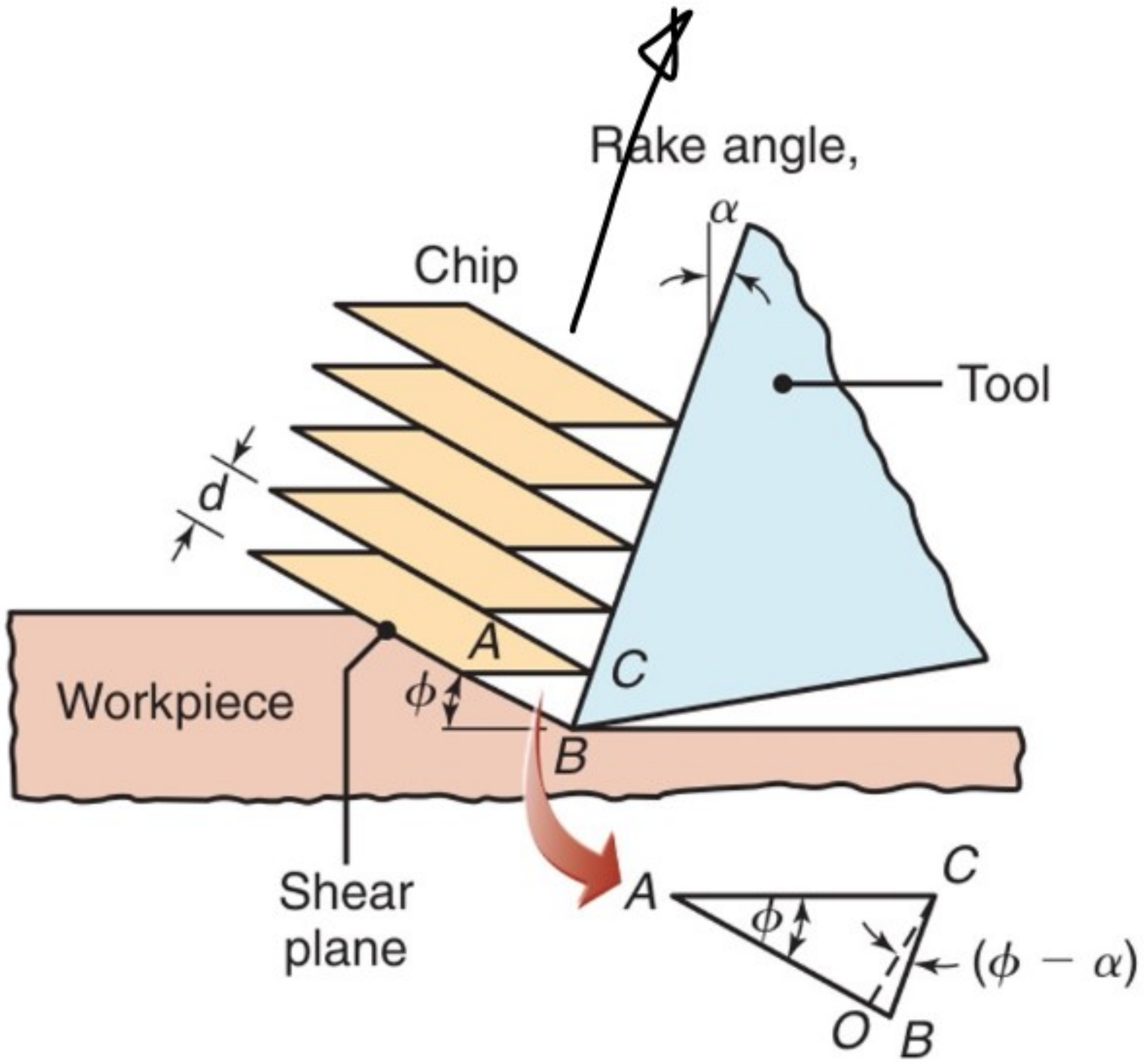
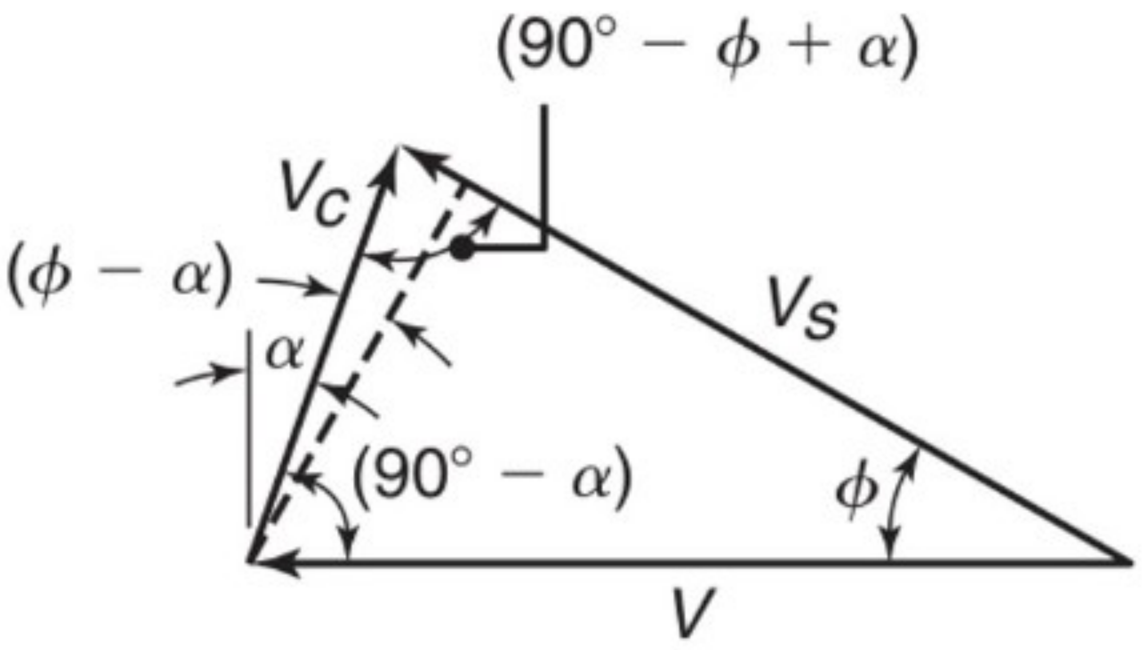




