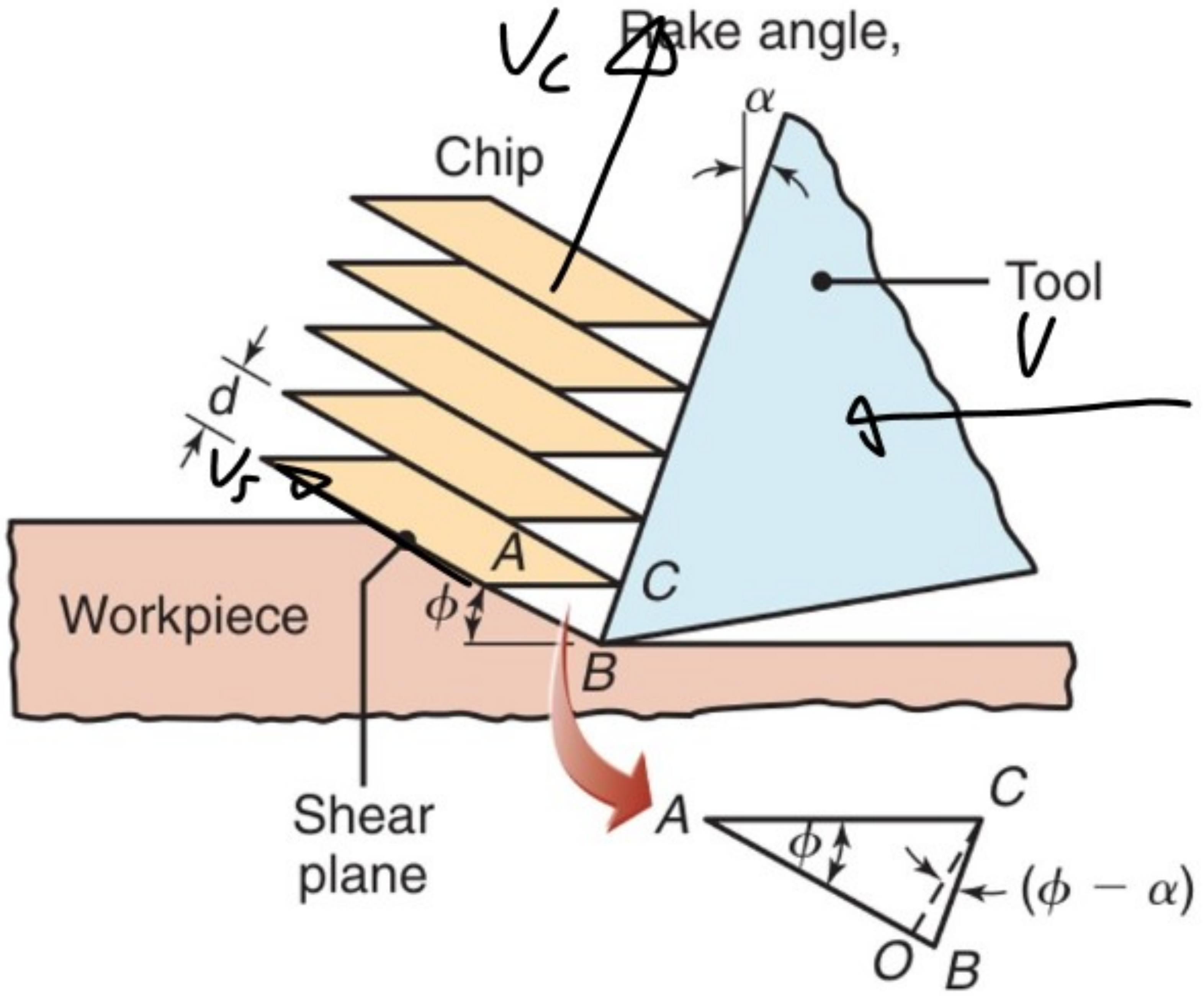
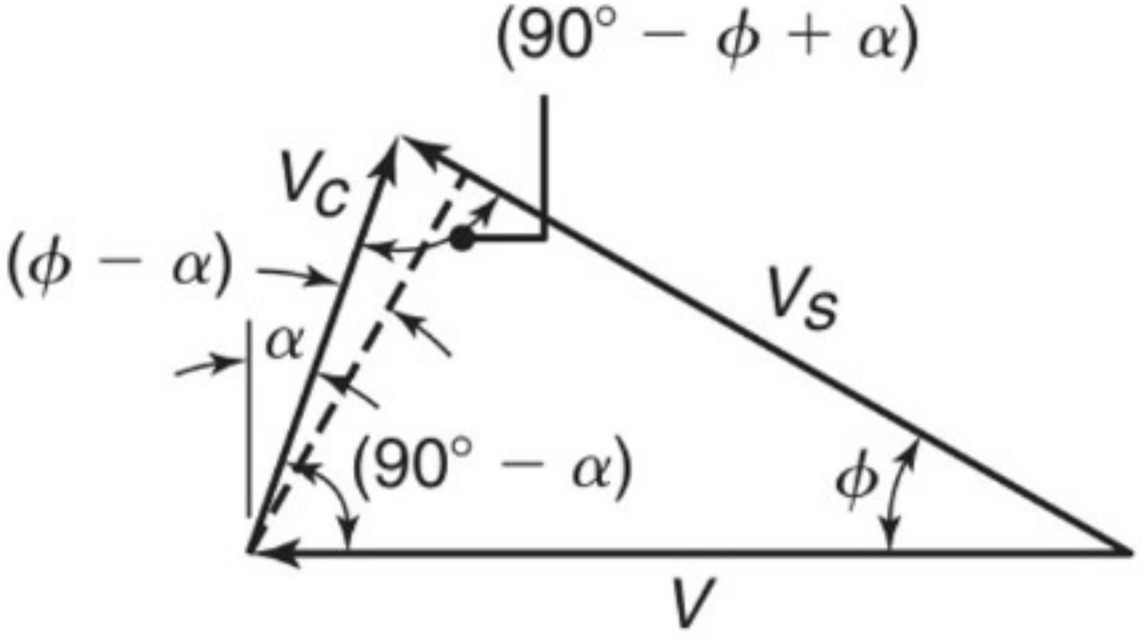
$$\frac{V}{\cos(\phi-\alpha)} = \frac{V_s}{\cos\alpha} = \frac{V_c}{\sin\phi}$$





