Óbuda University
Bánki Donát Faculty of Mechanical and Safety Engineering
Institute of Material Science and Manufacturing Engineering

Manufacturing Engineering 2

BAGGT23NEC

2013/14 I.

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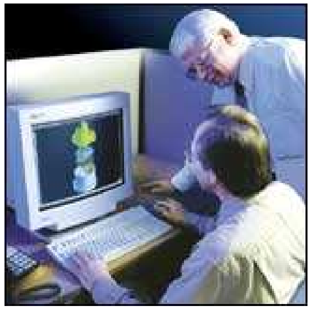




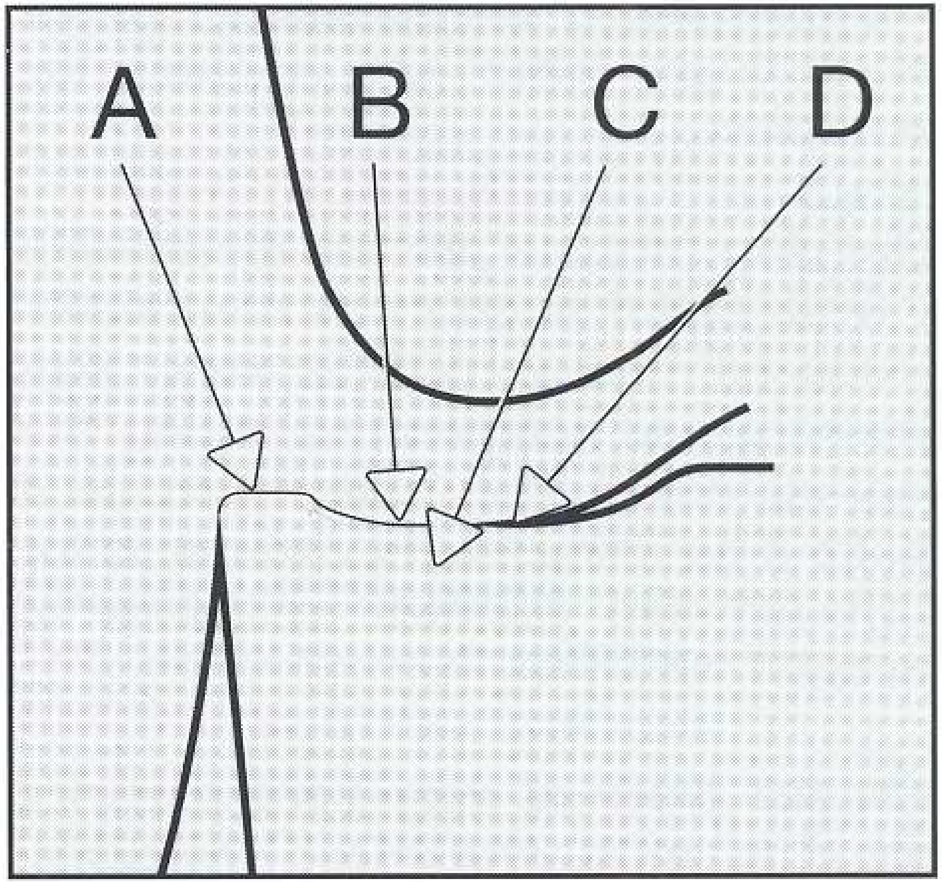
02

CUTTING PERFORMANCES

- Tool wear
  - Load of a cutting tool
  - Tool wear mechanisms
  - Tool wear types
- Forces
- Cooling

Load factors of a tool

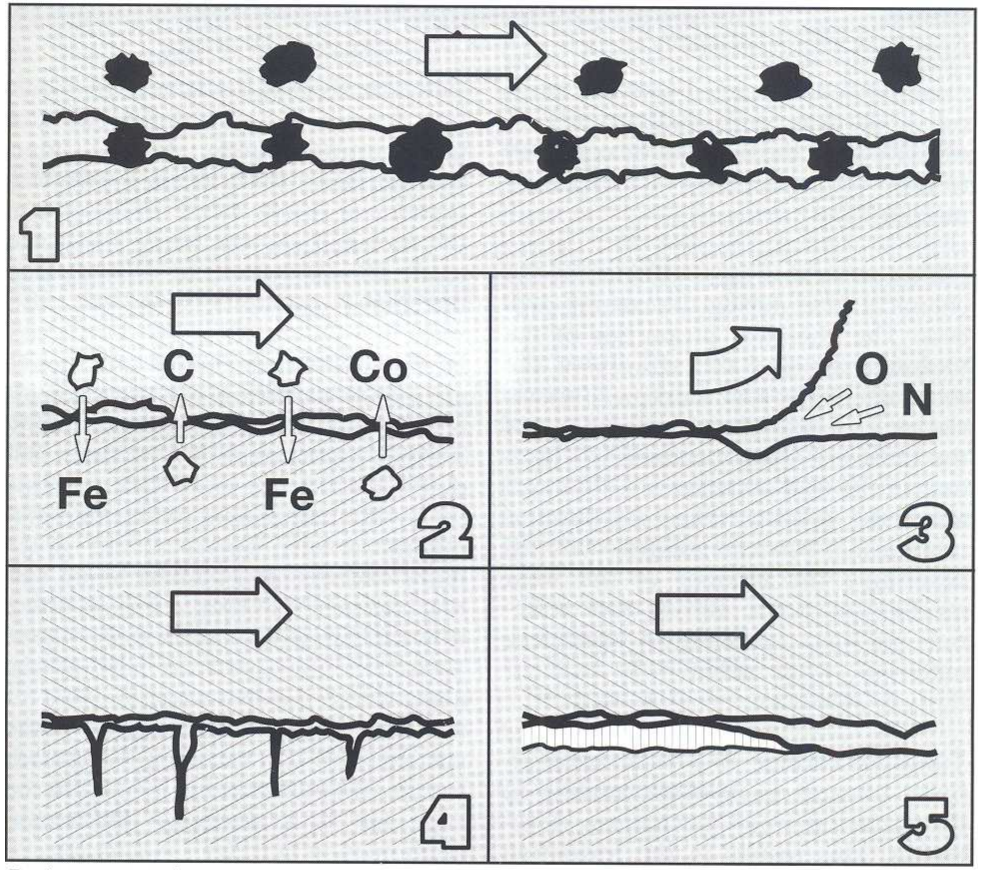
- A – mechanical
- B – thermal
- C – chemical
- D - abrasive



Typical wear zones

Tool wear mechanism

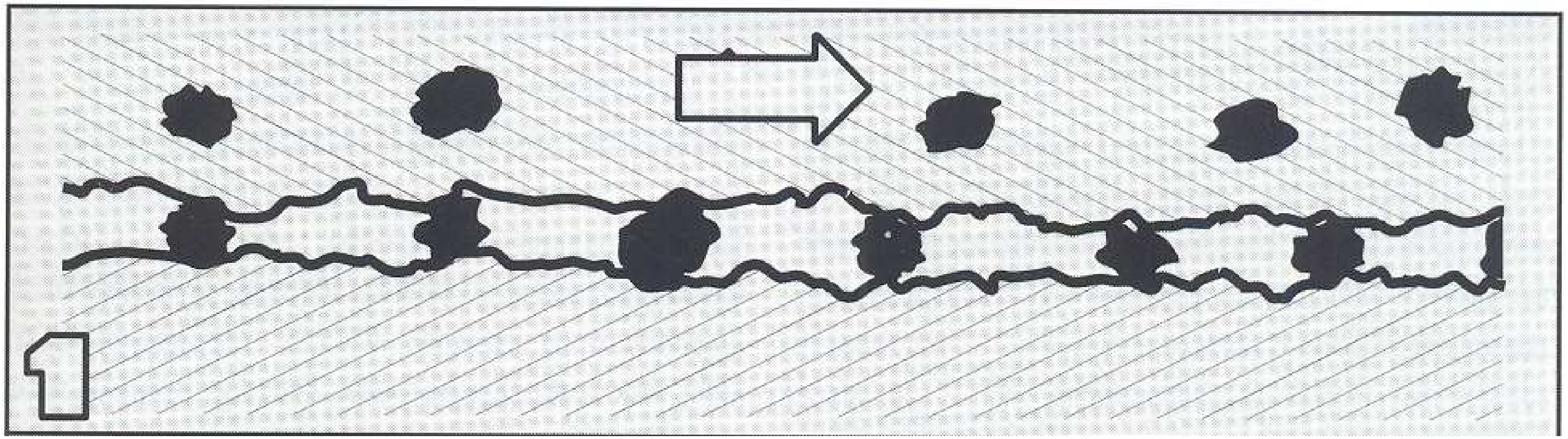
- 1 – abrasion wear
- 2 – diffusion wear
- 3 – oxidation wear
- 4 - fatigue wear
- 5 - adhesion wear