$$\frac{V}{\cos(\phi-\alpha)} = \frac{V_s}{\cos\alpha} = \frac{V_c}{\sin\phi}$$

Cutting Forces

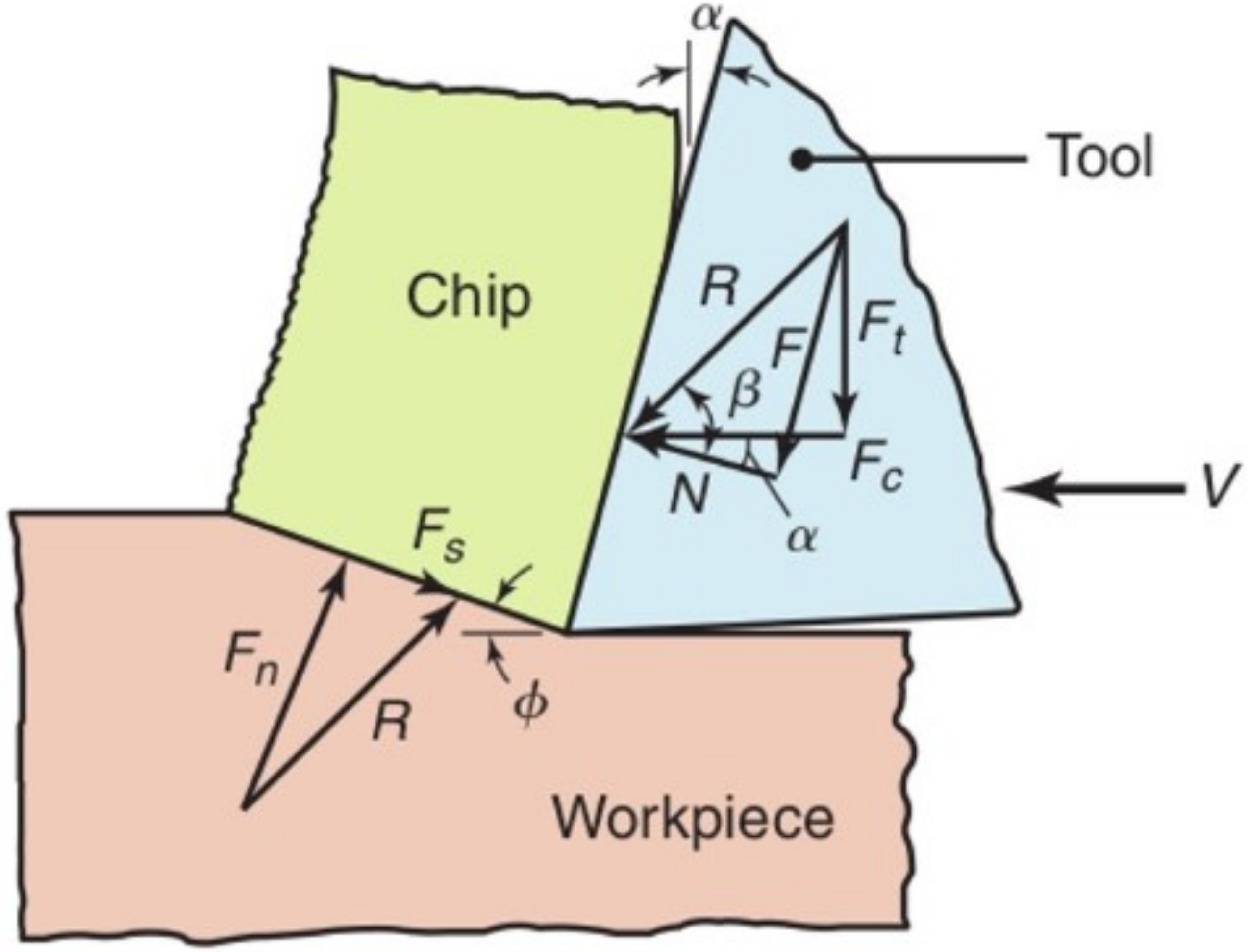
R resultant

F friction

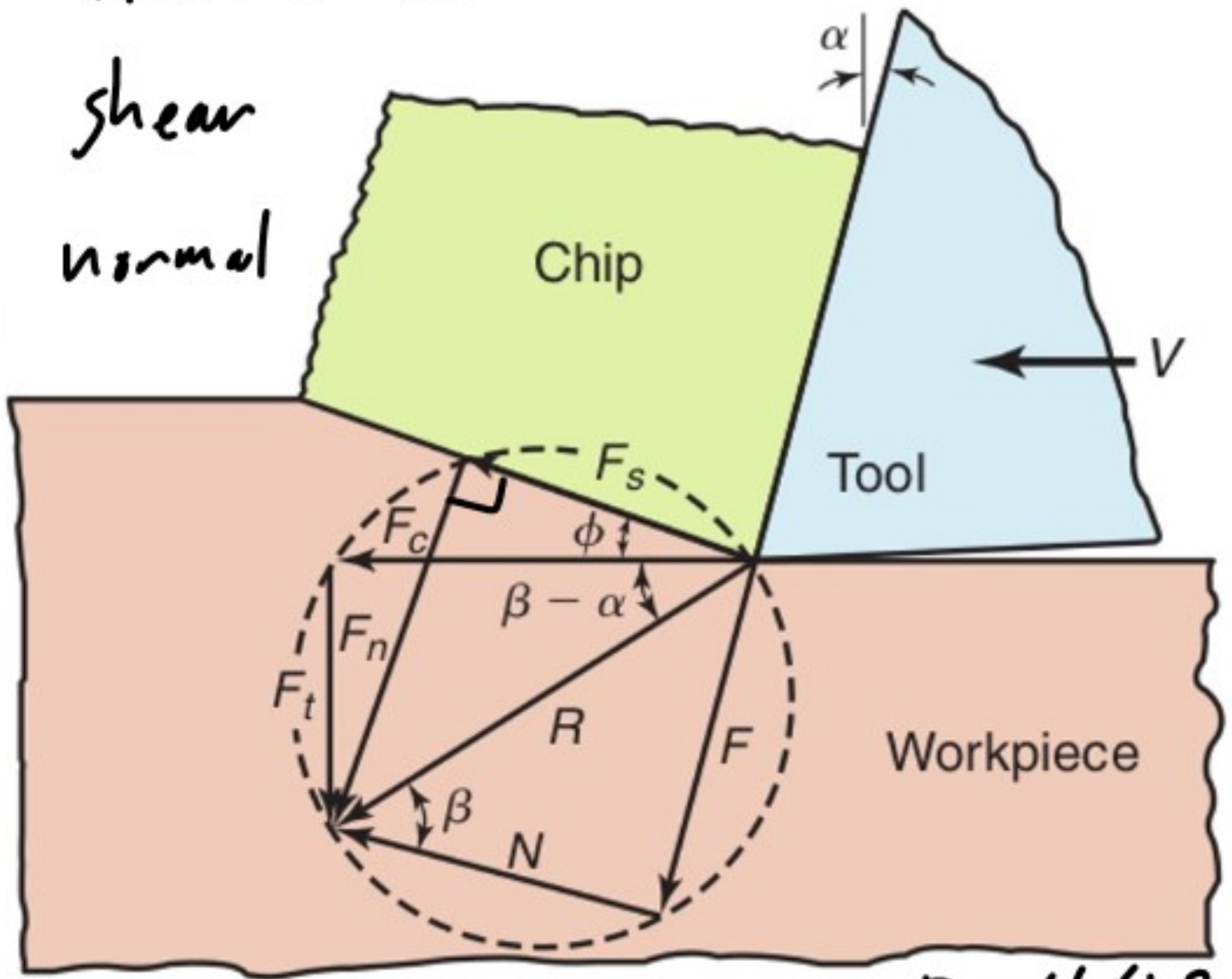
N normal force

F_s shear

F_n normal



(a)



(b)

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

F_t thrust

F_c cutting

$$F = R \sin\beta$$

$$N = R\cos\beta$$

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

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

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

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

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

Power $F_c V$

Shearing Power $F_s V_s$

Friction Power $F V_c$

Specific Energy

Shearing

$$u_s = \frac{F_s V_s}{w t_o V}$$

Friction

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

$$u_t = u_s + u_f$$

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 $\mu = 0.25$

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

