Tool wear and tool life

Lecture-02-Part-2

Tool Life: Wear and Failure

Tool wear is gradual process; created due to:

1- High localized stresses at the tip of the tool

2- High temperatures (especially along rake face)

3- Sliding of the chip along the rake face

4- Sliding of the tool along the newly cut workpiece surface

The rate of tool wear depends on

- tool and workpiece materials
- tool geometry
- process parameters
- cutting fluids
- characteristics of the machine tool

Tool Life: Wear and Failure

- Tool wear and the changes in tool geometry and they are classified as:

a) *Flank wear*

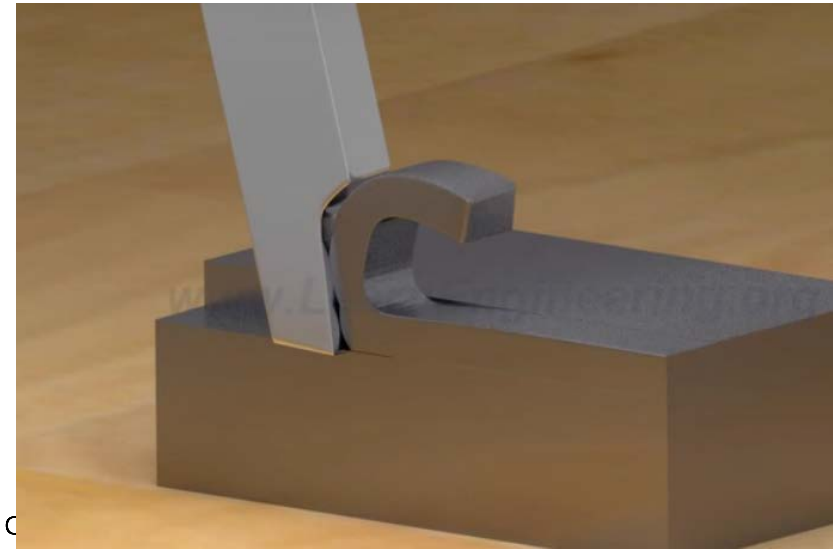
b) *Crater wear*

c) *Nose wear*

d) *Notching plastic deformation of the tool tip*

e) *Chipping*

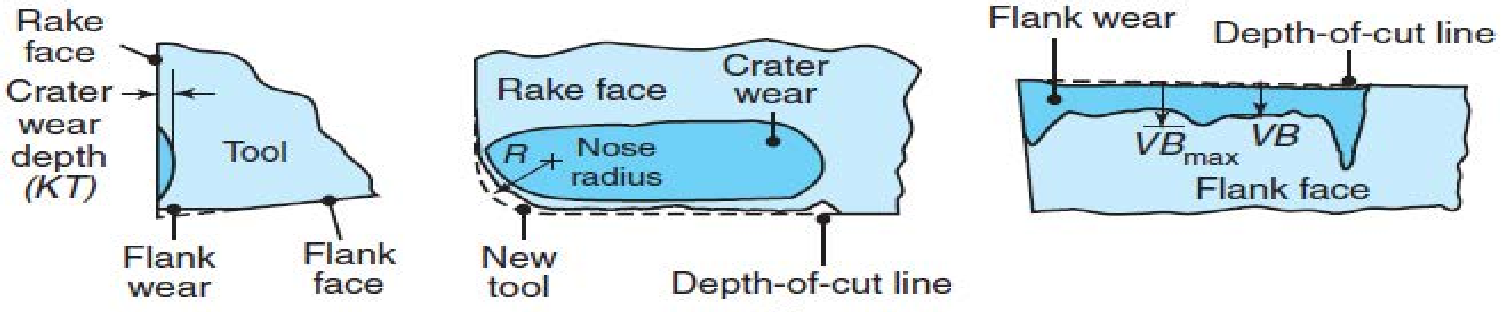
f) *Gross fracture*



Tool Life: Wear and Failure

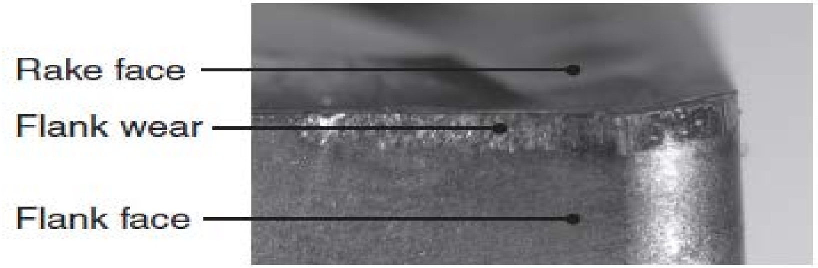
a) **Features of tool wear** in a turning operation. **VB**: indicates average flank wear