$$V_s = \frac{V\cos\alpha}{\cos(\phi-\alpha)}$$

Cutting Forces

F_s shearing

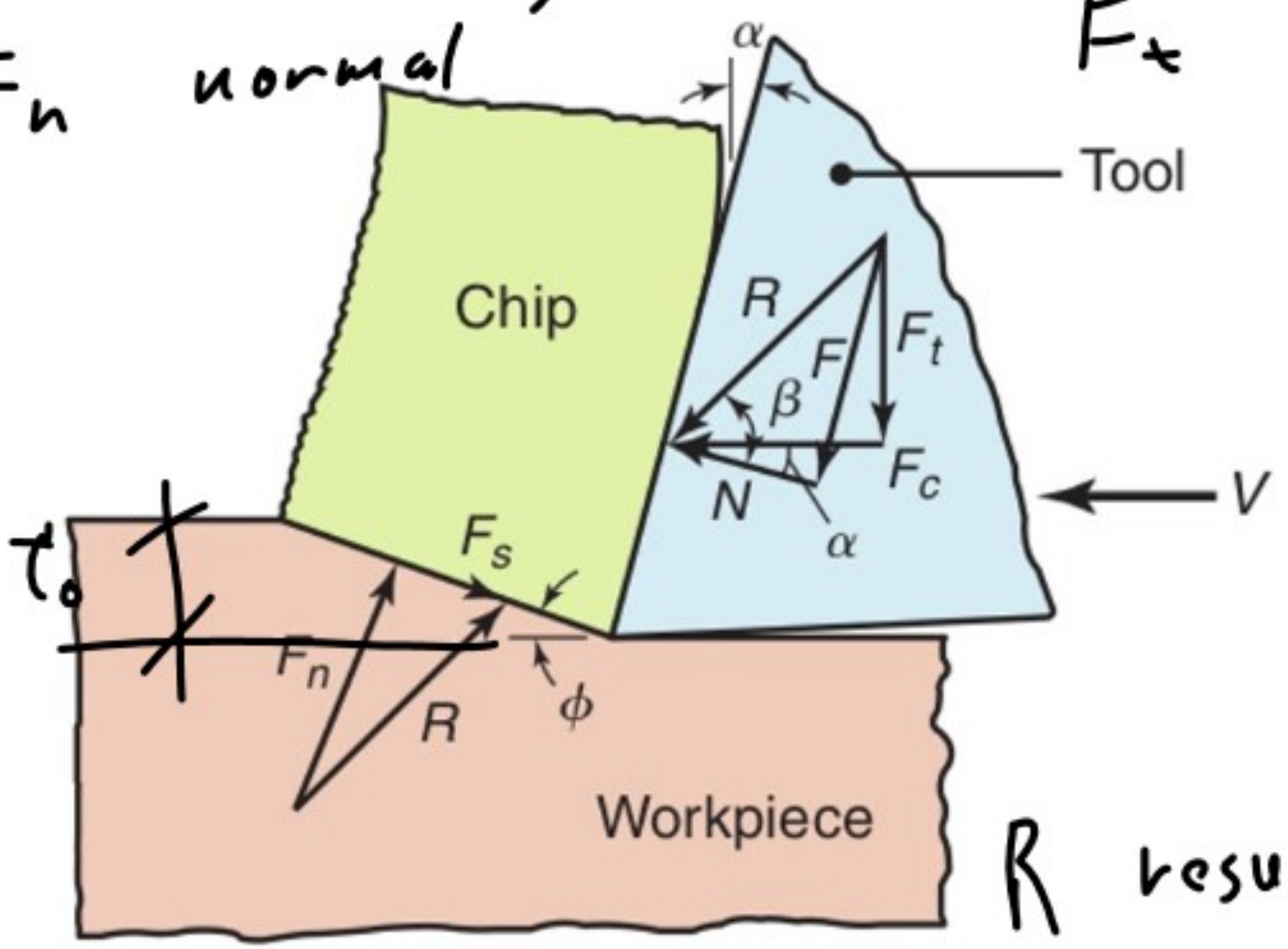