rake $\alpha = 10^\circ$

Steel specific energy $u_t = 5\ \frac{W\,s}{mm^3}$

$$u_t = u_s + u_f$$

$$5 = \frac{F_s V_s}{w\,t_0 V} + \frac{F r}{w\,t_0}$$

$$5 = \frac{F_s \cancel{V} \cos\alpha}{w\,t_0 \cancel{V} \cos(\phi - \alpha)} + \frac{F r}{w\,t_0}$$

$$\beta = \tan^{-1}(\mu) = \tan^{-1}(0.25) = 14^\circ$$

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

$$= 43^\circ$$

$$r = \frac{t_0}{t_c} \qquad r = \frac{\sin\phi}{\cos(\phi - \alpha)} = 0.81$$

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

$$S = \frac{F_s \cos\alpha}{w t_0 \cos(\phi - \alpha)} + \frac{F_r}{w t_0}$$

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

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

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

$$S = R \frac{0.67}{0.84\, w t_0} + R \frac{0.24}{w t_c}$$

$$\frac{S}{\frac{0.67}{0.84\, w t_0} + \frac{0.24}{w t_c}} = R$$

$$\frac{S \frac{WS}{mm^3}}{\frac{0.8}{6mm\ 0.2mm} + \frac{0.24}{6mm\ 0.25mm}} = R$$

