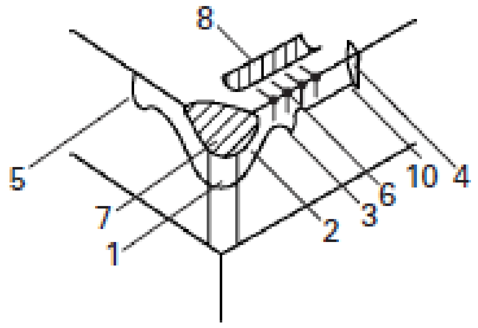
Cross section AA

Tool Failure and Too Life



- ➢ ***Abrasion.*** This is a mechanical wearing action caused by hard particles in the work material gouging and removing small portions of the tool. This abrasive action occurs in both flank wear and crater wear; it is a significant cause of flank wear.
- ➢ ***Adhesion.*** When two metals are forced into contact under high pressure and temperature, adhesion or welding occur between them. These conditions are present between the chip and the rake face of the tool. As the chip flows across the tool, small particles of the tool are broken away from the surface, resulting in attrition of the surface.
- ➢ ***Diffusion.*** This is a process in which an exchange of atoms takes place across a close contact boundary between two materials (Section 4.3). In the case of tool wear, diffusion occurs at the tool–chip boundary, causing the tool surface to become depleted of the atoms responsible for its hardness. As this process continues, the tool surface becomes more susceptible to abrasion and adhesion. Diffusion is believed to be a principal mechanism of crater wear.
- ➢ ***Chemical reactions.*** The high temperatures and clean surfaces at the tool–chip interface in machining at high speeds can result in chemical reactions, in particular, oxidation, on the rake face of the tool. The oxidized layer, being softer than the parent tool material, is sheared away, exposing new material to sustain the reaction process.
- ➢ ***Plastic deformation.*** Another mechanism that contributes to tool wear is plastic deformation of the cutting edge. The cutting forces acting on the cutting edge at high temperature cause the edge to deform plastically, making it more vulnerable to abrasion of the tool surface. Plastic deformation contributes mainly to flank wear.

Tool Failure and Too Life



No.	Failure	Cause	
1-3	Flank wear	Physical	Due to the abrasive effect of hard grains contained in the work material
4-5	Groove		Due to wear at the DCL or outer edge of the cut
6	Chipping		Fine chips caused by high-pressure cutting, chatter, vibration, etc.
7	Partial fracture		Due to the mechanical impact when an excessive force is applied to the cutting edge
8	Crater wear	Chemical	Carbide particles are removed due to degradation of tool performances and chemical reactions at high temperature
9	Deformation		The cutting edge is deformed due to its softening at high temperature
10	Thermal crack		Thermal fatigue in the heating and cooling cycle with interrupted cutting
1	Built-up edge		A portion of the workpiece material adheres to the insert cutting edge