b) – e) **Examples of wear in cutting tools**



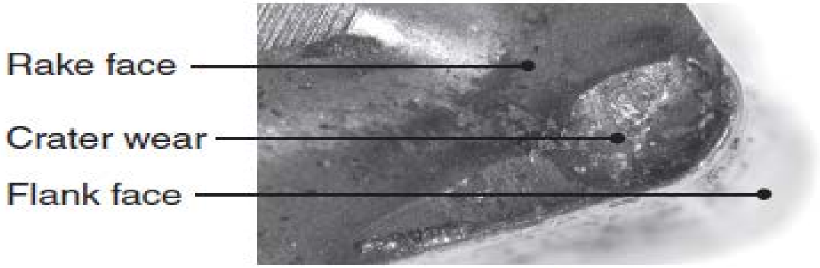
(a)

b) **Flank wear**



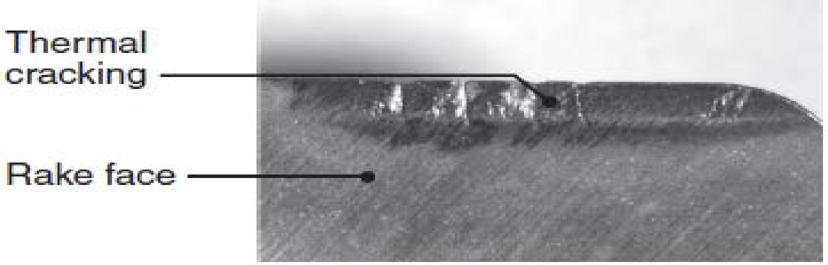
(b)

c) **Crater wear**



(c)

d) **Thermal cracking**



(d)

e) **Flank wear** and built-up edge (**BUE**)

(e)

Also see: http://www.sandvik.coromant.com/en-us/knowledge/general_turning/troubleshooting-

Tool Life: Wear and Failure:

Flank Wear

Flank wear occurs on the relief (flank) face of the tool

It is due to

- rubbing of the tool along machined surface (⇒ adhesive/abrasive wear)
- high temperatures (adversely affecting tool-material properties)

Taylor tool life equation :

$$VT^n = C$$

Ranges of *n* Values for the Taylor Equation (21.20a) for Various Tool Materials	
High-speed steels	0.08–0.2
Cast alloys	0.1–0.15
Carbides	0.2–0.5
Coated carbides	0.4–0.6
Ceramics	0.5–0.7

V = cutting speed [*m/minute*]
T = time [*minutes*] taken to develop a certain flank **wear land** (VB)
n = an exponent that generally depends on tool material (see above)
C = constant; depends on cutting conditions
note, magnitude of C = cutting speed at *T* = 1 min (can you show how?)
Also note: *n*, *c* : determined experimentally

Tool Life: Wear and Failure

Flank Wear

- For turning, it can be modified to

$$VT^n d^x f^y = C$$

- Since *x* and *y* must be determined experimentally for each cutting condition, we have

$$T = C^{1/n} V^{-1/n} d^{x/n} f^{y/n}$$

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- To obtain a constant tool life:

1. The cutting speed must be decreased
2. Depending on the exponents

Tool Life: Wear and Failure:

Flank Wear

Allowable Wear Land

- Cutting tools need to be replaced when:

1. Surface finish of the machined workpiece begins to deteriorate
2. Cutting forces increase significantly
3. Temperature rises significantly

Allowable Average Wear Land (see *VB* in Fig. 21.15a) for Cutting Tools in Various Machining Operations

	Allowable wear land (mm)	
Operation	High-speed steel tools	Carbide tools
Turning	1.5	0.4
Face milling	1.5	0.4
End milling	0.3	0.3
Drilling	0.4	0.4
Reaming	0.15	0.15

Note: Allowable wear for ceramic tools is about 50% higher. Allowable notch wear, VB_{max}, is about twice that for VB.

Tool-life Curves

The measurement of the amount of crater wear is not as simple as that of the flank wear.

The dependence of the flank wear on the time of the tool operation is shown below.