Basic wear mechanisms in metal cutting

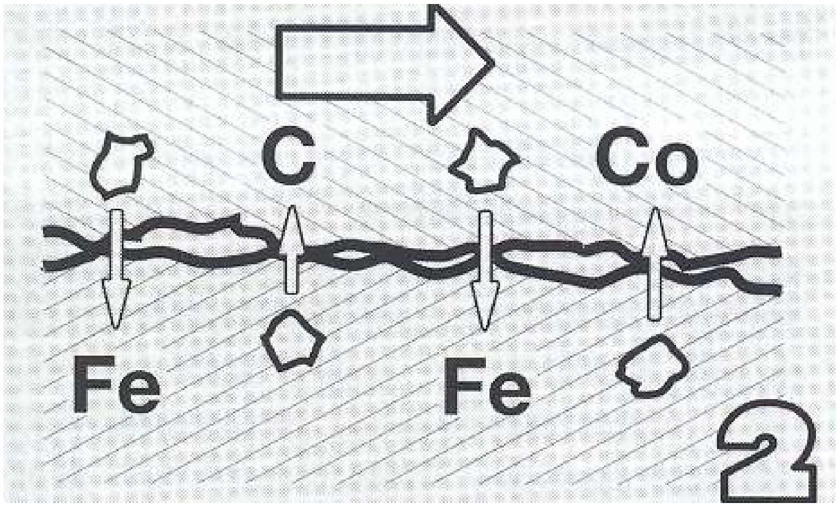
Abrasive wear

- Friction
- Different hardness
- Mechanical load



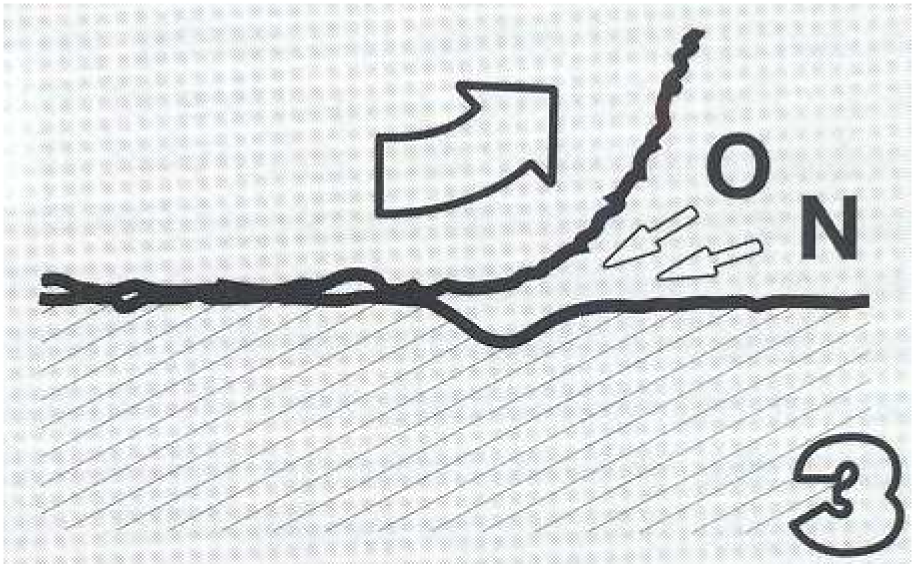
Diffusion wear

- Different chemical properties
- Atomic interchange
- Affinity of the tool material to the workpiece material
- Temperature depend
- High cutting speed



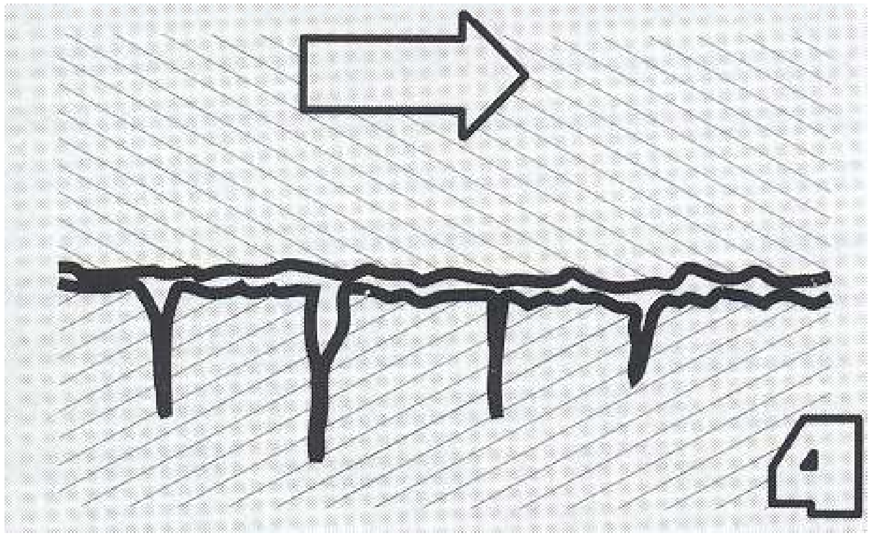
Oxidation wear

- High temperature + Air (oxigen)
- Some oxides are harder than the tool material