Tool Failure and Too Life

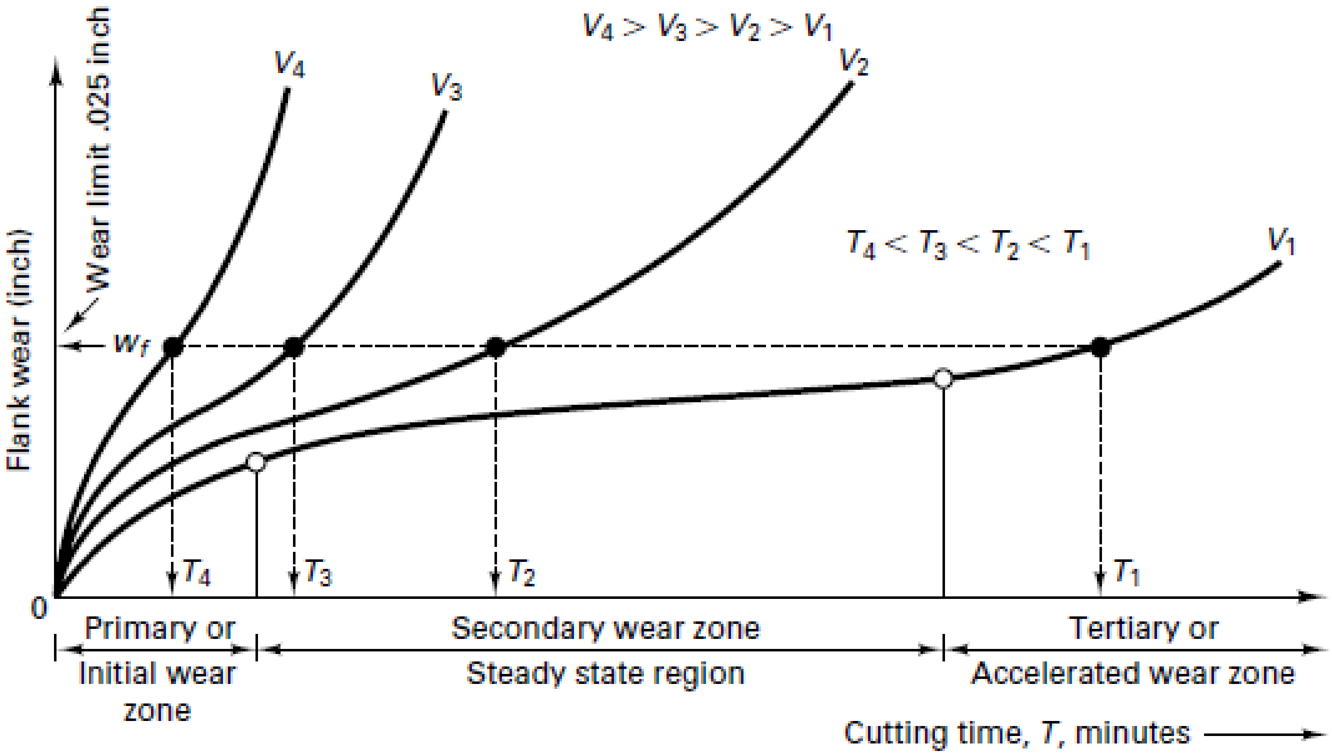
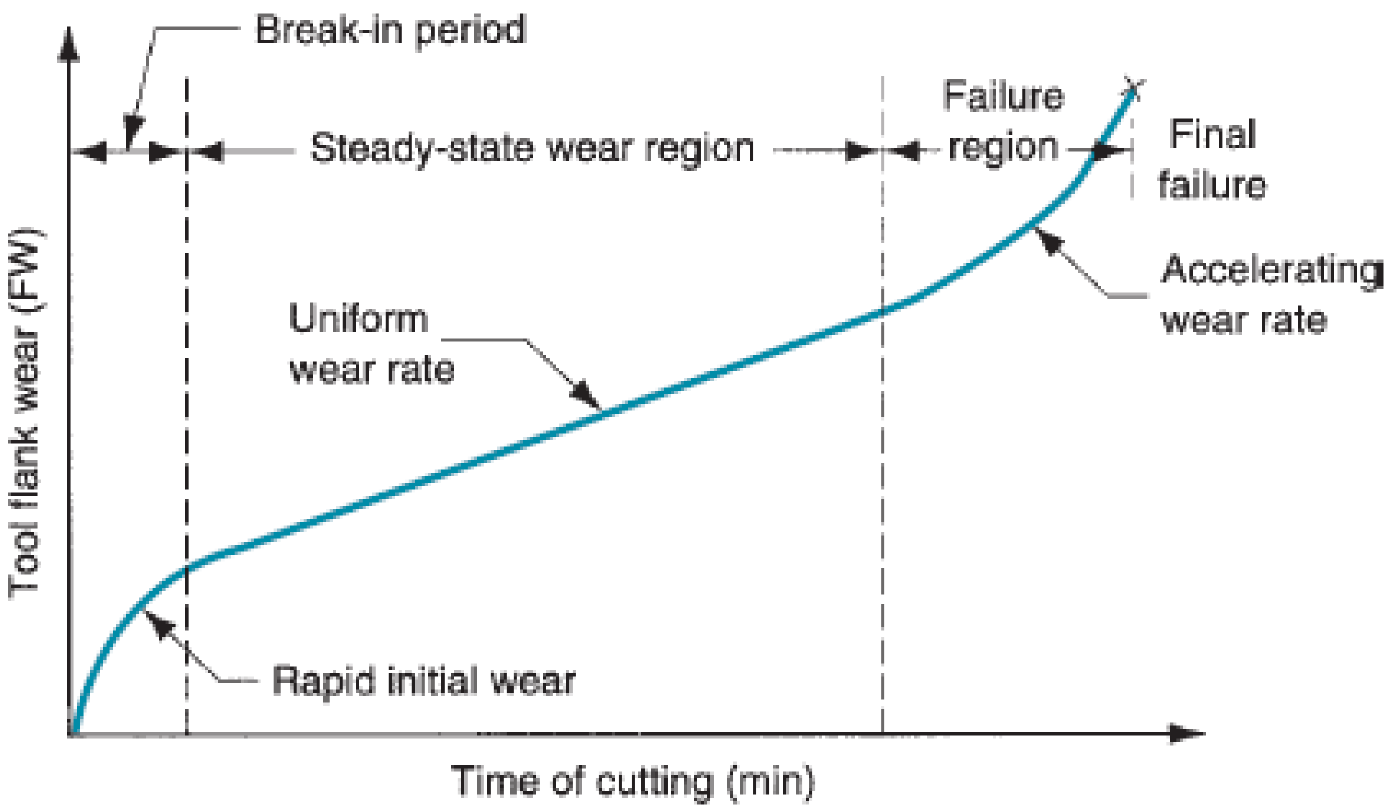