F_n normal

F_c cutting

F_t thrust

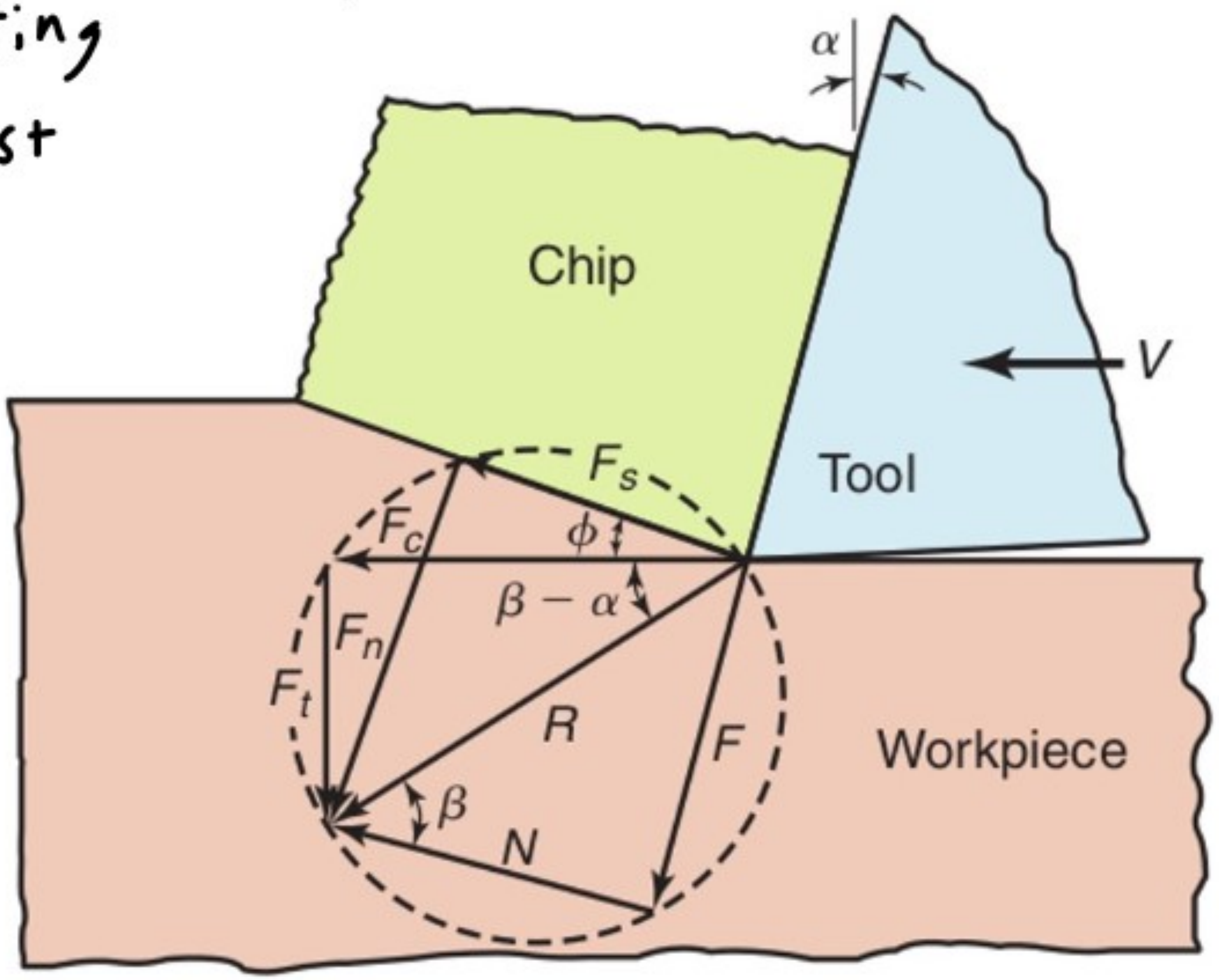
F friction

N normal



(a)