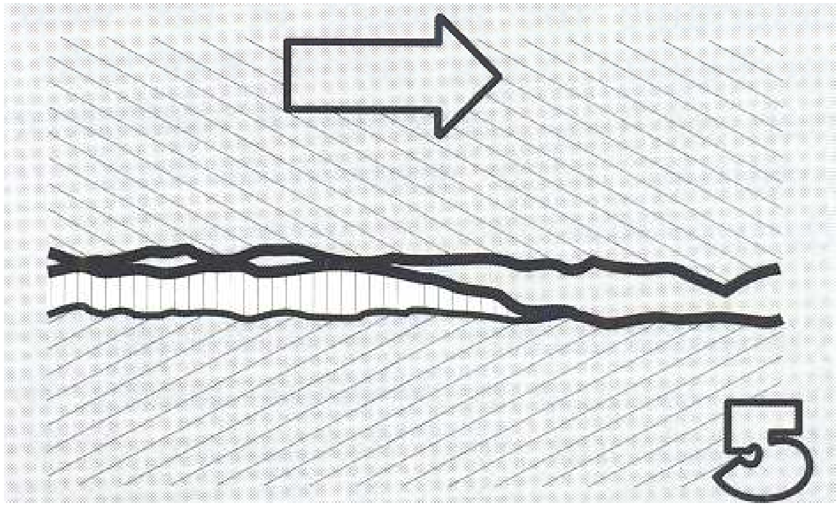
Fatigue wear

- Thermo-mechanical process
- Change of thermal and mechanical load
- Breaking

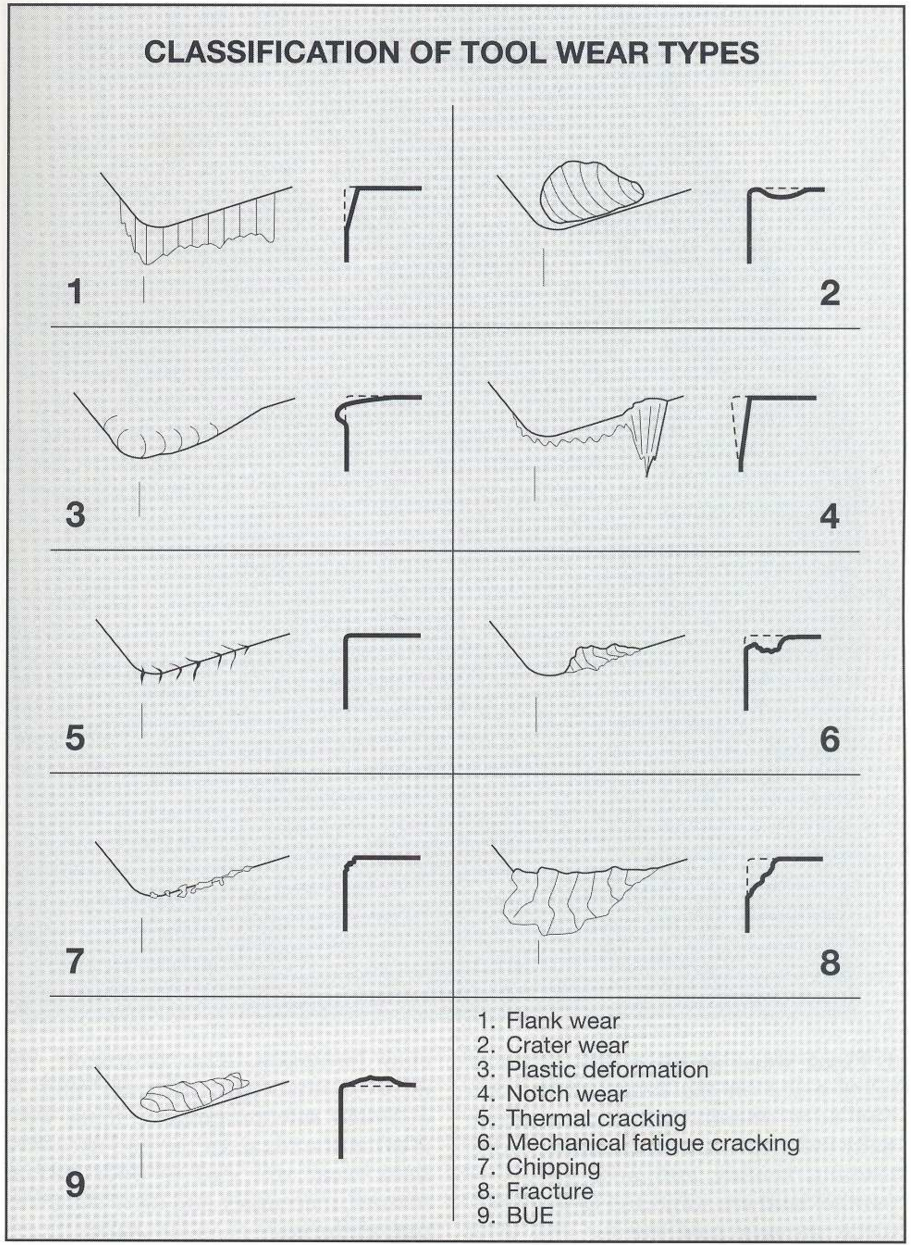


Adhesion wear

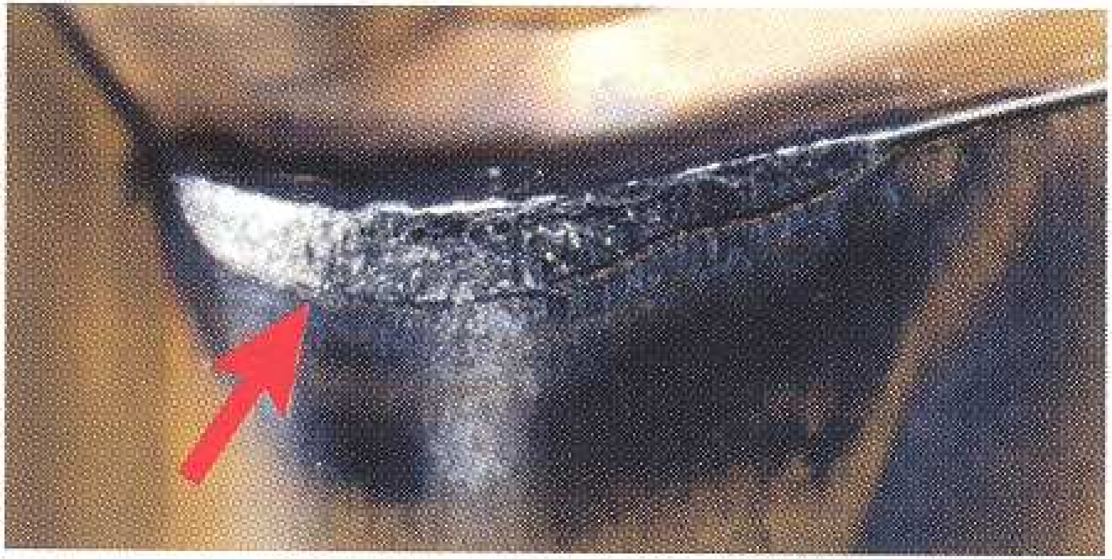
- Low machining temperature
- The chip is welded to the tool – build-up edge (BUE)



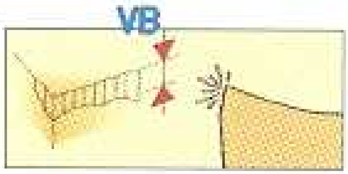
Tool wear types



Flank wear

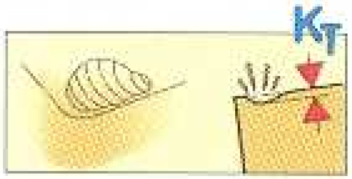


FLANK WEAR



Tool wear	Possible cause	Possible remedy
Rapid flank wear causing poor suface texture or inconsis-tency in tolerance.	Cutting speed too high or insufficient wear resistance.	Select a more wear resi-stant grade. For work-hardening materials, select a smaller entering angle. Reduce cutting speed when machining heat resistant material.

Crater wear



CRATER WEAR

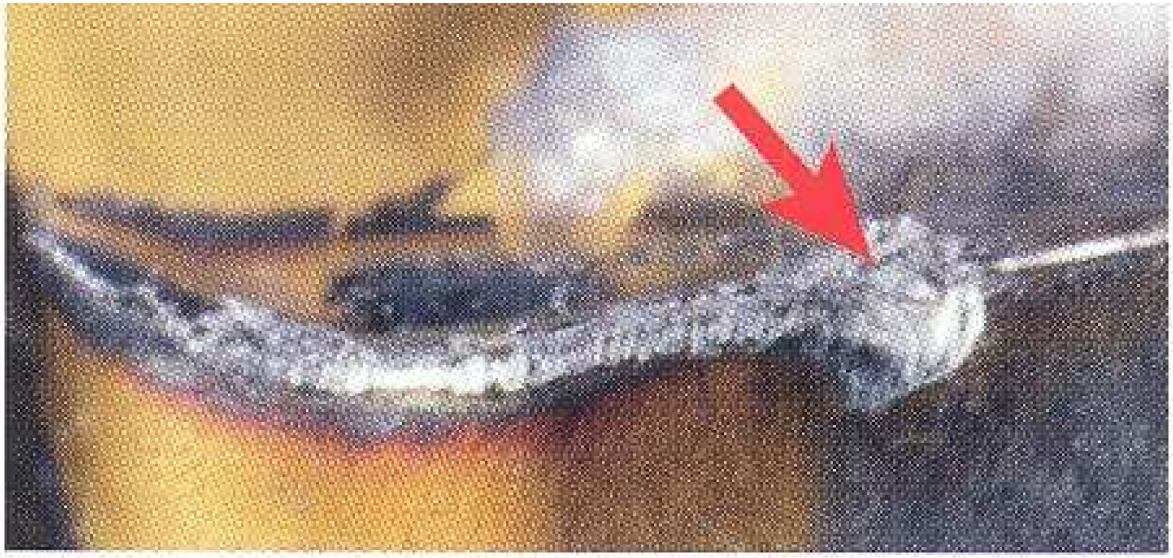
Tool wear	Possible cause	Possible remedy
Excessive crater wear causing a weakened edge and poor surface finish.	Excessive cutting temperatures and pressure on the top face of inserts.	First, reduce cutting speed to obtain a lower temperature and secondly, the feed. Select a more wear resistant grade. Select a positive insert geometry

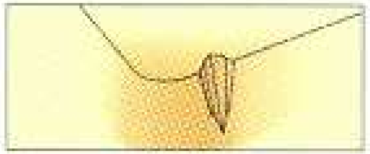
Plastic deformation

PLASTIC DEFORMATION

Tool wear	Possible cause	Possible remedy
Plastic deformation of edge, depression or flank impression, leading to poor chip control poor surface finish and insert breakage.	Cutting temperature and pressure too high.	Select a more wear resistant grade, which is harder. • Reduce cutting speed. • Reduce feed.

Notch wear





NOTCH WEAR

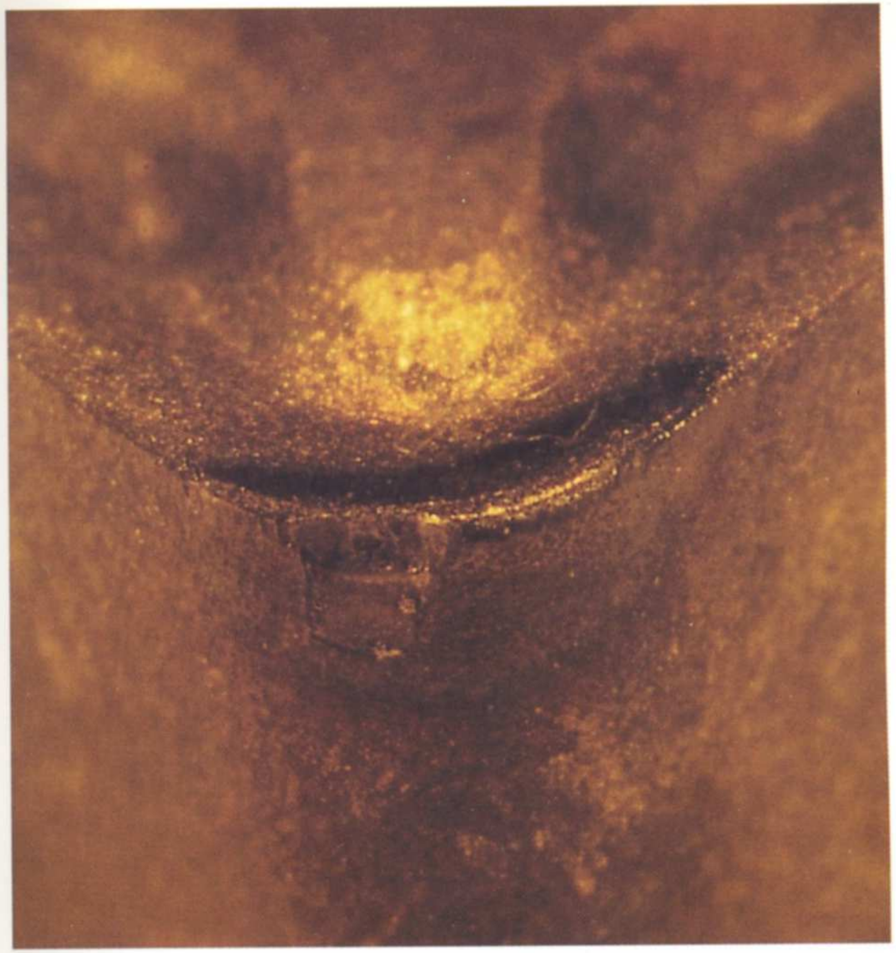
Tool wear	Possible cause	Possible remedy
Notch wear causing poor surface texture and risk of edge breakage.	Cutting speed too high or insufficient wear resistance.	Select a more wear resistant grade. For work-hardening materials, select a smaller entering angle. Reduce cutting speed when machining heat resistant material.