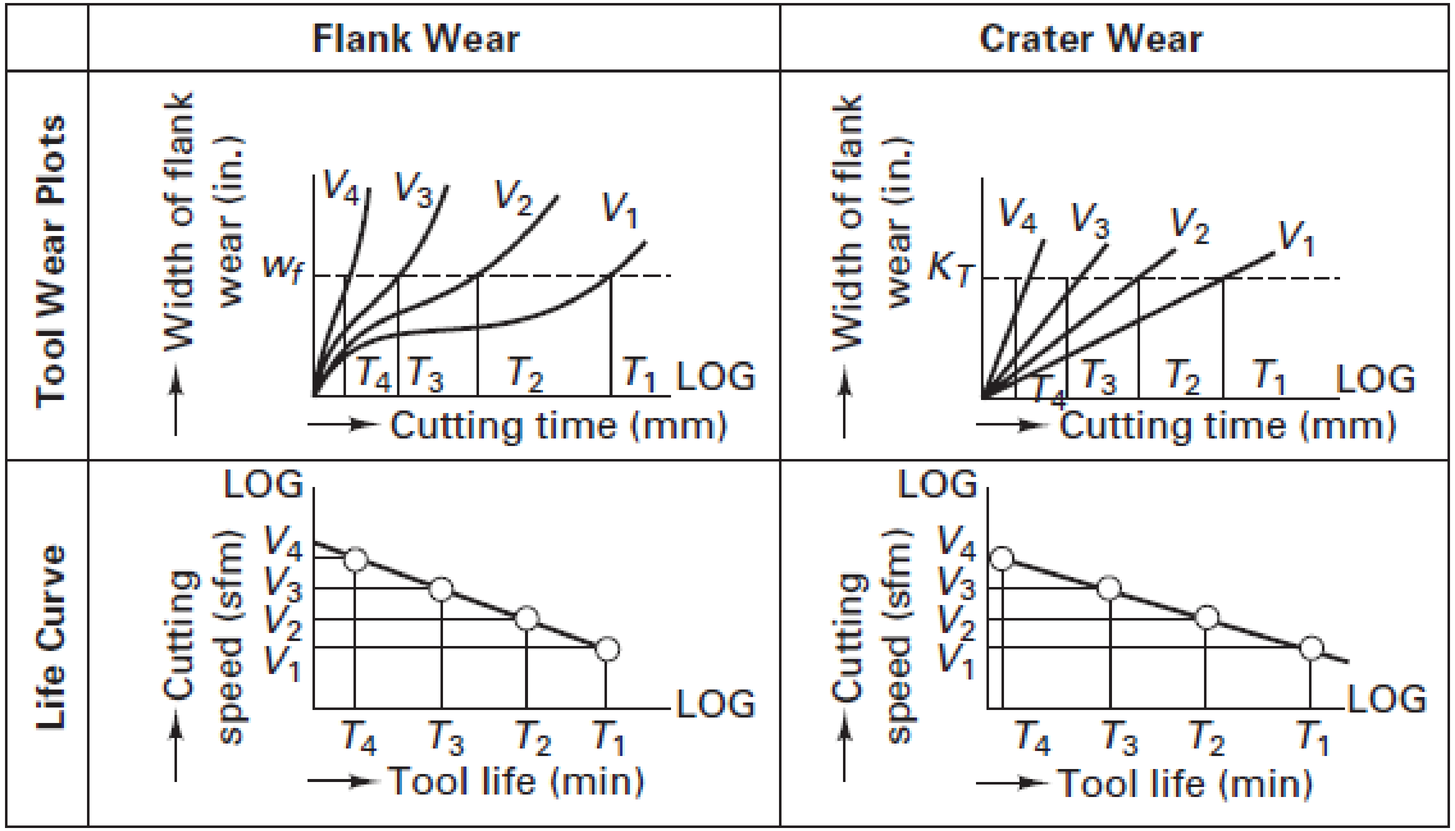
FIGURE 21-17 Typical tool wear curves for flank wear at different velocities. The initial wear is very fast, then it evens out to a more gradual pattern until the limit is reached; after that, the wear substantially increases.