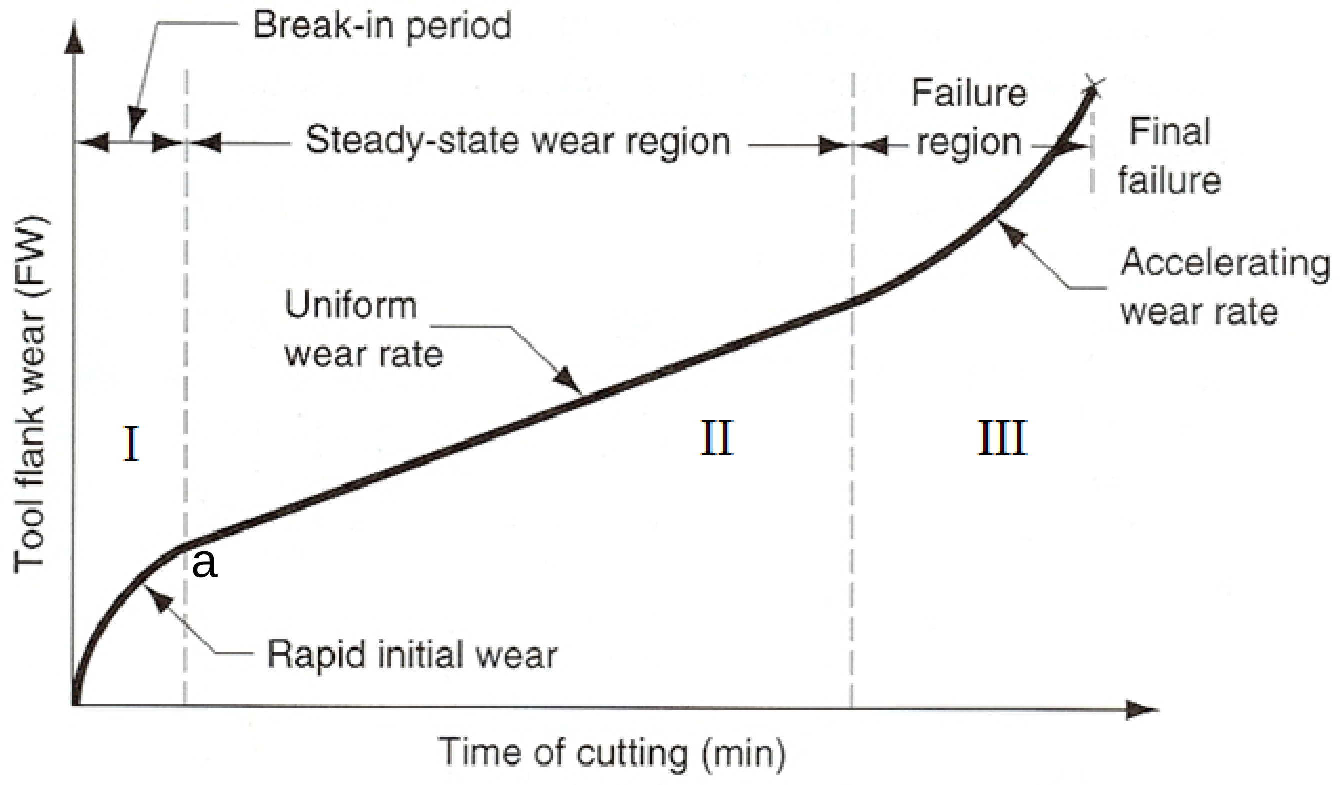


Figure 4.2: Tool wear as a function of cutting time, flank wear is used here as the measure of tool wear.

within interval I:

The flank wear increases rapidly till point “a”. Rapid increase of the wear is due to the unevenness of the newly sharpened edge is being quickly smoothed.

within interval II:

It increases at normal rate and termed as normal wear, and the slope of the wearing curve is dependent upon the cutting conditions such as speed, geometry, work piece material and coolant type.