R resultant



(b)

$$F_s = R\cos(\phi + \beta - \alpha)$$

$$F = R\sin\beta$$

$$N = R\cos\beta$$

$$F_s = F_c\cos\phi - F_t\sin\phi$$

$$F_n = F_c\sin\phi + F_t\cos\phi$$

$$F_t = R\sin(\beta-\alpha)$$

$$F_t = F_c\tan(\beta-\alpha)$$

$$\mu = \frac{F}{N} = \frac{F_t + F_c\tan\alpha}{F_c - F_t\tan\alpha}$$

Total Power $F_c V$

Shearing power $F_s V_s$

Friction power $F V_c$

Specific energy

Shear $u_s = \dfrac{F_s V_s}{w t_o V}$

Friction $u_f = \dfrac{F V_c}{w t_o V} = \dfrac{F r}{w t_o}$

Total $u_t = u_s + u_f$

Material	Specific energy W-s/mm^3
Aluminum alloys	0.4–1
Cast irons	1.1–5.4
Copper alloys	1.4–3.2
High-temperature alloys	3.2–8
Magnesium alloys	0.3–0.6
Nickel alloys	4.8–6.7
Refractory alloys	3–9
Stainless steels	2–5
Steels	2–9
Titanium alloys	2–5

Example

Friction $\mu = 0.25$

chip width $w = 6\,mm$ $\quad$ $1/4$ in

cut depth $t_0 = 0.2\,mm$ $\quad$ 0.008 in

cutting speed $V = 0.12\,m/s$ $\quad$ 23 fpm

steel specific energy $u_t = 5\ \frac{Ws}{mm^3}$

rake angle $\alpha = 10^\circ$

find R and Power

$$r = \frac{t_0}{t_c} \qquad t_c = \frac{t_0}{r} = \frac{0.2\,mm}{0.81} = 0.25\,mm$$

$$u_t = u_s + u_f$$

$$5 = \frac{F_s V_s}{w t_0 V} + \frac{Fr}{w t_0}$$

$$= \frac{F_s V_s}{w t_0 V} + \frac{F t_0}{w t_0 t_c}$$

$$= \frac{F_s V \cos\alpha}{w t_0 V \cos(\phi - \alpha)} + \frac{F}{w t_c}$$

$$\beta = \tan^{-1}(\mu) = 14^\circ$$

$$\phi = 45^\circ + \alpha/2 - \beta/2 = 45 + 10/2 - 14/2$$

$$= 43^\circ$$

$$r = \frac{\sin\phi}{\cos(\phi - \alpha)} = 0.81$$

$$S = \frac{F_s \cos\alpha}{w t_0 \cos(\beta-\alpha)} + \frac{F}{w t_c}$$

$$S = \frac{F_s \cos\alpha}{w t_0 \cos(\beta-\alpha)} + \frac{R \sin\beta}{w t_c}$$

$$S = \frac{R \cos(\beta+\beta-\alpha)\cos\alpha}{w t_0 \cos(\beta-\alpha)} + \frac{R \sin\beta}{w t_c}$$

$$S = R\left(\frac{0.3}{w t_0} + \frac{0.24}{w t_c}\right)$$

$$\frac{S}{\frac{0.3}{w t_0} + \frac{0.24}{w t_c}} = R$$

$$\frac{5 \frac{Ws}{mm^2}}{\frac{0.3}{6mm \cdot 0.2mm} + \frac{0.24}{6mm \cdot 0.25mm}} = 6 \frac{Ws}{mm}$$

$$6 \frac{Ws}{mm} \frac{1 \; Kg\, m^2/s^3}{1 \; W} \frac{1000 \; mm}{1 \; m} = 6000 \frac{Kg\, m}{s^2}$$

$$= 6 KN$$

$$\approx 1350 lb$$

Power $F_c V = 6\ kN\ 0.12\ m/s = 721\ W \simeq 1\ hp$

$F_c = R\cos(\beta - \alpha) = 6\ kN \cos(14 - 10) = 6\ kN$

Temperature in cutting

- Material softness
- tool softness
- Metalurgy change
- Melt
- Fire Danger
- Thermal expansion