Tool life

Tool life is defined as the length of cutting time that the tool can be used



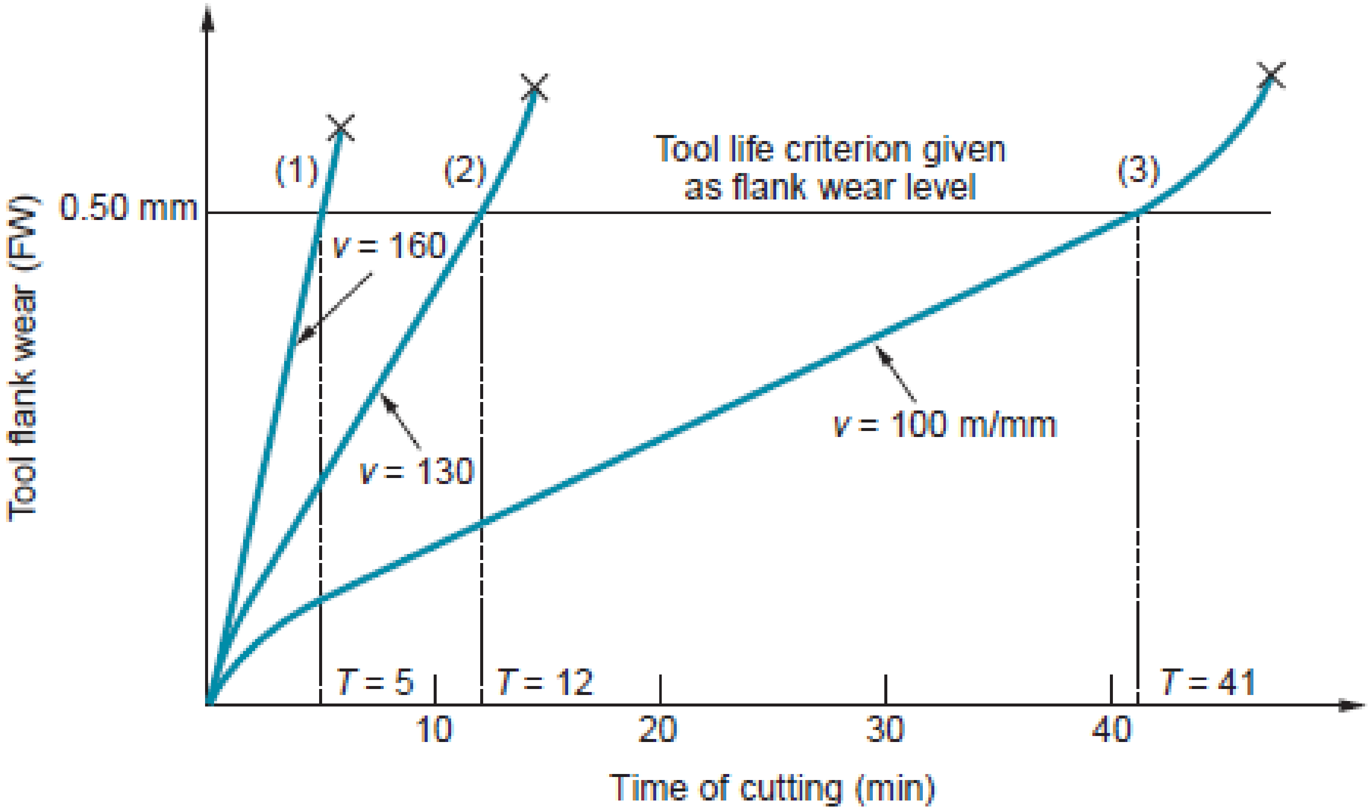
Tool Failure and Too Life



$$VT^n = \text{constant} = C$$

This equation is called the Taylor tool life equation

Tool life



Tool flank wear (FW)
0.50 mm
(1)
(2)
(3)
Tool life criterion given
as flank wear level
v = 160
v = 130
v = 100 m/mm
T = 5
T = 12
T = 41
10
20
30
40
Time of cutting (min)