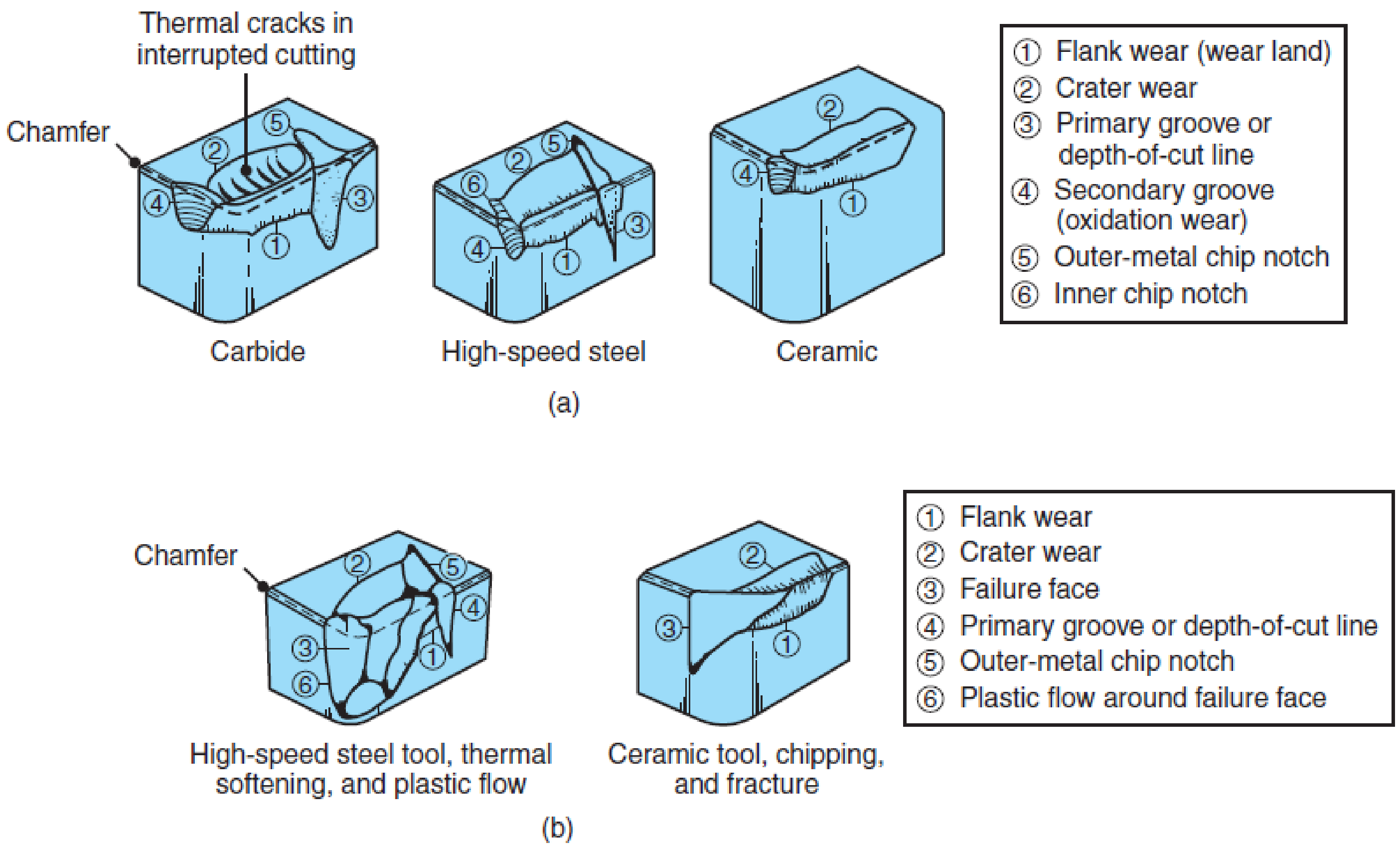
within interval III:

The flank wear increases rapidly till the cutting edge is completely damaged and any control is hardly possible. The reason is the appearance of the flank wear associated with the formation of thermal cracks and plastic deformation.

Tool Life: Wear and Failure:

Crater Wear

- *Crater wear* occurs on the rake face of the tool



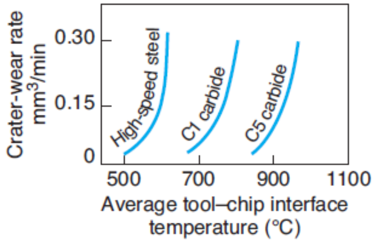
Tool Life: Wear and Failure:

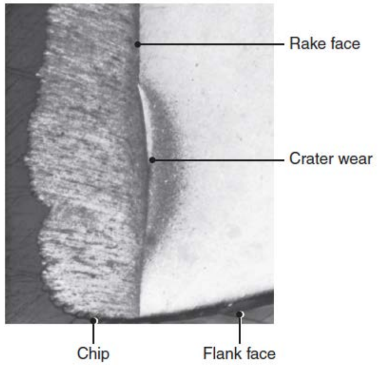
Crater Wear

- Factors influencing crater wear are

1. The temperature at the tool–chip interface
2. The chemical affinity between the tool and workpiece materials

- Diffusion rate increases with increasing temperature, crater wear increases as temperature increases
- Location of the max depth of crater wear, *KT*, coincides with the location of the *max temperature* at the tool–chip interface





Tool Life: Wear and Failure:
Other Types of Wear, Chipping, and Fracture

- *Nose wear* is the rounding of a sharp tool due to mechanical and thermal effects
- It dulls the tool, affects chip formation and causes rubbing of the tool over the workpiece
- Tools also may undergo *plastic deformation* because of temperature rises in the cutting zone
- Tools may undergo *chipping*, where small fragment from the cutting edge of the tool breaks away
- Chipping may occur in a region of the tool where a small crack already exists
- Two main causes of chipping: **Mechanical shock & Thermal fatigue**

Tool life monitoring (cutting edge durability)

The tool life can be expressed in different ways:

1. Actual cutting time to failure.
2. Length of work cut to failure.
3. Volume of material removed to failure.
4. Number of components produced to failure.
5. Cutting speed for a given time of failure.

Factors affecting tool life:

1. Material of machined workpiece.
2. Required surface quality of the workpiece.
3. Tool material.
4. Tool geometry and sharpening condition.
5. Fixation of tool and workpiece.
6. Machining variables such as, speed, feed, and depth of cut.
7. Type of coolant used.
8. Condition of cutting tool with respect to vibrations.

The most important factor affecting the tool life is the cutting speed. Therefore, its effect will be discussed in detail.