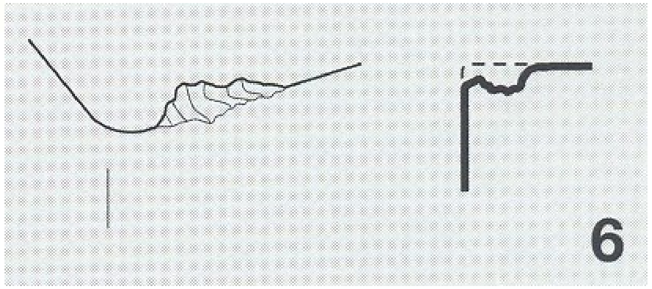
Thermal cracking

THERMAL CRACKS

Tool wear	Possible cause	Possible remedy
Small cracks perpendicular to the cutting edge causing chipping and poor surface finish.	Excessive temperature variations. Intermittent machining. Varying coolant supply.	Select a tougher insert grade. Coolant should be applied copiously or not at all.

Mechanical fatigue cracking

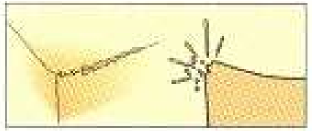




6. Mechanical fatigue cracking can take place when the cutting force shocks are excessive. It is fracture due to continual variations in load where the load in itself is not large enough to cause fracture. Start of cut and variations in cutting force magnitude and direction may be too much for the strength and toughness of the insert. These cracks are mainly parallel to the cutting edge.

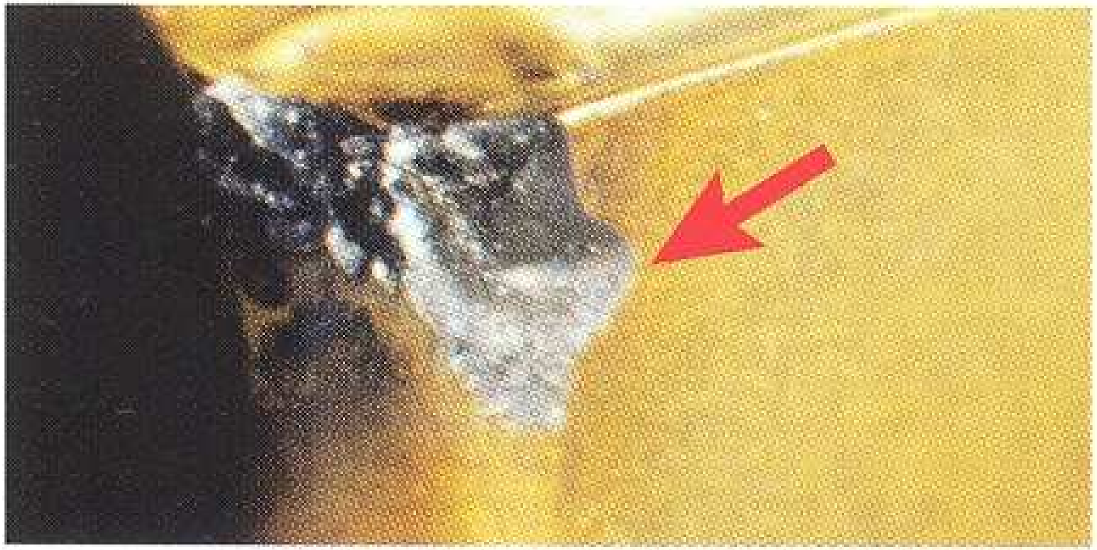
Chipping of the edge

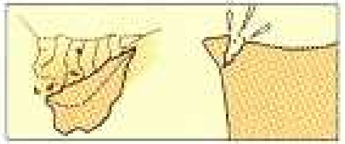
CHIPPING



Tool wear	Possible cause	Possible remedy
Small cutting edge chipping leading to poor surface texture and excessive flank wear.	Cutting edge too brittle.	Select tougher grade.
	Insert edge too weak.	Select an insert with a stronger cutting edge.
	Built-up edge has been formed.	Increase cutting speed. Select a positive geometry.
		Reduce feed at beginning of cut.
		Improve stability.

Fracture

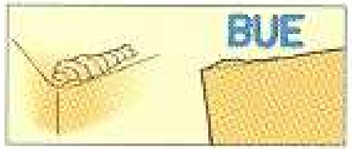




EDGE FRACTURE

Tool wear	Possible cause	Possible remedy
Damages not only the insert but can also ruin the shim and workpiece.	Excessive tool wear. Grade and geometry too weak.	Reduce feed and/or depth of cut.
	Excessive load on the insert.	Select a stronger geometry, preferably a single sided insert.
	Built-up edge has been formed.	Select a thicker/larger insert and tougher grade.
		Improve stability.

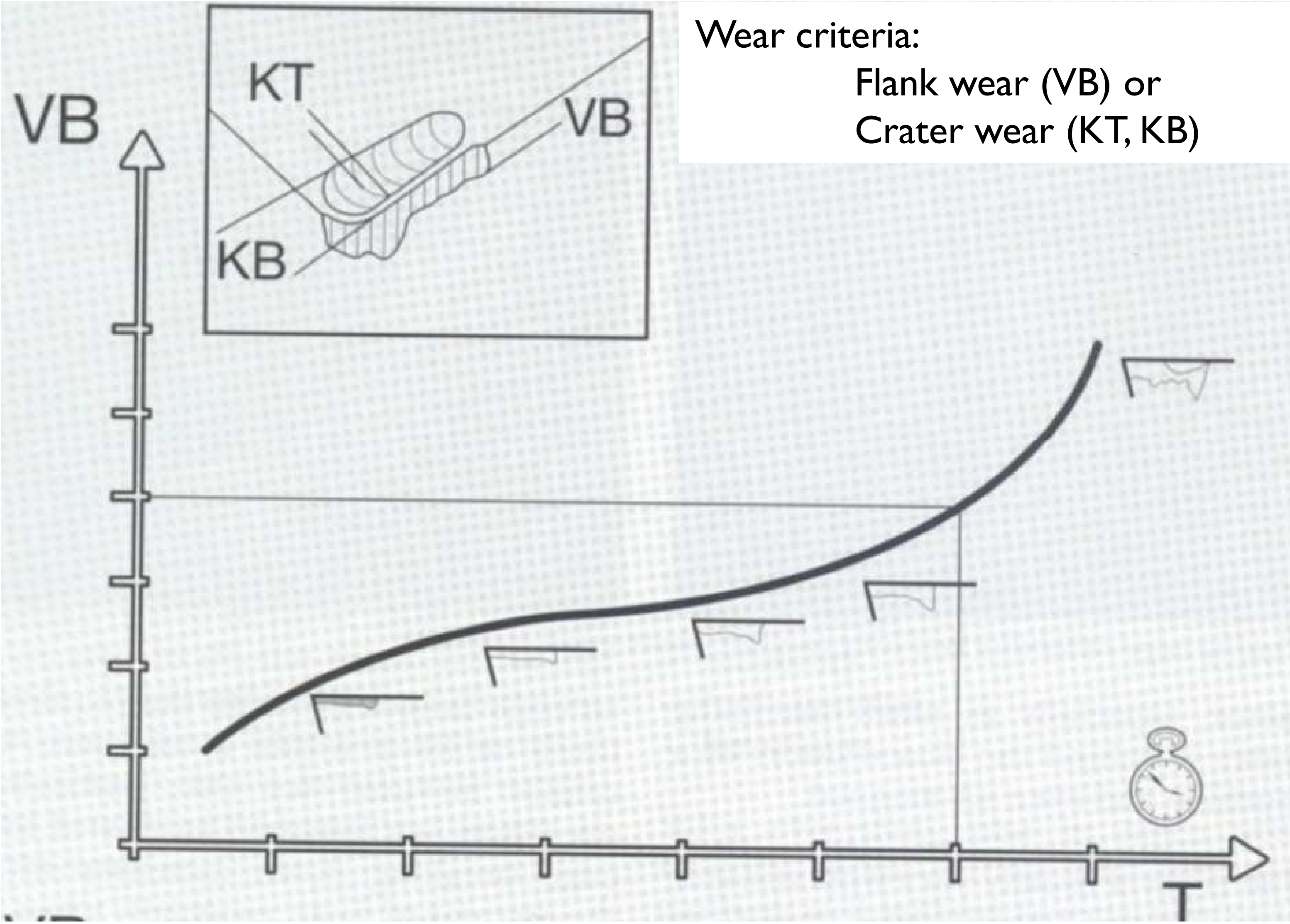
Built-up edge (BUE)



BUILT-UP EDGE

Tool wear	Possible cause	Possible remedy
Built-up edge causing poor surface finish and cutting edge chipping, when the BUE is torn away.	Cutting zone temperature is too low.	Increase cutting speed. Change to a more suitable coated grade.
	Negative cutting geometry.	Select a positive geometry insert.
	Very sticky material, such as low-carbon steel, stainless steels and aluminium.	