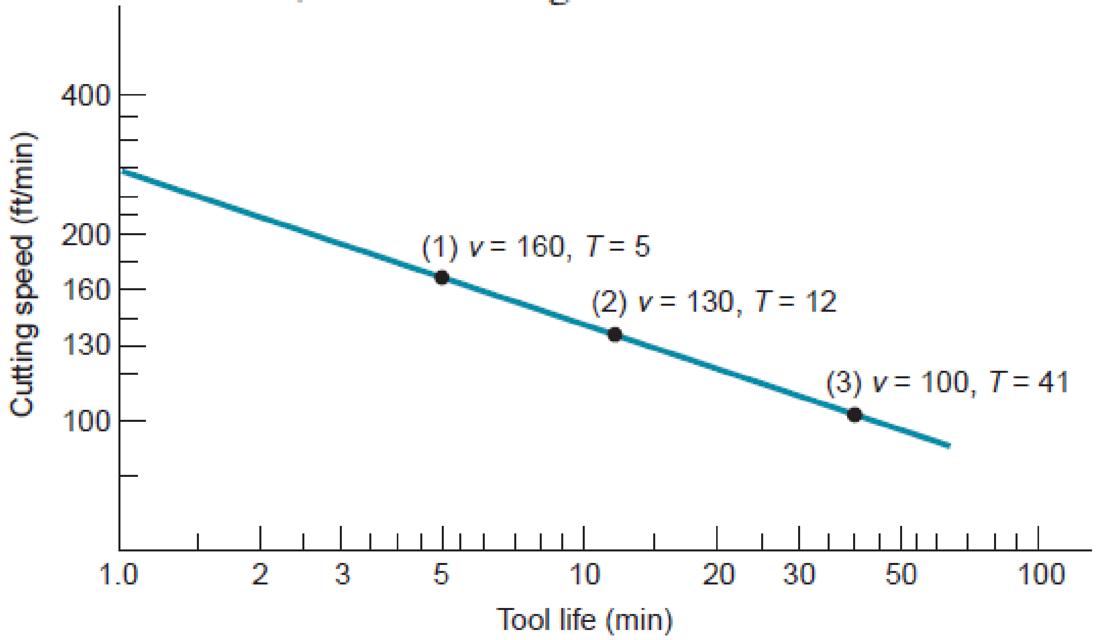
Tool Failure and Too Life

TABLE 21-5 Tool Life Information for Various Materials and Conditions

				Size of Cut (in.)			$VT^n = C$	
Source	Tool Material	Geometry	Workpiece Material	Depth	Feed	Cutting Fluid	n	C
1	High-carbon steel	8.14, 6.6, 6.15, 3/64	Yellow brass (.60 Cu,	.050	.0255	Dry	.081	242
			40 Zn, 85 NI. .006 Pb)	.100	.0127	Dry	.096	299
1	High-carbon steel	8.14, 6.6, 6.15, 3/64	Bronze (.9 Cu, .1.5n)	.050	.0255	Dry	.086	190
				.100	.0127	Dry	.111	232
1	HSS-18-4-1	8.14, 6.6, 6.15, 3/64	Cast Iron 160 Bhn	.050	.0255	Dry	.101	172
			Cast iron, Nickel, 164 Bhn	.050	.0255	Dry	.111	186
			Cast iron, NI-Cr, 207 Bhn	.050	.0255	Dry	.088	102
1	HSS-18-4-1	8.14, 6.6, 6.15, 3/64	Stell, SAE B1113 C.D.	.050	.0127	Dry	.080	260
			Stell, SAE B1112 C.D.	.050	.0127	Dry	.105	225
			Stell, SAE B1120 C.D.	.050	.0127	Dry	.100	270
			Stell, SAE B1120 + Pb C.D.	.050	.0127	Dry	.060	290
			Stell, SAE B1035 C.D.	.050	.0127	Dry	.110	130
			Stell, SAE B1035 + Pb C.D.	.050	.0127	Dry	.110	147
1	HSS-18-4-1	8.14, 6.6, 6.15, 3/64	Stell, SAE 1045 C.D.	.100	.0127	Dry	.110	192
		8.14, 6.6, 6.13, 3/66	Stell, SAE 2340 185 Bhn	.100	.0125	Dry	.147	143
		8.14, 6.6, 6.15, 3/64	Stell, SAE 2345 198 Bhn	.050	.0255	Dry	.105	126
		8.14, 6.6, 6.15, 3/64	Stell, SAE 3140 190 Bhn	.100	.0125	Dry	.160	178
1	HSS-18-4-1	8.14, 6.6, 6.15, 3/64	Stell, SAE 4350 363 Bhn	.0125	.0127	Dry	.080	181
			Stell, SAE 4350 363 Bhn	.0125	.0255	Dry	.125	146
			Stell, SAE 4350 363 Bhn	.0250	.0255	Dry	.125	95
			Stell, SAE 4350 363 Bhn	.100	.0127	Dry	.110	78
			Stell, SAE 4350 363 Bhn	.100	.0255	Dry	.110	46
1	HSS-18-4-1	8.14, 6.6, 6.15, 3/64	Stell, SAE 4140 230 Bhn	.050	.0127	Dry	.180	190
			Stell, SAE 4140 271 Bhn	.050	.0127	Dry	.180	159
			Stell, SAE 6140 240 Bhn	.050	.0127	Dry	.150	197

Tool life

Taylor Tool Life Equation If the tool life values for the three wear curves in Figure 23.4 are plotted on a natural log–log graph of cutting speed versus tool life, the resulting relationship is a straight line



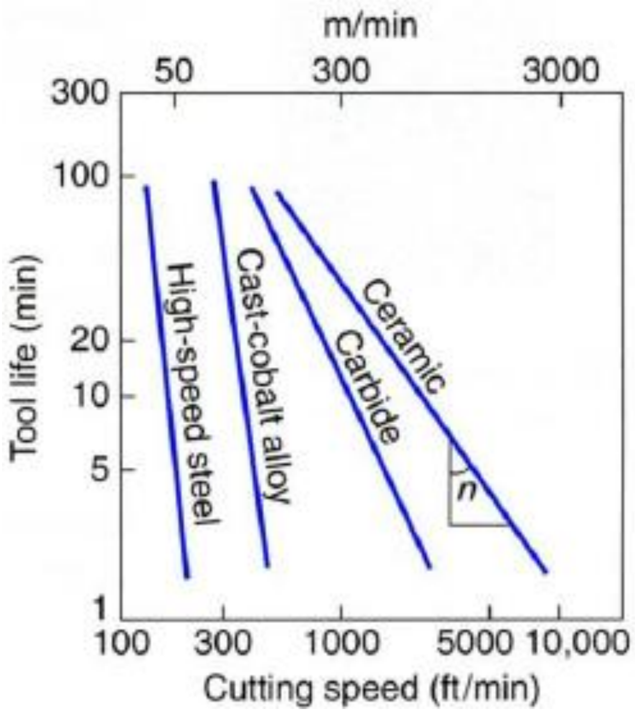
$$vT^n = C$$

where v = cutting speed, m/min (ft/min); T = tool life, min; and n and C are parameters whose values depend on feed, depth of cut, work material, tooling (material in particular), and the tool life criterion used.

The value of n is relative constant for a given tool material, whereas the value of C depends on tool material, work material, and cutting conditions.

C represents the cutting speed that results in a 1-min tool life.