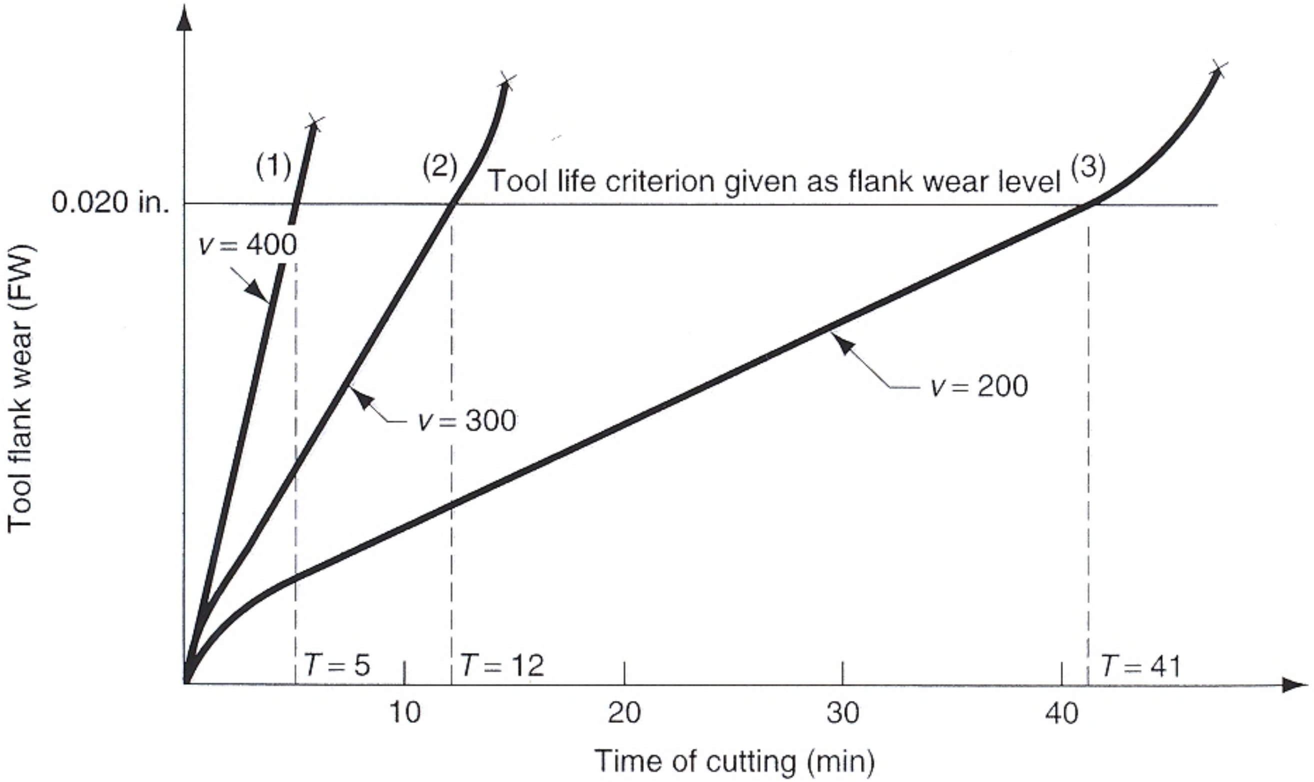


Figure 4.3: Effect of cutting speed on tool flank wear for three cutting speeds. Hypothetical values of speed and tool life are shown for a tool life criterion of 0.020 inch flank wear.

Taylor tool life equation:

If the tool life values for the three wear curves are plotted on a natural log – log graph, cutting speed versus tool life.

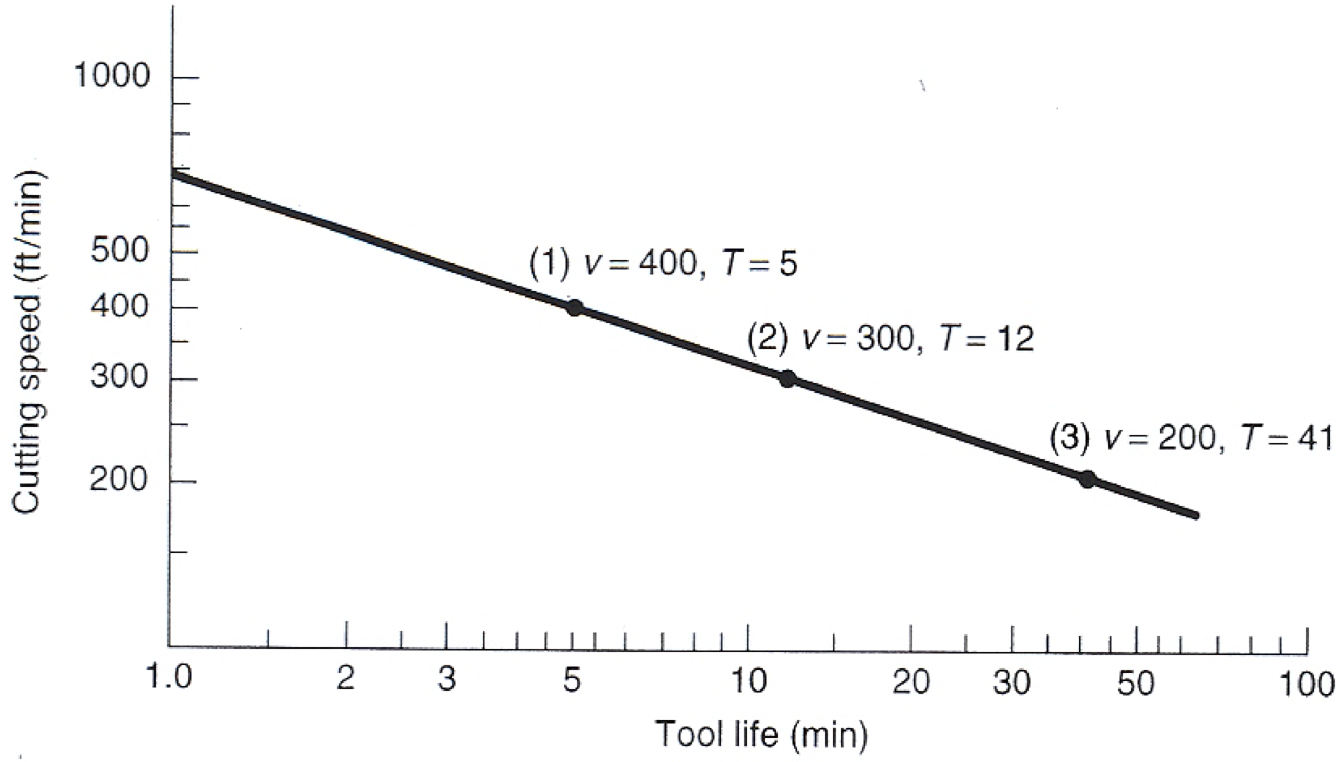


Figure 4.4: Natural log – log plot of cutting speed versus tool life.