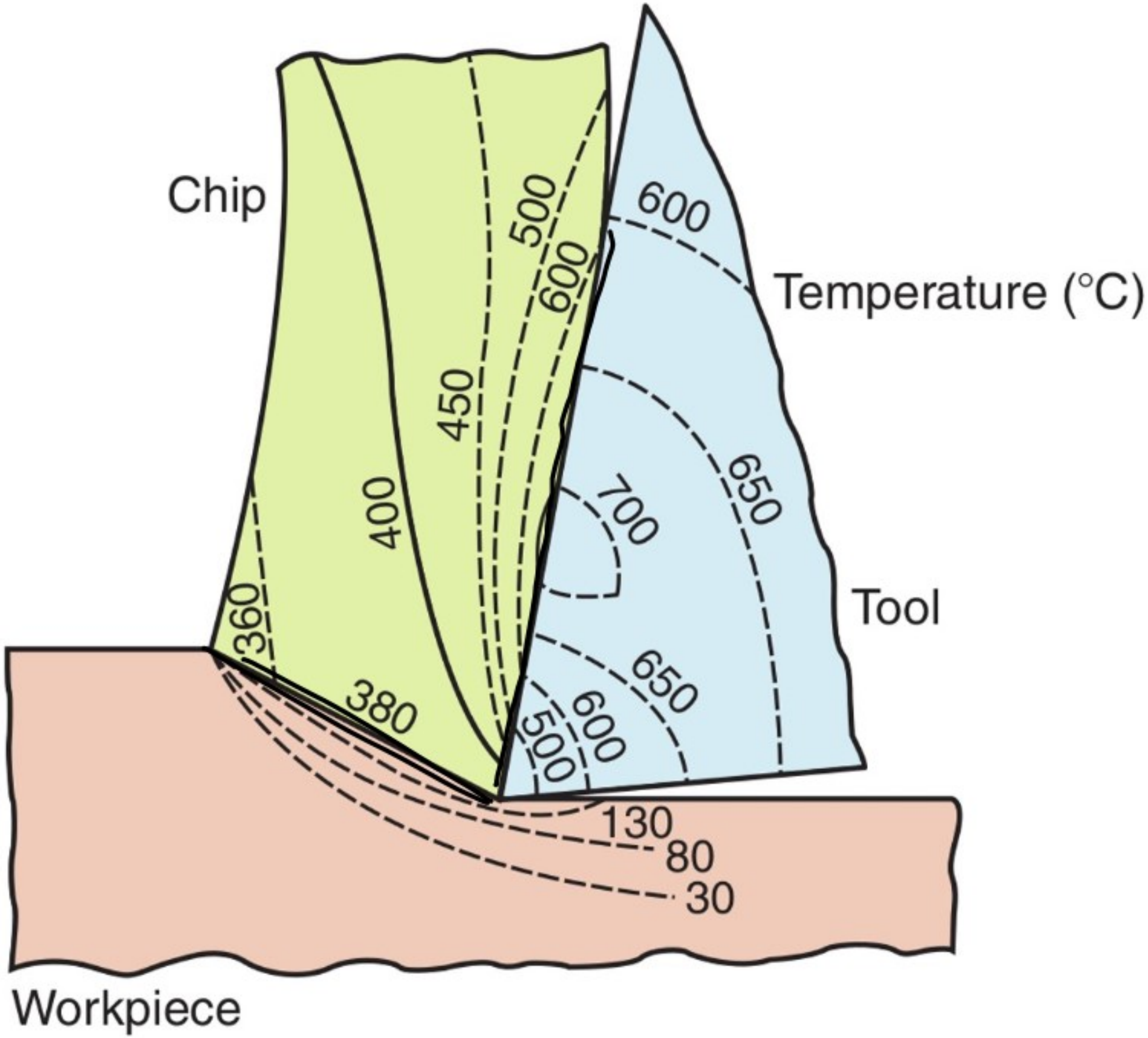
$T_{mean} \propto V^a f^b$

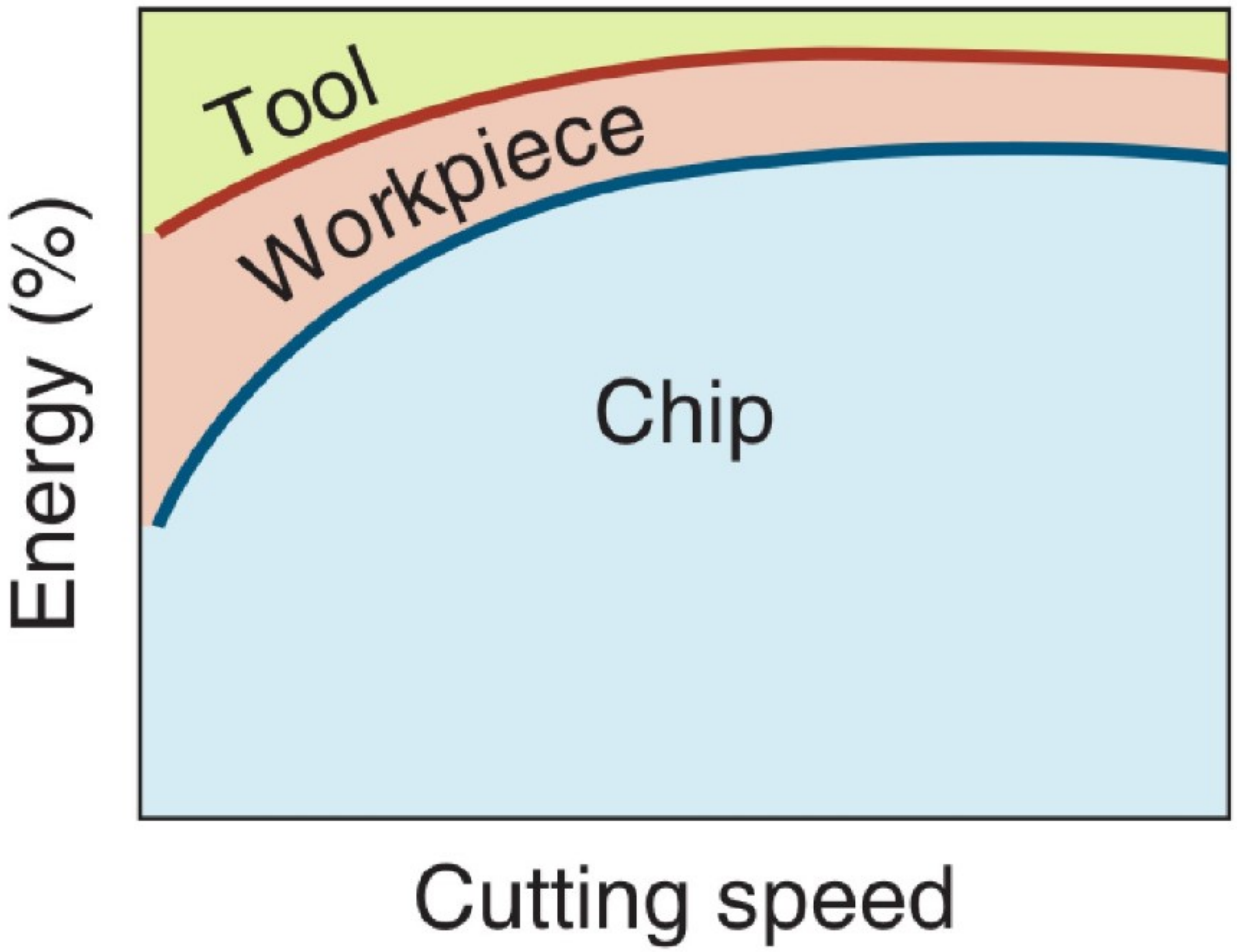
V cutting speed

f feed rate

Cabide $a = 0.2$, $b = 0.125$

high speed steel $a = 0.5$, $b = 0.375$


Chip
Temperature (°C)
Tool
Workpiece
600
500
600
450
400
360
380
700
650
650
600
500
130
80
30