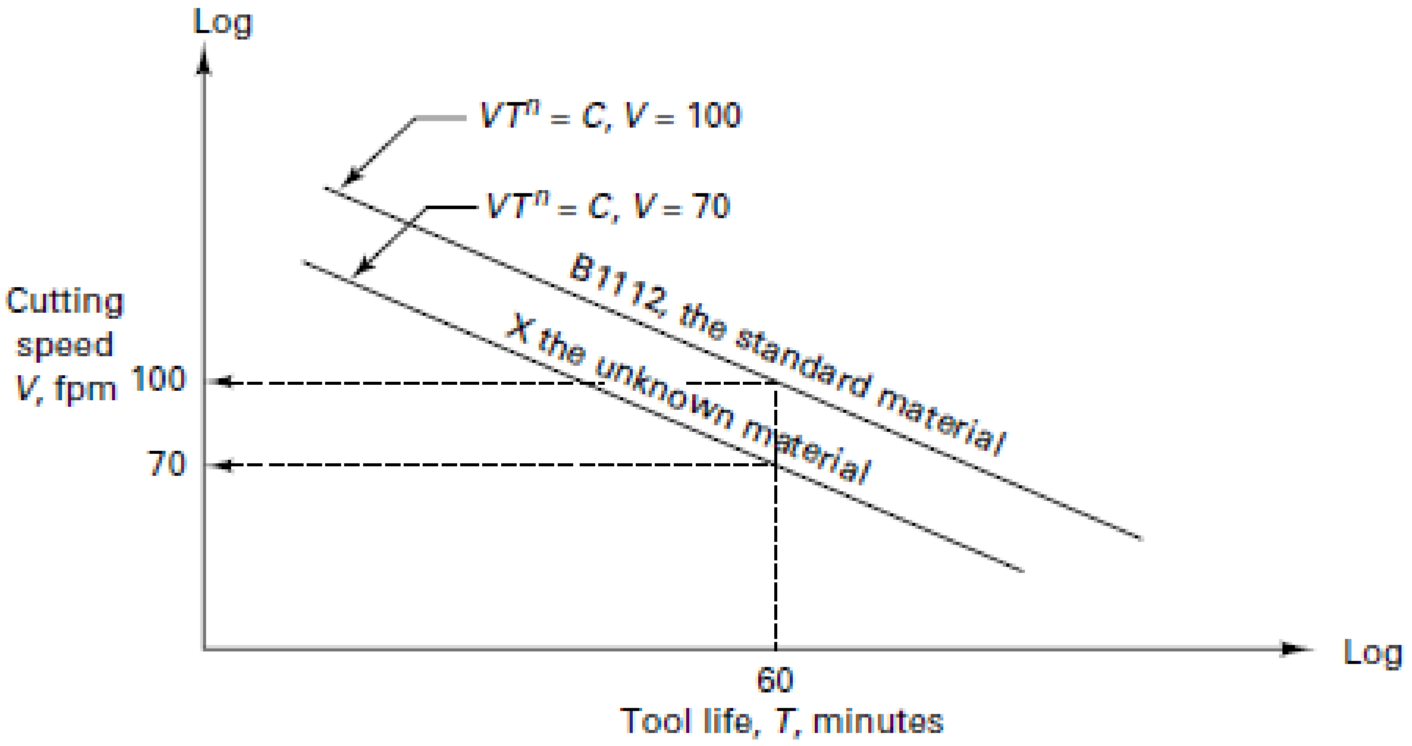
Tool Life



Tool-life curves for a variety of cutting-tool materials. The negative reciprocal of the slope of these curves is the exponent n in the Taylor tool-life equation (21.25), and C is the cutting speed

$$VT^n = C$$

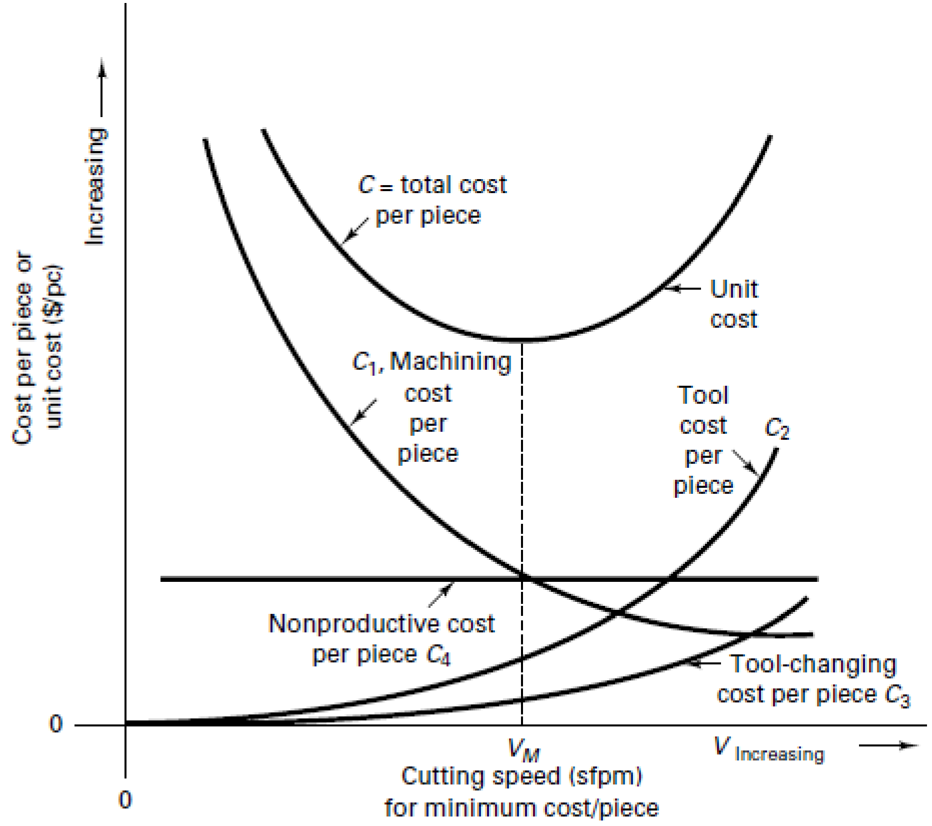
$$T = \left(\frac{C}{V}\right)^{1/n}$$



Log
$VT^n = C, V = 100$
$VT^n = C, V = 70$
B1112, the standard material
X the unknown material
Cutting speed V, fpm
100
70
Log
60
Tool life, T, minutes