$$R = 6 \frac{WS}{mm}$$

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

$$= 6\,kN \qquad \simeq 1350\,lb$$

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

Power $\quad 6\,kN \;\; 0.12\,m/s = 721\,W$

$$\simeq 1\,hp$$

Temperature in cutting

metelurgy of tool and workpiece

fire danger

thermal expansion

- workpiece
- tool

softens

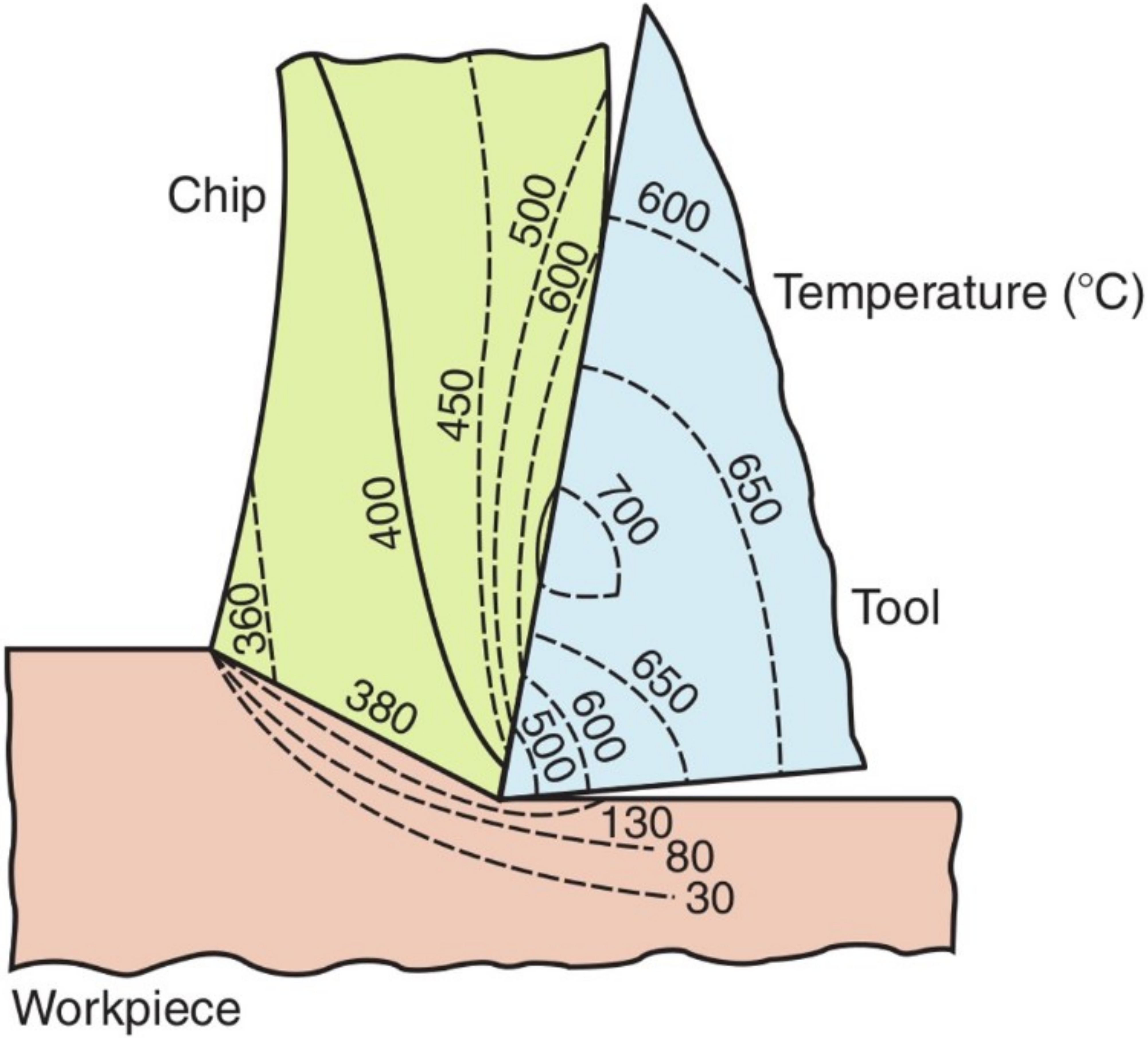
$T_{mean} \propto V^a f^b$

V cutting speed

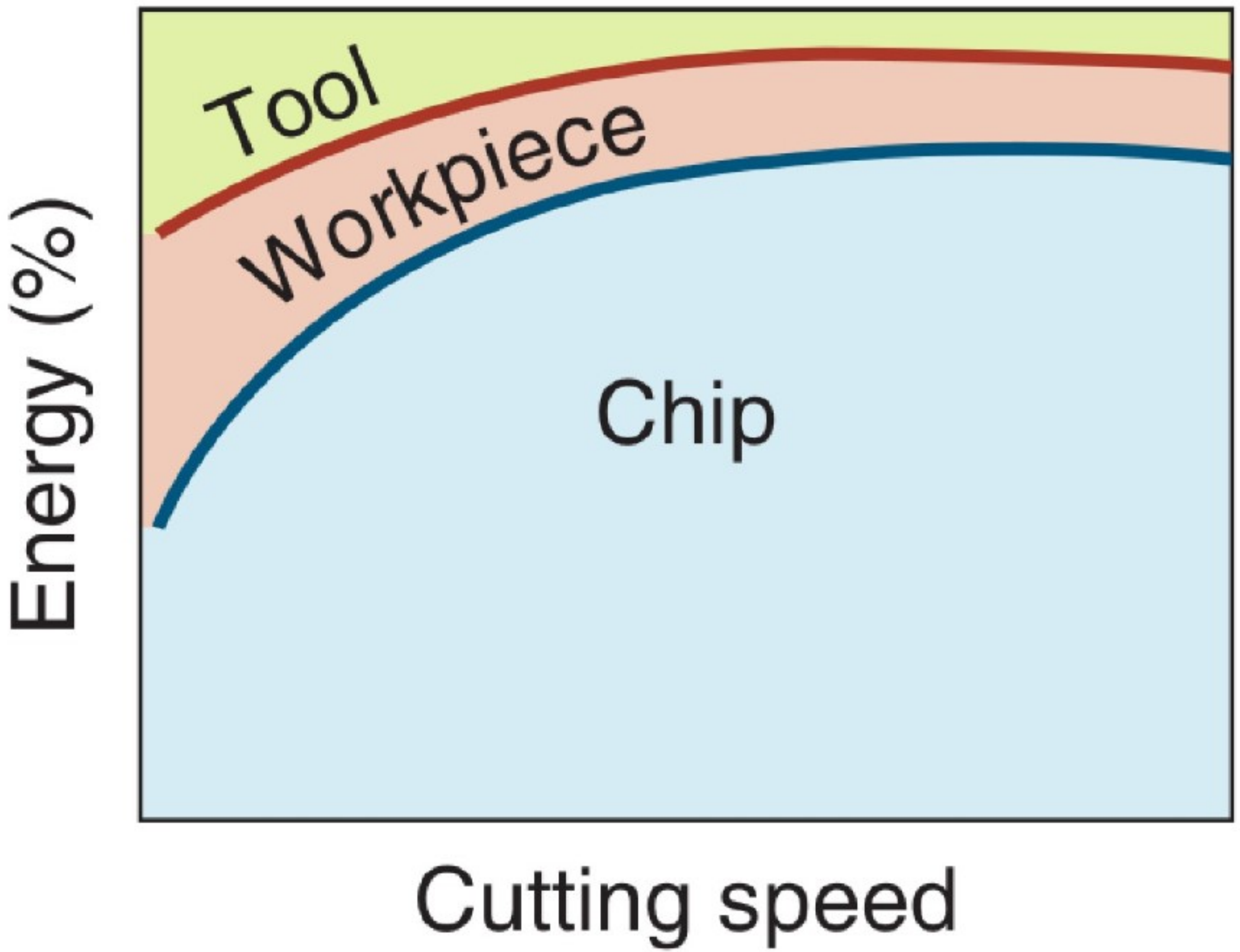