The discovery of this relation around 1900 is credited to F.W. Taylor. It can be expressed in equation form and it is called Taylor tool life equation.

$$VT^n = C$$

where:

V = cutting speed (m/min)

T = Tool life (min)

C = a constant representing the cutting speed that results in 1 min tool life

n can be found as following:

$$V_1 T_1^{\ n} = V_2 T_2^{\ n}$$

$$\frac{V_2}{V_1} = \left(\frac{T_1}{T_2} \right)^n$$

$$n = \frac{\log V_2 - \log V_1}{\log T_1 - \log T_2}$$

Tool life criterion in production:

The criterion of Taylor equation is not practical in a factory environment, the following are some alternates that are more convenient to use in production:

1. Changes in the sound emitting from operation.
2. Degradation of the surface finish on work.
3. Complete failure of cutting edge.
4. Workpiece count.
5. Chips become ribbon form or string

Machining economic:

In machining a certain part, we want to determine the parameters that will give us either the minimum cost per part or the maximum production rate.

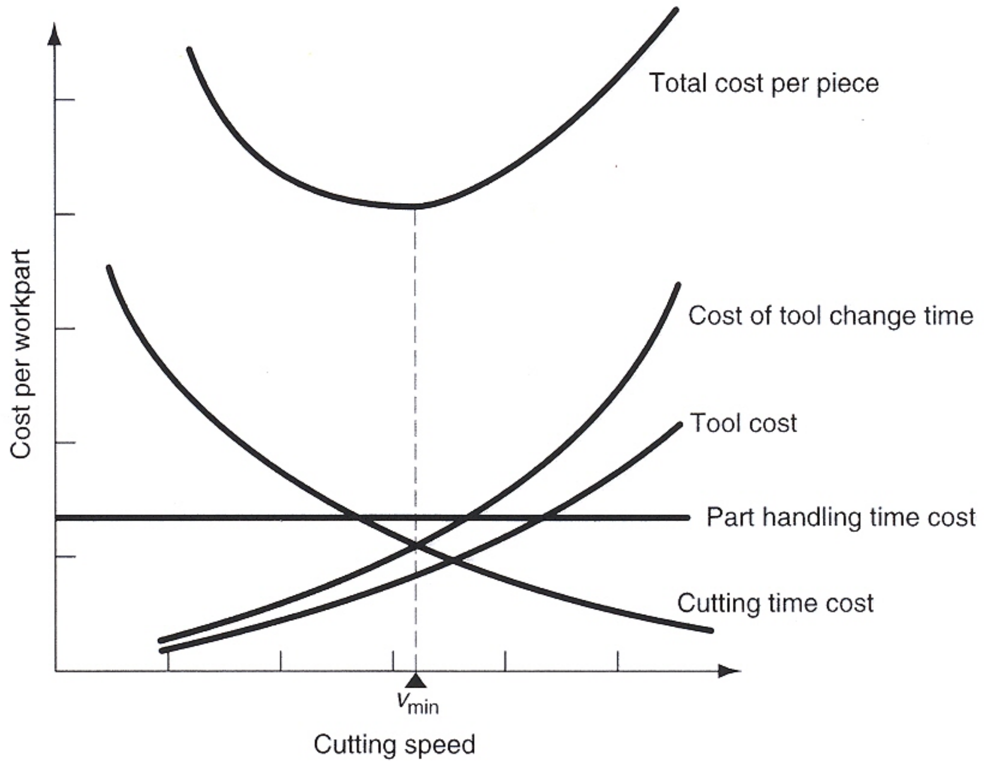


Figure 4.5: Cost per unit for a machining process versus cutting speed.