Wear process



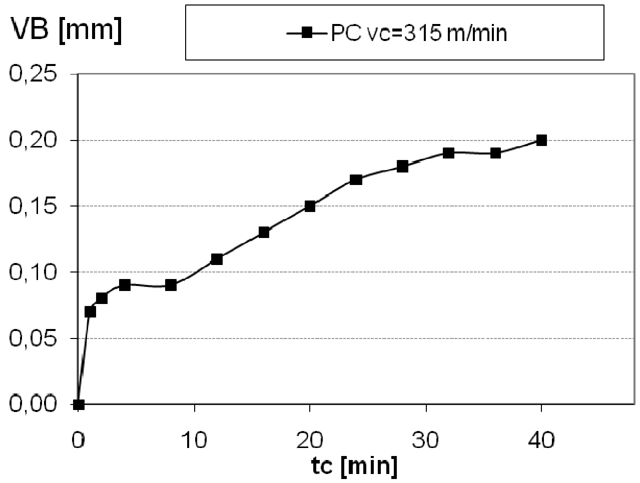
Wear criteria:

Flank wear (VB) or

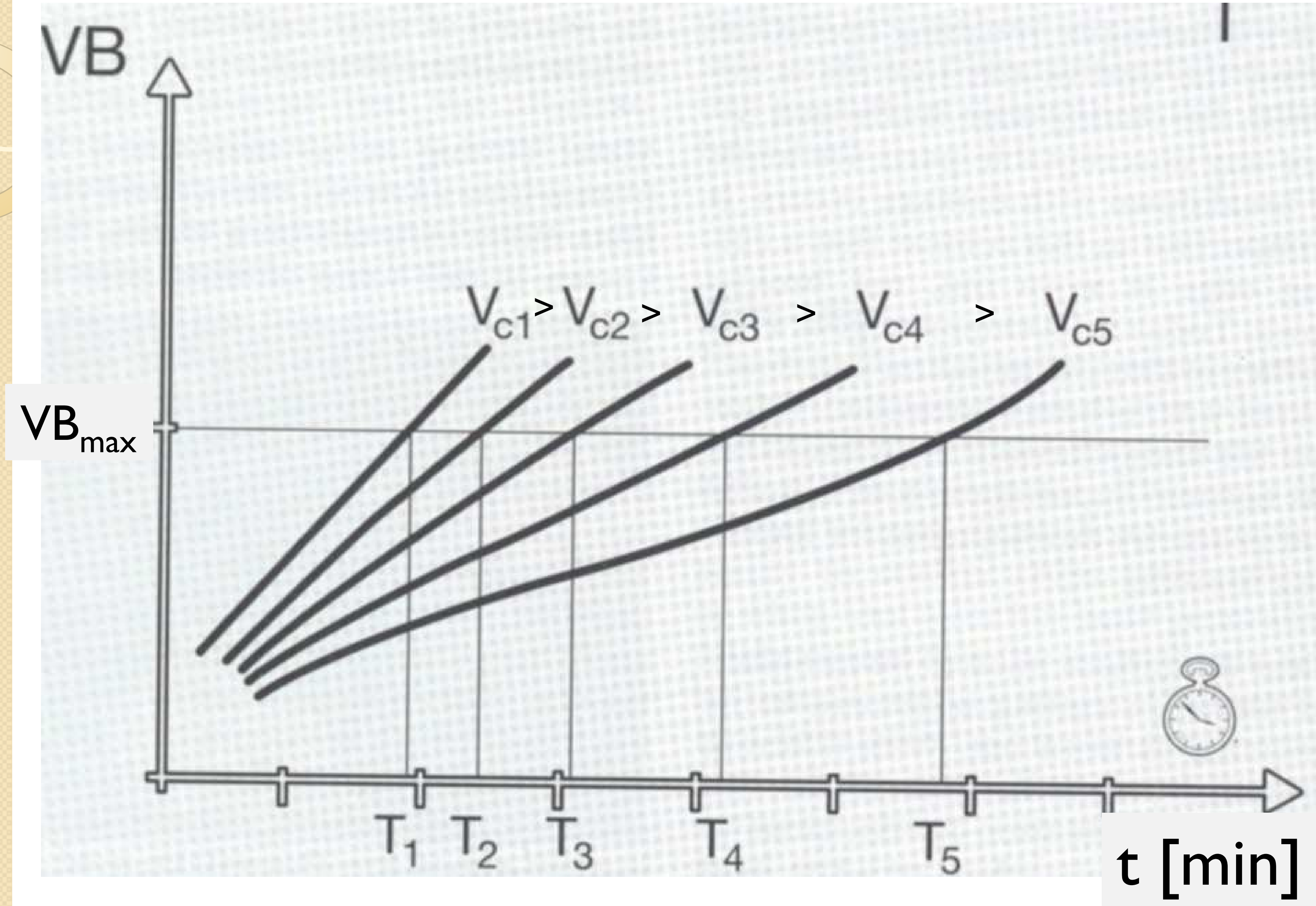
Crater wear (KT, KB)

Wear process

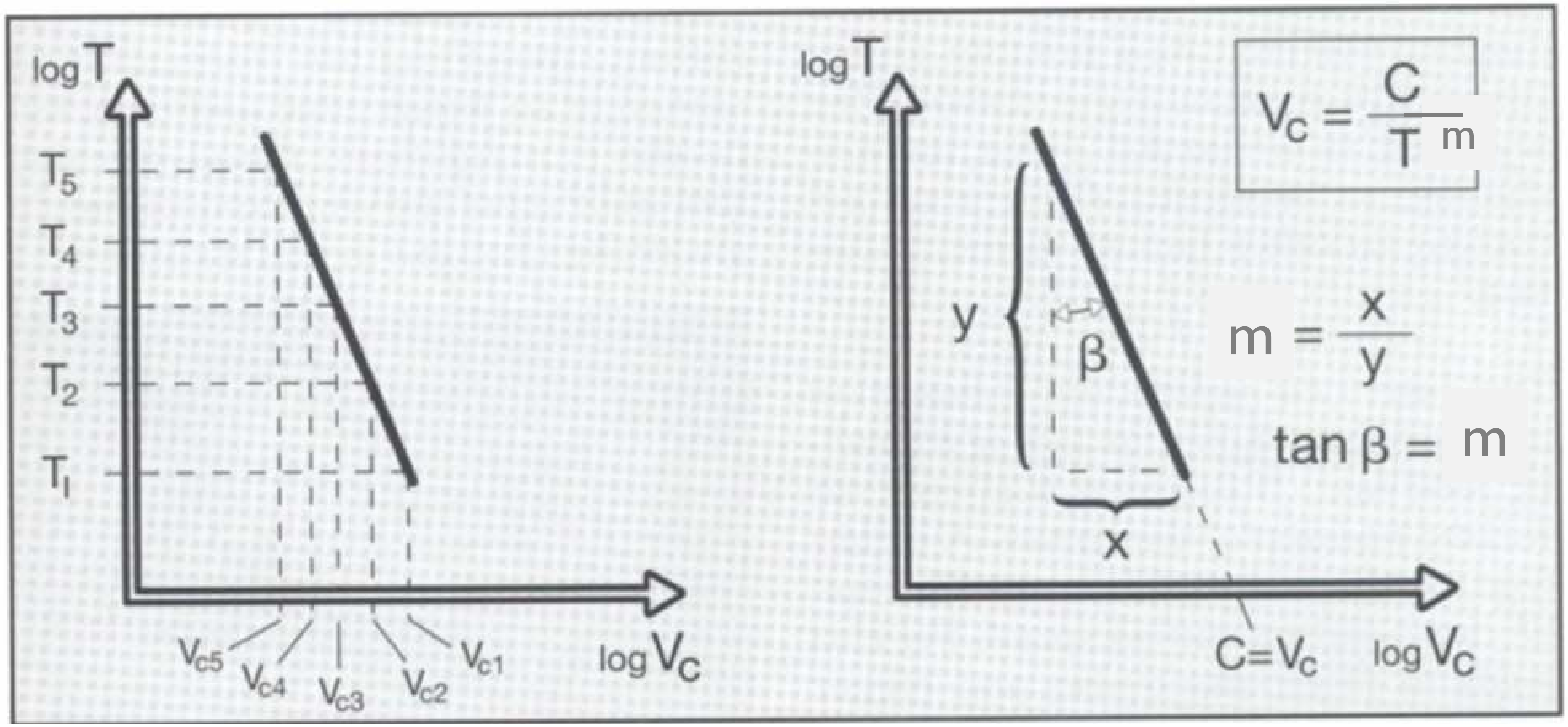
- Cutting speed: v_c = 315 m/min
- Depht of c.: a = 1,5 mm
- Feed: f = 0.2 mm
- Material: C45