Economy Of Machining

For a turning operation, the total cost per piece C equals



$$C = C_1 + C_2 + C_3 + C_4 \tag{21-7}$$

$= \text{Machining cost} + \text{tooling cost} + \text{tool-changing cost} + \text{handling cost per piece}$

Expressing each of these cost terms as a function of cutting velocity will permit the summation of all the costs.

$C_1 = T_m \times C_o$ where C_o = operating cost ($/min)
T_m = cutting time (min/piece)

$C_2 = \left(\frac{T_m}{T}\right) C_t$ where T = tool life (min/tool)
C_t = initial cost of tool ($)

$C_3 = t_c \times C_o \left(\frac{T_m}{T}\right)$ where t_c = time to change tool (min)

$\frac{T_m}{T}$ = number of tool changes per piece

C_4 labor, overhead, and machine tool costs consumed while part is being loaded or unloaded, tools are being advanced, machine has broken down, and so on.

Since $T_m = L/Nf_r$ for turning
$= \pi DL/12Vf_r$

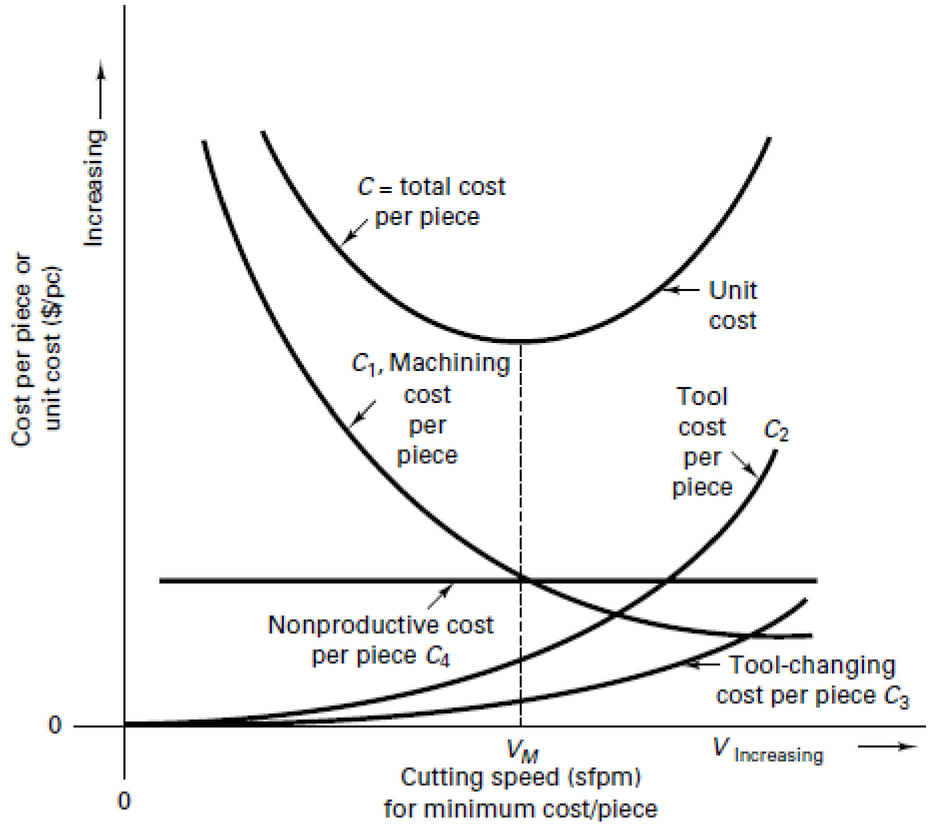
and $T = (K/V)^{1/n}$, by rewriting equation 21-3,

and using "K" for the constant "C", the cost per unit, C, can be expressed in terms of V:

$$C = \frac{L\pi DC_o}{12Vf_r} + \frac{C_t V^{1/n}}{K^{1/n}} + \frac{t_c C_o V^{1/n}}{K^{1/n}} + C_4 \tag{21-8}$$

To find the minimum, take $dc/dV = 0$ and solve for V:

$$V_m = \left[\frac{1}{n} - 1\right]\left[\frac{C_t + (C_o \times t_c)}{C_o}\right]$$



Problem 1

Using the Taylor equation for tool wear and letting $n = 0.3$, calculate the percentage increase in tool life if the cutting speed is reduced by (a) 30% and (b) 60%.

Problem 2

Tool life tests on a lathe have resulted in the following data: (1) at a cutting speed of 375 ft/min, the tool life was 5.5 min; (2) at a cutting speed of 275 ft/min, the tool life was 53 min. (a) Determine the parameters n and C in the Taylor tool life equation. (b) Based on the n and C values, what is the likely tool material used in this operation? (c) Using your equation, compute the tool life that corresponds to a cutting speed of 300 ft/min. (d) Compute the cutting speed that corresponds to a tool life T = 10 min.