f feed rate

Carbide $a = 0.2$
$b = 0.125$

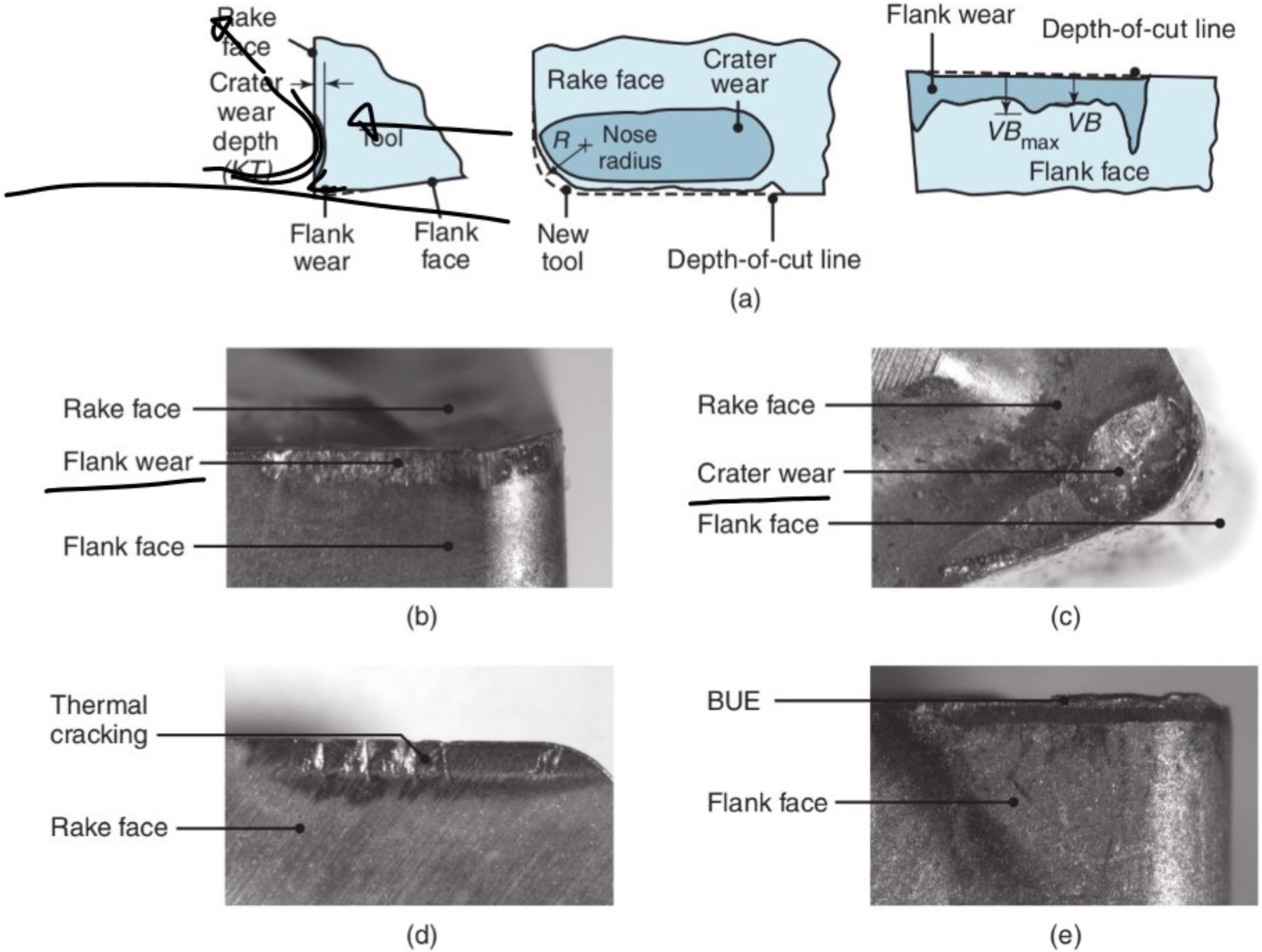
high speed steel $a = 0.5$
$b = 0.375$



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


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)