Wear vs. Cutting speed



Logarithmic diagram



m – Constant, depends on workpiece material

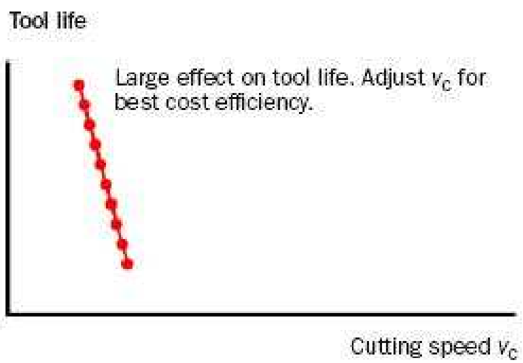
T – Tool life

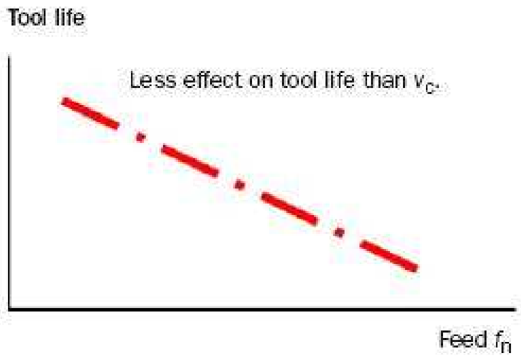
1907. W. A. Taylor – turning, v_c

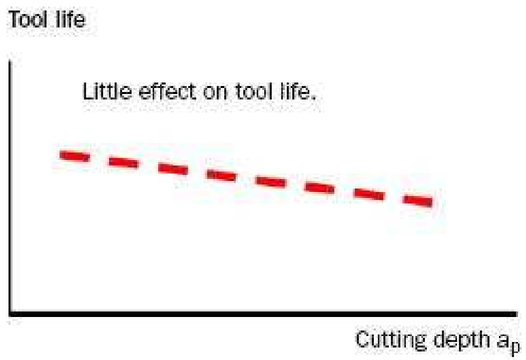
Extended Taylor formulea

Turning

$$v_c = \frac{C_v}{f^{x_v} \cdot a^{y_v} \cdot T^m} \left[\frac{\mathrm{m}}{\mathrm{min}}\right]$$







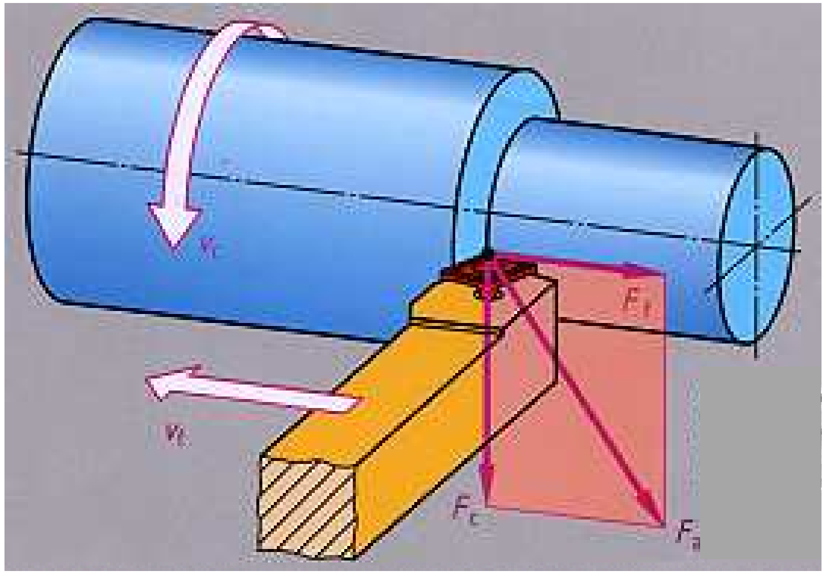
Drilling

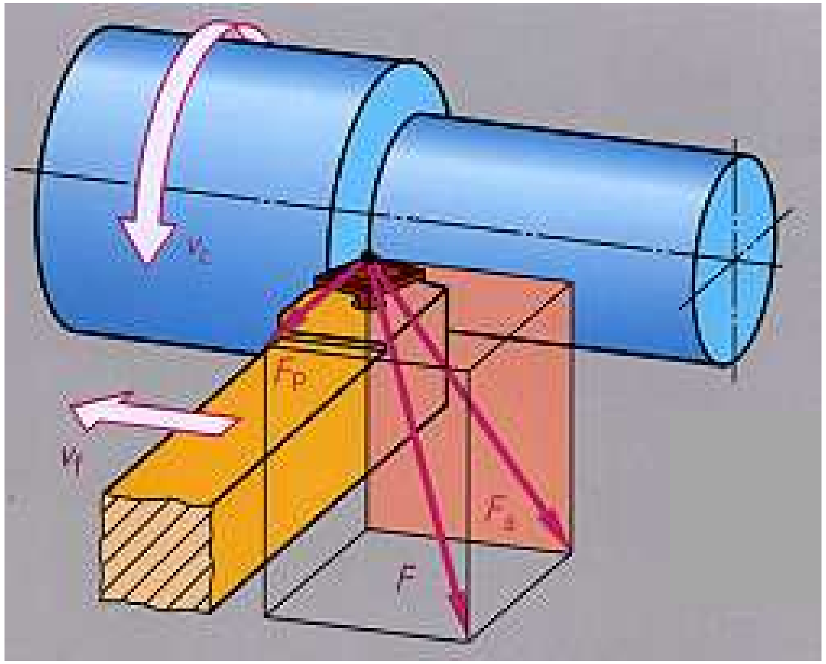
$$v_c = \frac{C_v \cdot d^{z_v}}{f^{x_v} \cdot T^m} \left[\frac{\mathrm{m}}{\mathrm{min}}\right]$$

Milling

$$v_c = \frac{C_v}{f_z^{\,x_v} \cdot a_e^{\,y_v} \cdot a_p^{\,z_v} \cdot T^m} \left[\frac{\mathrm{m}}{\mathrm{min}}\right]$$

Cutting forces





F – Cutting force

F_c – Tangential component of the cutting force
F_f – Axial component of the cutting force (feed force)
F_a – Active cutting force
F_p – Radial component of the cutting force (pasive force)

Cutting force

Method 1 $$\mathrm{F_c} = k_c \cdot A \; [\mathrm{N}]$$ $$k_c = \frac{k_{c1}}{h^m}$$

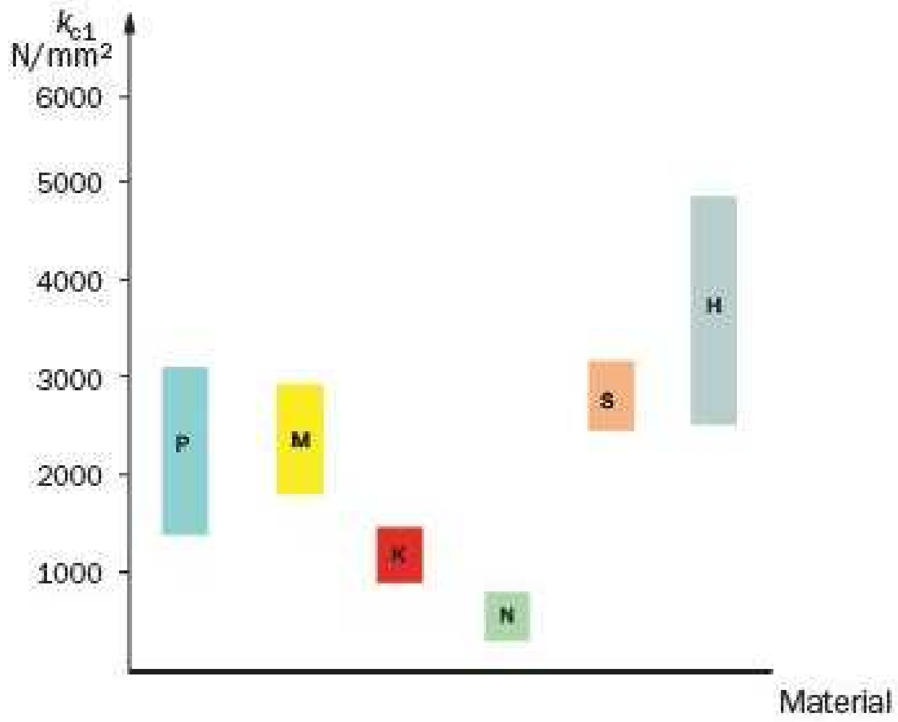
k_c – specific cutting force,
required force for cutting a 1 mm^2 chip
k_{c1} – main value of the specific cutting force
h – chip thickness
m - exponent