TABLE 23.2 Representative values of *n* and *C* in the Taylor tool life equation, Eq. (23.1), for selected tool materials.

		C			
		Nonsteel Cutting		Steel Cutting	
Tool Material	n	m/min	(ft/min)	m/min	ft/min
Plain carbon tool steel	0.1	70	(200)	20	60
High-speed steel	0.125	120	(350)	70	200
Cemented carbide	0.25	900	(2700)	500	1500
Cermet	0.25			600	2000
Coated carbide	0.25			700	2200
Ceramic	0.6			3000	10,000

Problem 3

Tool life tests in turning yield the following data: (1) when cutting speed is 100 m/min, tool life is 10 min; (2) when cutting speed is 75 m/min, tool life is 30 min. (a) Determine the n and C values in the Taylor tool life equation. Based on your equation, compute (b) the tool life for a speed of 110 m/min, and (c) the speed corresponding to a tool life of 15 min.

Problem 4

Turning tests have resulted in 1-min tool life at a cutting speed = 4.0 m/s and a 20-min tool life at a speed = 2.0 m/s. (a) Find the *n* and *C* values in the Taylor tool life equation. (b) Project how long the tool would last at a speed of 1.0 m/s.

Problem 5

A 15.0-in-by-2.0-in-workpart is machined in a face milling operation using a 2.5 in diameter fly cutter with a single carbide insert. The machine is set for a feed of 0.010 in/tooth and a depth of 0.20 in. If a cutting speed of 400 ft/min is used, the tool lasts for 3 pieces. If a cutting speed of 200 ft/min is used, the tool lasts for 12 parts. Determine the Taylor tool life equation.

Problem 6

In a production turning operation, the workpart is 125 mm in diameter and 300 mm long. A feed of 0.225 mm/rev is used in the operation. If cutting speed = 3.0 m/s, the tool must be changed every 5 workparts; but if cutting speed = 2.0 m/s, the tool can be used to produce 25 pieces between tool changes. Determine the Taylor tool life equation for this job.

Problem 7

The outside diameter of a cylinder made of titanium alloy is to be turned. The starting diameter is 400 mm and the length is 1100 mm. The feed is 0.35 mm/rev and the depth of cut is 2.5 mm. The cut will be made with a cemented carbide cutting tool whose Taylor tool life parameters are: $n = 0.24$ and $C = 450$. Units for the Taylor equation are min for tool life and m/min for cutting speed. Compute the cutting speed that will allow the tool life to be just equal to the cutting time for this part.

Problem 8

The outside diameter of a roll for a steel rolling mill is to be turned. In the final pass, the starting diameter = 26.25 in and the length = 48.0 in. The cutting conditions will be: feed = 0.0125 in/rev, and depth of cut = 0.125 in. A cemented carbide cutting tool is to be used and the parameters of the Taylor tool life equation for this setup are: $n = 0.25$ and $C = 1300$. Units for the Taylor equation are min for tool life and ft/min for cutting speed. It is desirable to operate at a cutting speed so that the tool will not need to be changed during the cut. Determine the cutting speed that will make the tool life equal to the time required to complete the turning operation.

Problem 9

In a production turning operation, the steel workpart has a 4.5 in diameter and is 17.5 in long. A feed of 0.012 in/rev is used in the operation. If cutting speed = 400 ft/min, the tool must be changed every four workparts; but if cutting speed = 275 ft/min, the tool can be used to produce 15 pieces between tool changes. A new order for 25 pieces has been received but the dimensions of the workpart have been changed. The new diameter is 3.5 in, and the new length is 15.0 in. The work material and tooling remain the same, and the feed and depth are also unchanged, so the Taylor tool life equation determined for the previous workparts is valid for the new parts. Determine the cutting speed that will allow one cutting tool to be used for the new order.

Problem (Class Activity 1)

From a raw material of 100 mm length and 10 mm diameter, a component having length 100 mm and diameter 8 mm is to be produced using a cutting speed of 31.41 m/min and a feed of 0.7 mm/revolution. How many times we have to re-sharpen or regrind, if 1000 work-pieces are to be produced. In the Taylor's expression use constants as n = 1.2 and C = 180

Problem (Class Activity 2)

While turning a carbon steel cylinder bar of length 3 m and diameter 0.2 m at a feed of 0.5 mm/revolution with an HSS tool, one of the two available cutting speeds is to be selected. These two cutting speeds are 100 m/min and 57 m/min. The tool life corresponding to the speed of 100 m/min is known to be 16 minutes with n=0.5. The cost of machining time, setup time and unproductive time together is Rs.1/sec. The cost of one tool re-sharpening is Rs.20.

Find the total cost in both cases.

Problem (Class Activity 3)

The work part in a turning operation is 88 mm in diameter and 400 mm long. A feed of 0.25 mm/rev is used in the operation. If cutting speed = 3.5 m/s, the tool must be changed every 3 work parts; but if cutting speed = 2.5 m/s, the tool can be used to produce 20 pieces between tool changes. Determine the cutting speed that will allow the tool to be used for 50 parts between tool changes.