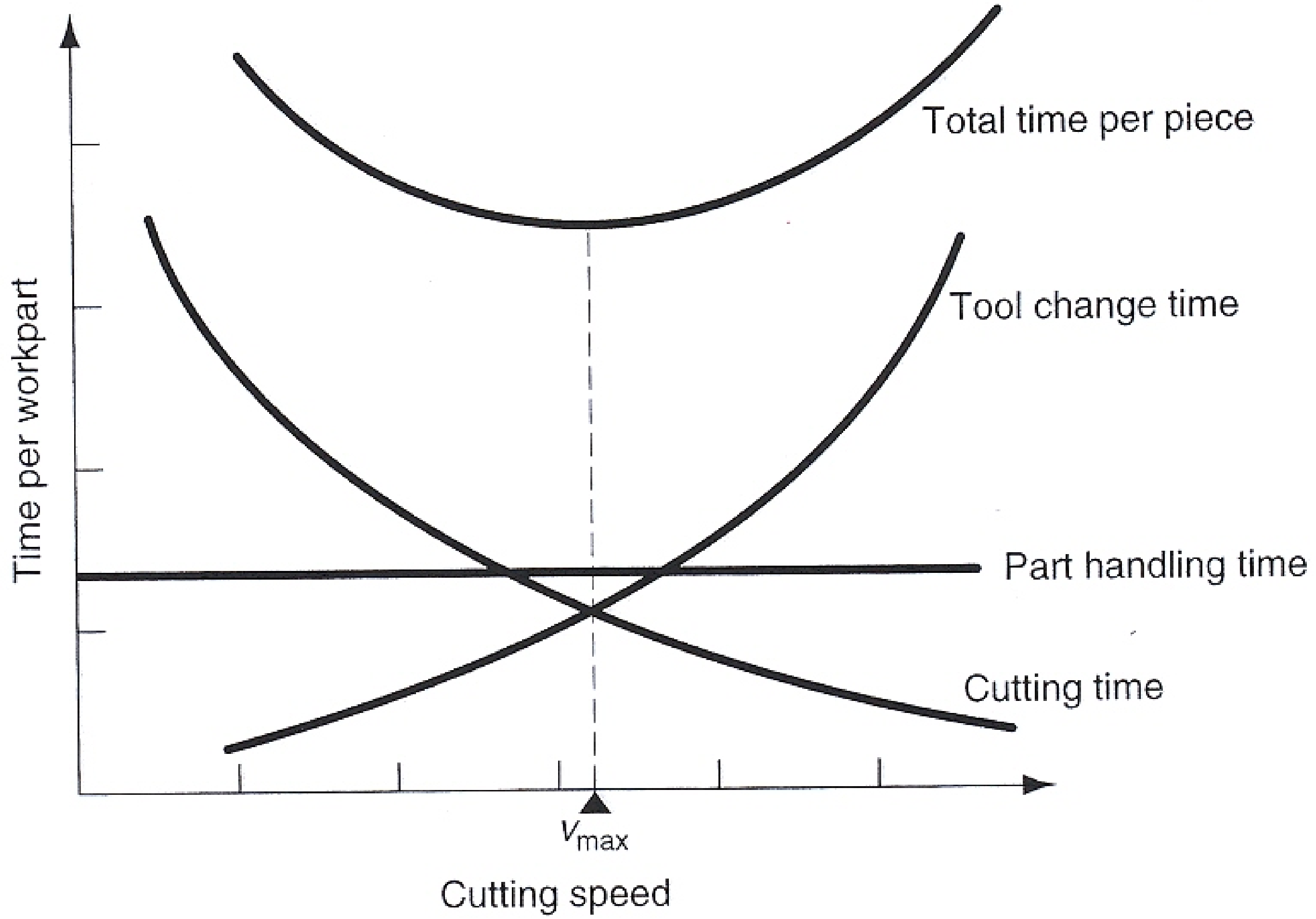


Figure 4.6: Production time versus cutting speed

The time needed to produce a part is:

$$T_p = T_l + T_m + \frac{T_c}{N_p}$$

Where:

T_l = time involved in loading and unloading the part, changing speed and feed rates.

T_m = machining time per part.

T_c = time required to grind the tool.

N_p = number of parts machined per tool ground.

$$T_m = \frac{L}{fN} = \frac{\pi L D}{fV}$$

From tool life equation, we have:

$$VT^n = C$$

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

Where T, is time, in minutes, required to reach a flank wear of certain dimension, after which the tool has to be reground or changed. The number of pieces per tool grind is thus can be obtained as following:

$$N_p = \frac{T}{T_m}$$

or

$$N_p = \frac{fC^{1/n}}{\pi LDV^{(1/n)-1}}$$

In order to find the optimum cutting speed and also the optimum tool life for maximum production, we have to differentiate Tp with respect to V and set it to zero.

$$\frac{\partial T_p}{\partial V}$$

we find that the optimum cutting speed V_{opt} now becomes,

$$V_{opt} = \frac{C}{\{[(1/n)-1]T_c\}^n}$$

and the optimum tool life is,

$$T_{opt} = [(1/n)-1]T_c$$

Problems from sheet