A – chip cross section area (A = a f = b h)

$$\mathrm{F_c} : \mathrm{F_p} : \mathrm{F_f} = 100 : 40 \div 80 : 10 \div 30$$

$$\mathrm{F_p} = A \cdot \frac{k_{p1}}{h^m} \; [\mathrm{N}] \qquad \mathrm{F_f} = A \cdot \frac{k_{f1}}{h^m} \; [\mathrm{N}]$$

Material	k_{c1}	m
C15	1820	0,22
C45	1680	0,26
100Cr6	1410	0,39
90MnCrV	2300	0,21
x5CrNi1810	2350	0,21
GG20	1020	0,25
AlMg3	780	0,23



Method 2

$$F_c = C_F \cdot f^{x_F} \cdot a^{y_F} \cdot v_c^{z_F} \cdot \prod K_{Fci} \quad [\mathrm{N}]$$

C_F – constant coefficient, N

x_F , y_F , z_F - exponent

a, f, v_c – cuttig data

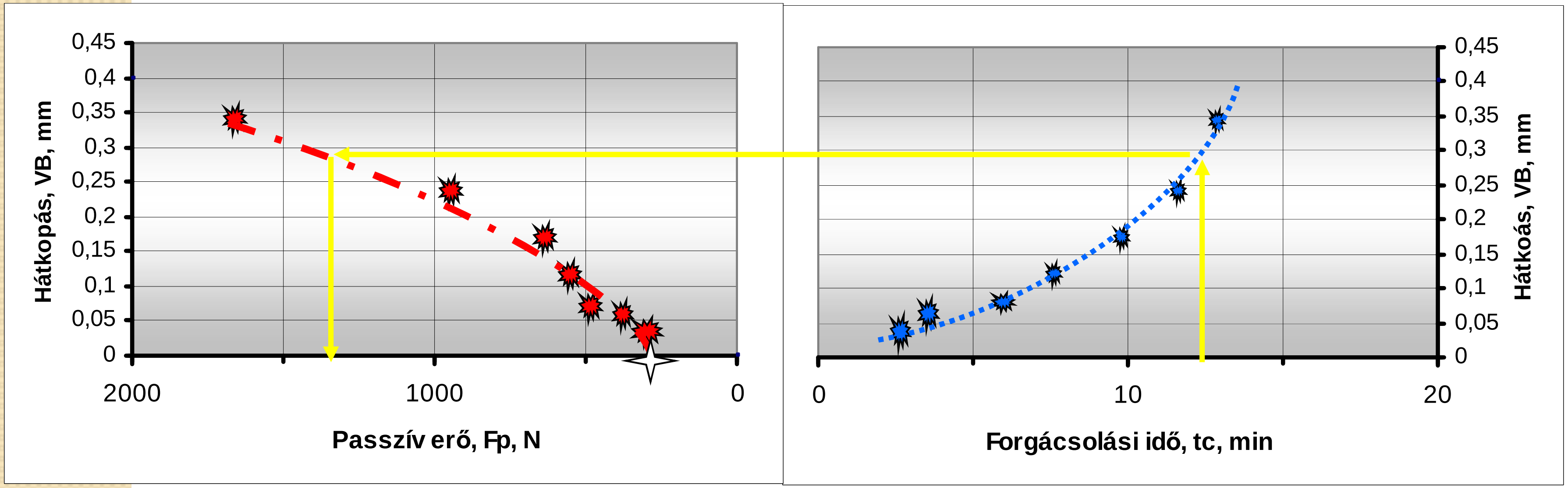
K_{Fci} – modification coefficients

Torque in the axes, Nm

$$M_c = \frac{F_c \cdot d}{2000} \quad [\mathrm{Nm}]$$

Power, kW

$$P_c = \frac{F_c \cdot v_c}{60000} = \frac{M_c \cdot n}{9550} \quad [\mathrm{kW}]$$



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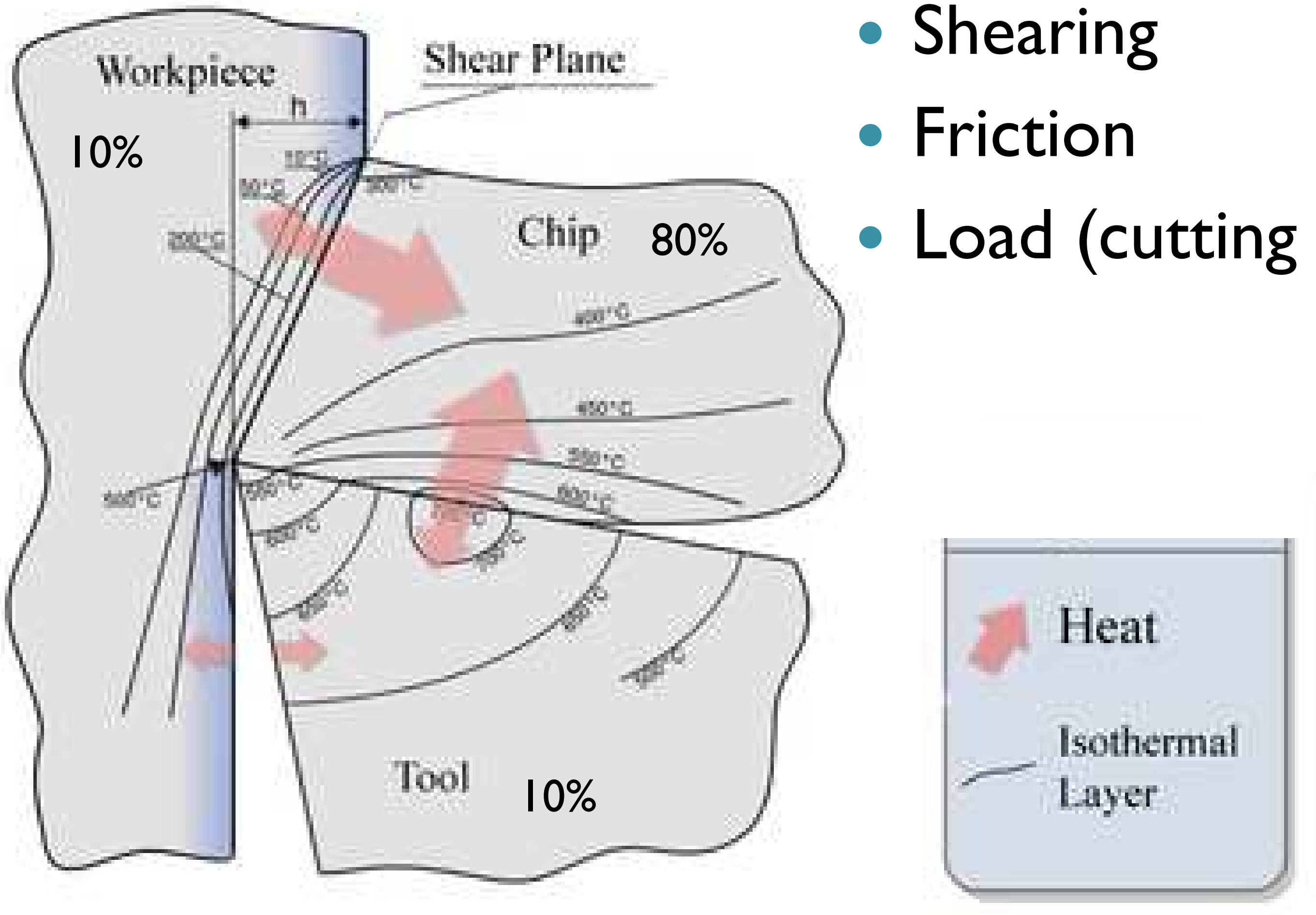
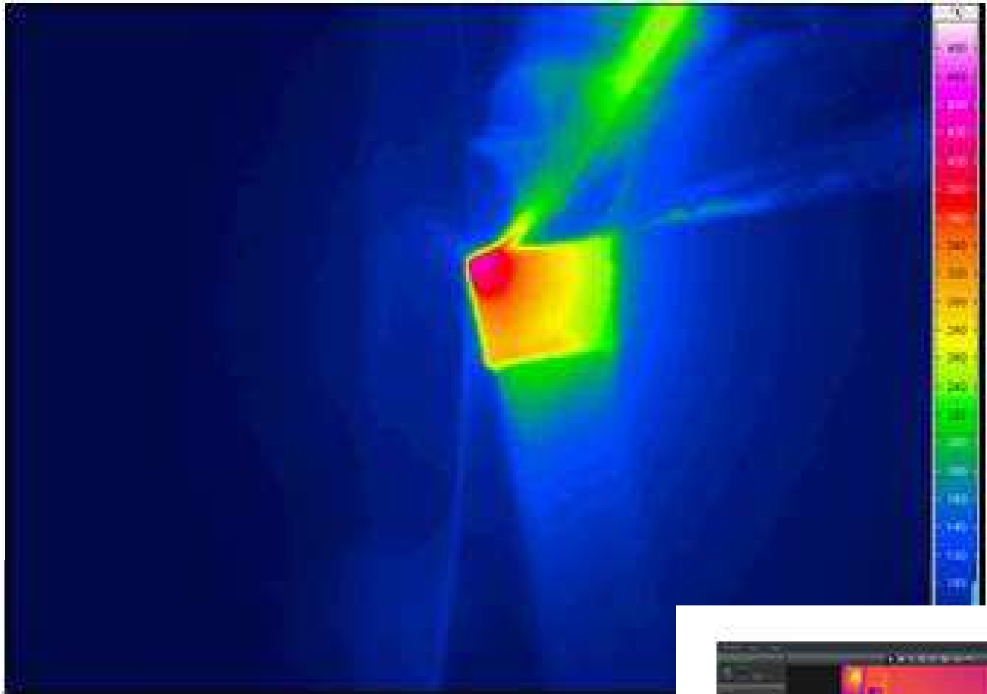
Temperature