Tool
Workpiece
Chip
Energy (%)
Cutting speed

Tool Wear

Taylor tool life equation

$$VT^n = C$$

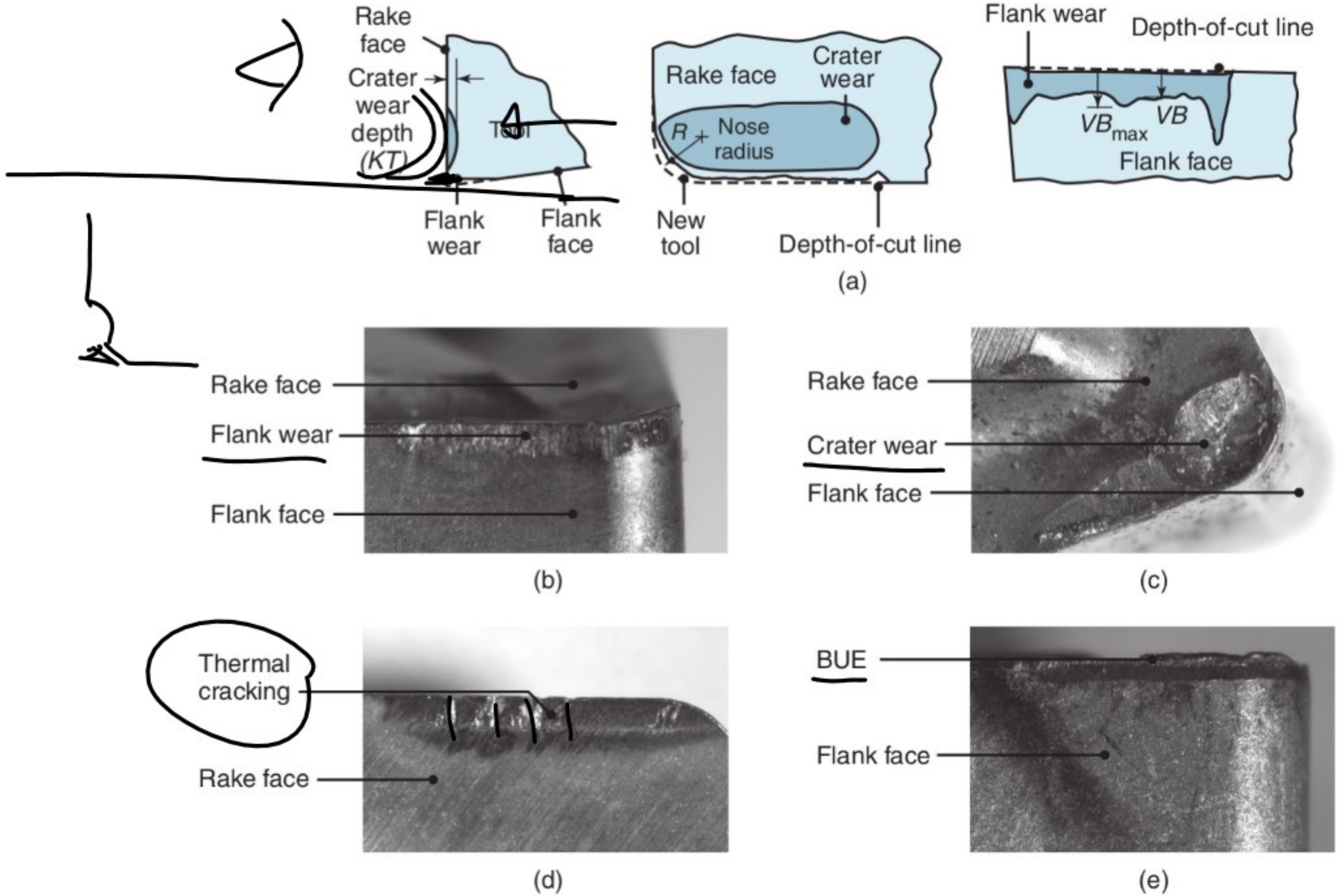
V cutting speed

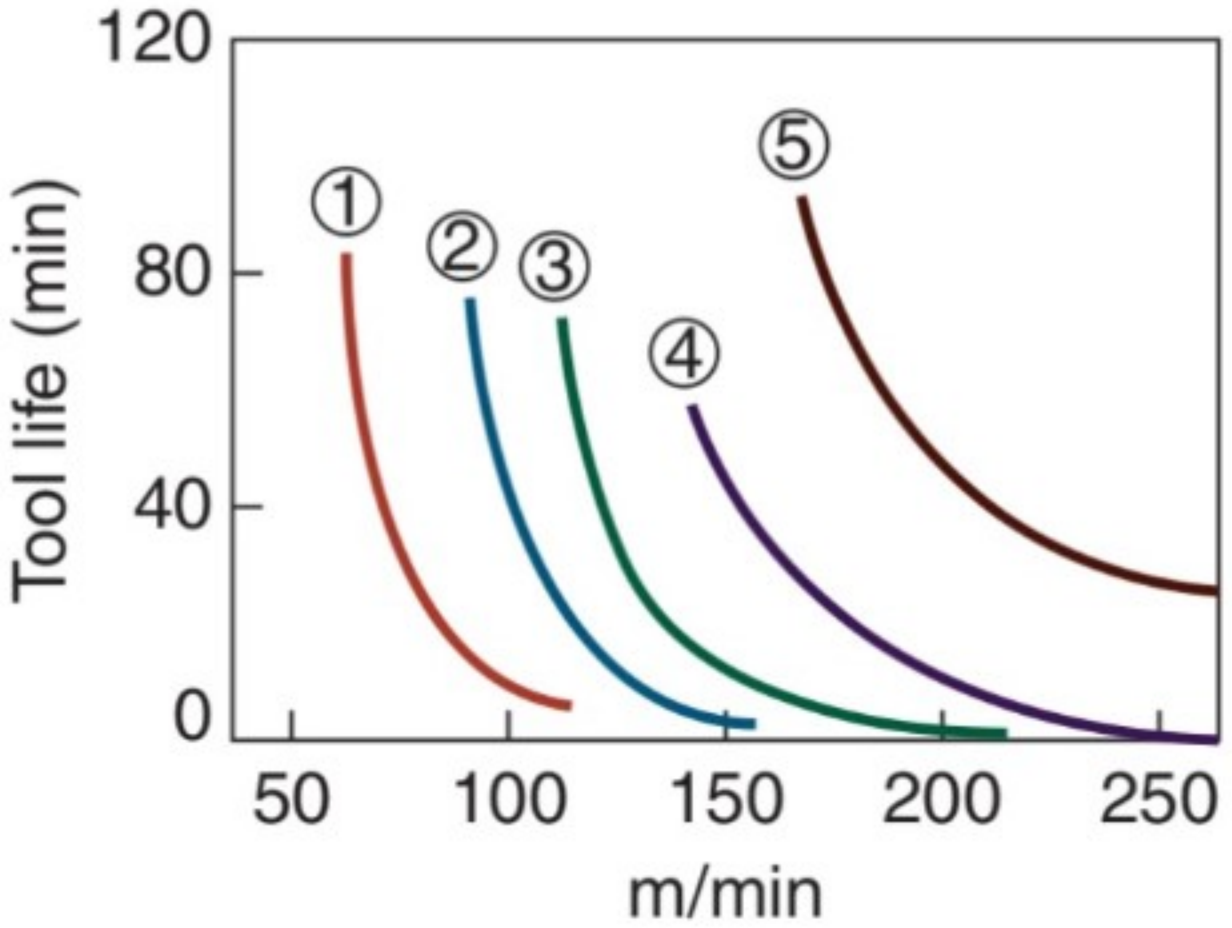
T time to replacement

n exponent

C constant

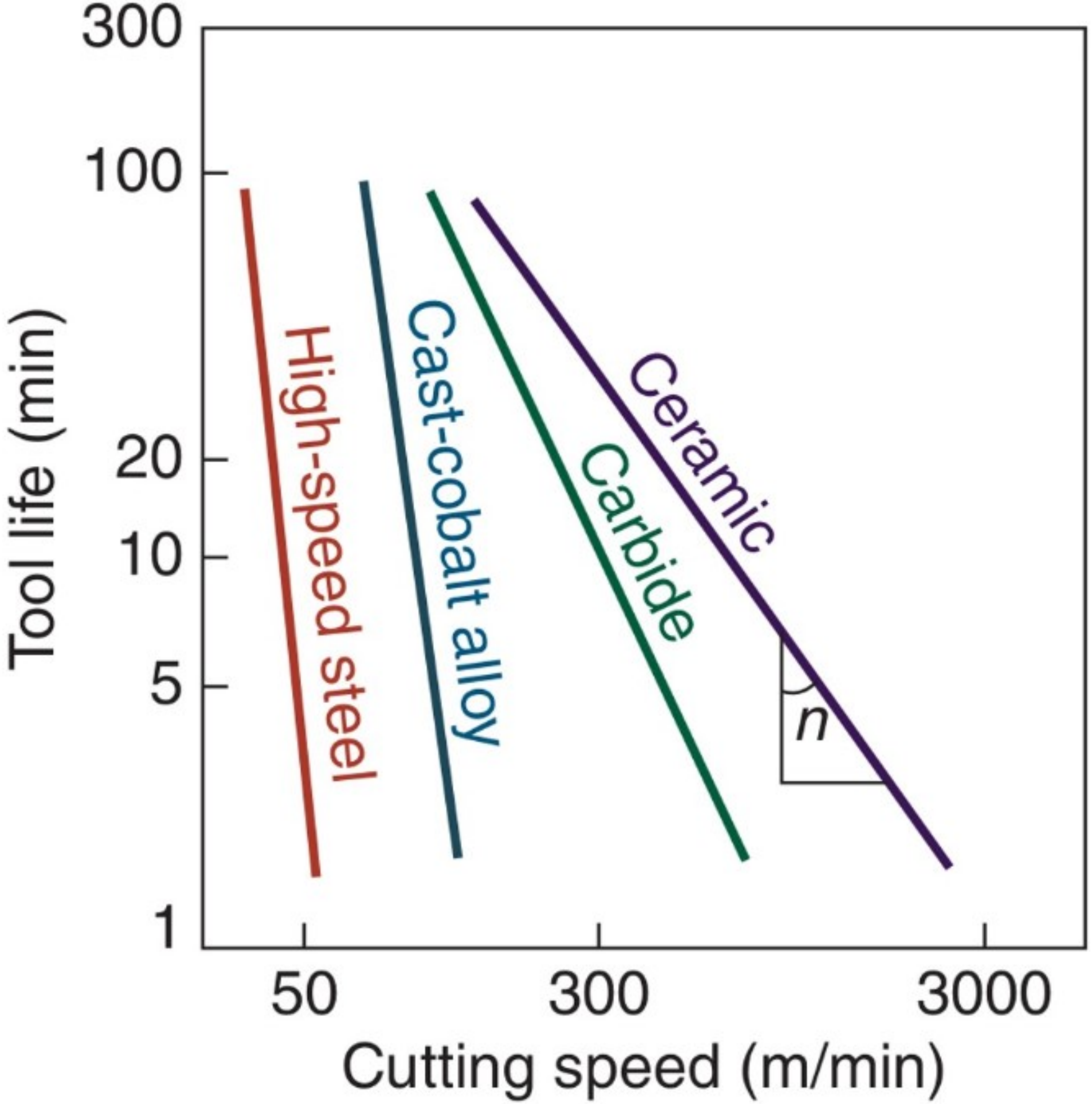
(n and C) depend on tool/material


Rake face
Crater wear depth (KT)
Tool
Flank wear
Flank face
Rake face
Crater wear
R
Nose radius
New tool
Depth-of-cut line
Flank wear
Depth-of-cut line
VB_max
VB
Flank face
(a)
Rake face
Flank wear
Flank face
(b)
Rake face
Crater wear
Flank face
(c)
Thermal cracking
Rake face
(d)
BUE
Flank face
(e)



		Hardness (HB)	Ferrite	Pearlite
①	As cast	265	20%	80%
②	As cast	215	40	60
③	As cast	207	60	40
④	Annealed	183	97	3
⑤	Annealed	170	100	—

Ductile Iron


300
100
20
10
5
1
Tool life (min)
50
300
3000
Cutting speed (m/min)
High-speed steel
Cast-cobalt alloy
Carbide
Ceramic
n

Optimal Cutting speed

Tool life Lower is better

Cycle times Higher is better

Tool cost Tool replacement time

Deadline