Taylor tool life equation

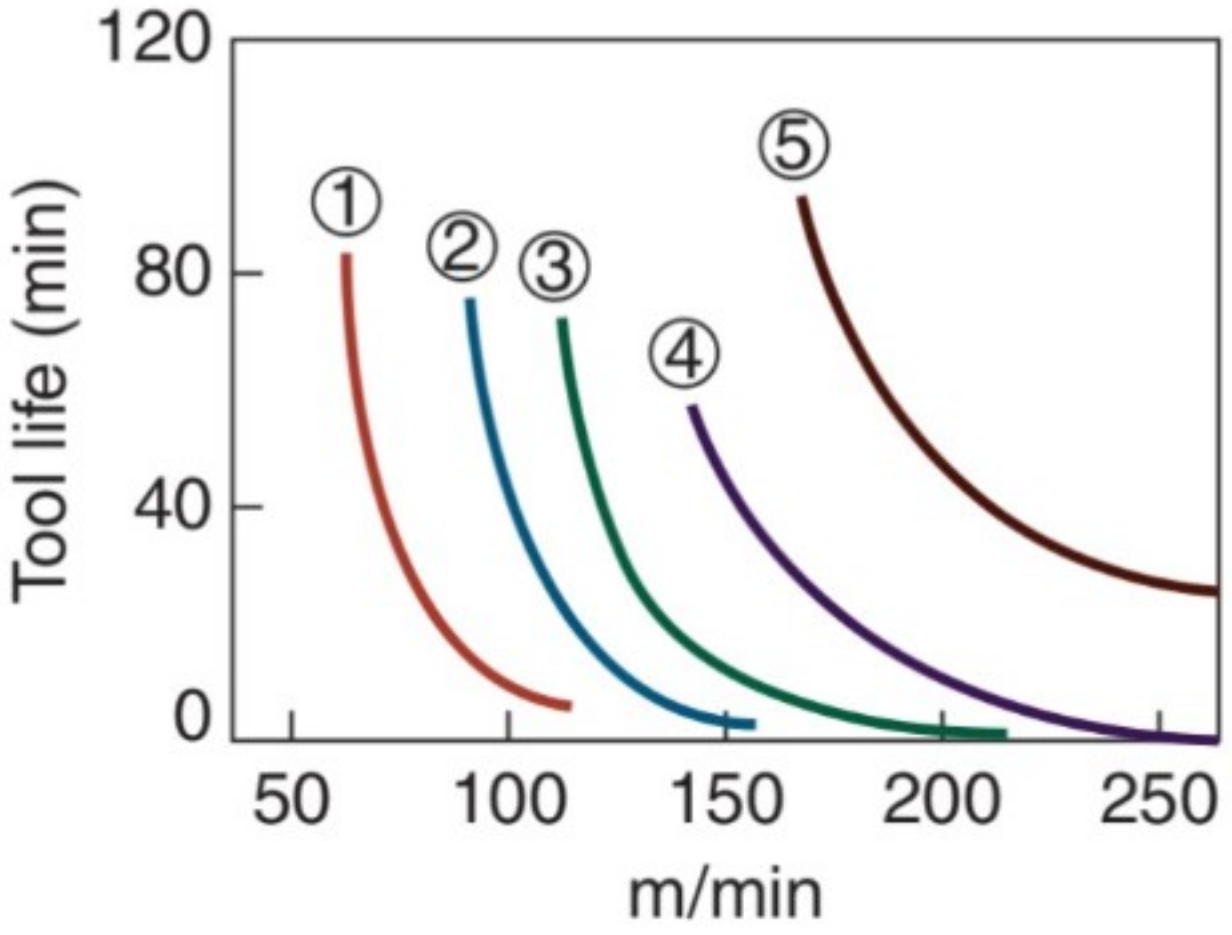
$$VT^n = C$$

V cutting speed

T time

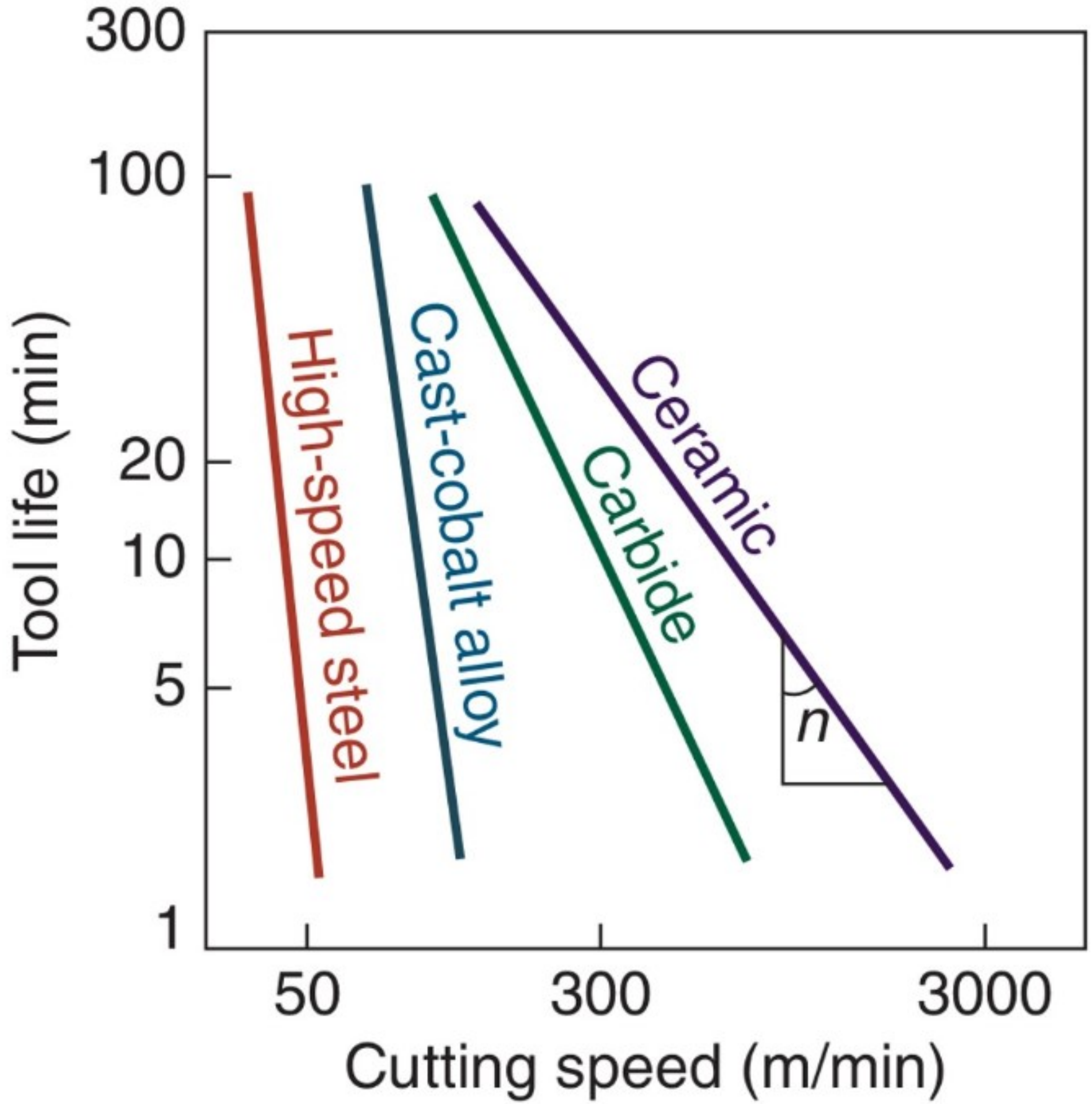
n exponent } depend on tool/material

C constant }



		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 wear — lower cutting speed better

Cycle time — faster cutting speed better

Tool cost — tool replacement time

Machine time — Deadline