- Shearing
- Friction
- Load (cutting force)

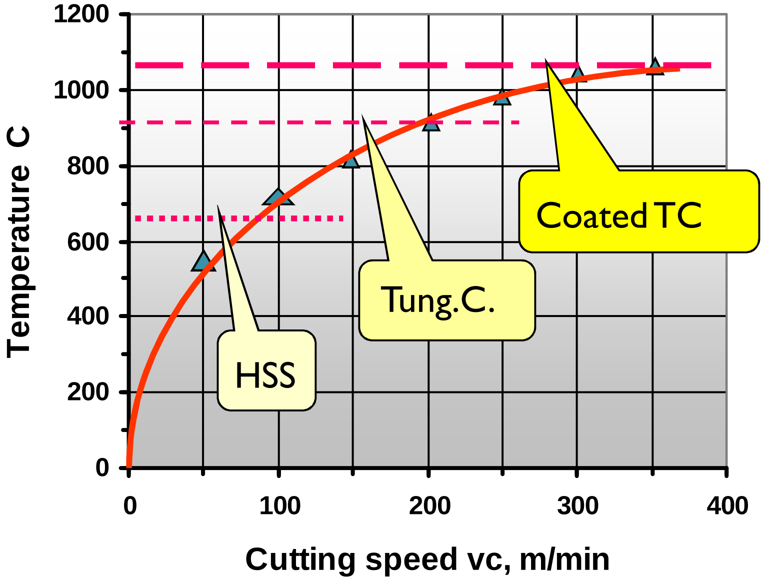
Measure?

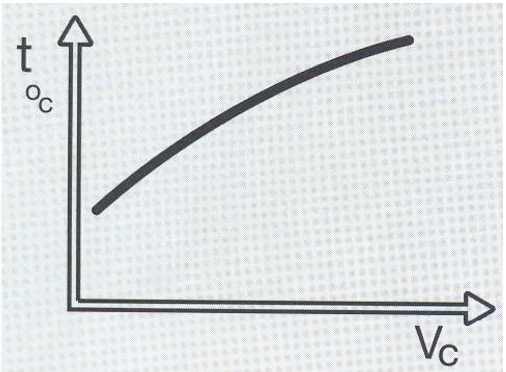


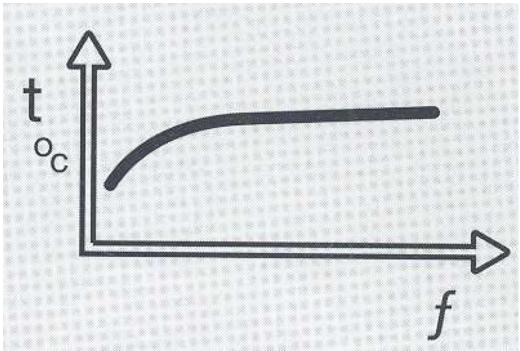
Calculation

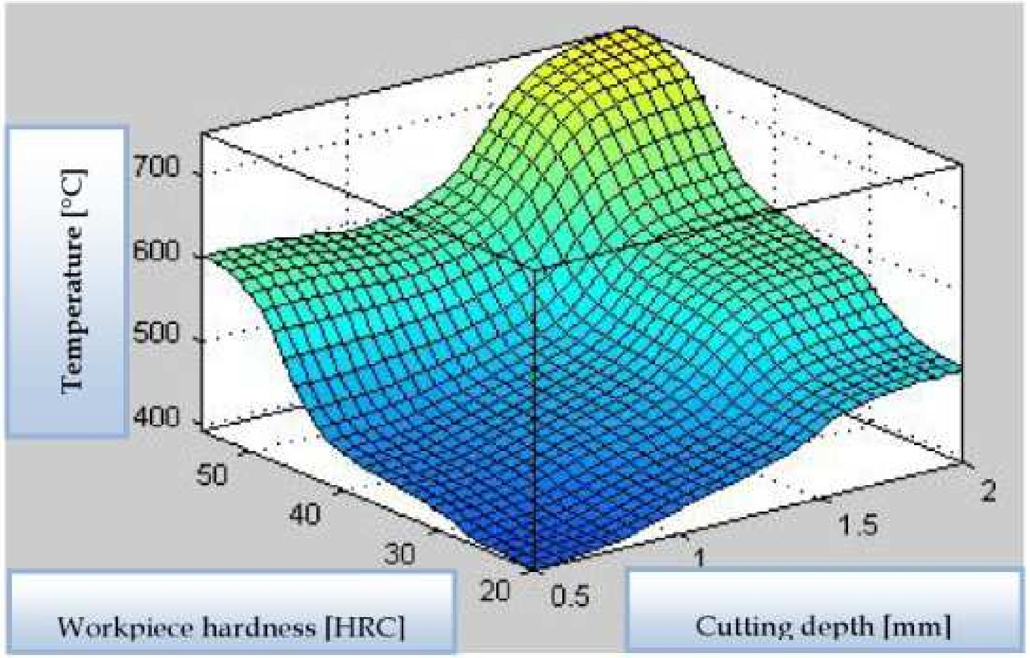
$$\Theta = C_\Theta \cdot f^{x_\Theta} \cdot a^{y_\Theta} \cdot v_c^{z_\Theta} \; [^\circ C]$$

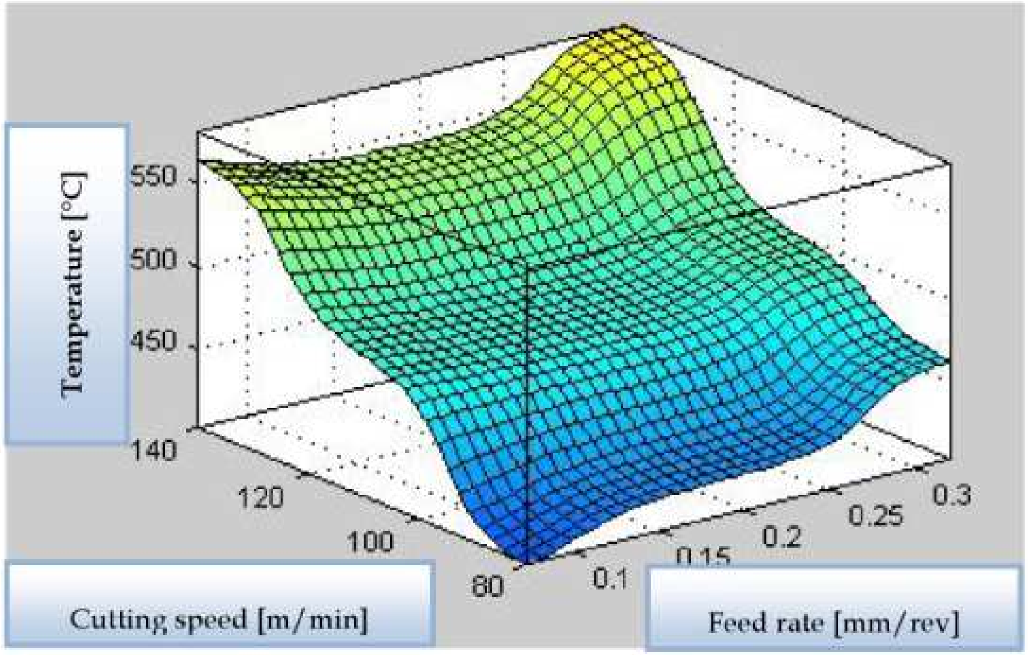
C_Θ	– constant coefficient
x_Θ , y_Θ , z_Θ	– exponent (<1)
a, f, v_c	– cutting data








Temperature [°C]
700
600
500
400
50
40
30
20
0.5
1
1.5
2
Workpiece hardness [HRC]
Cutting depth [mm]

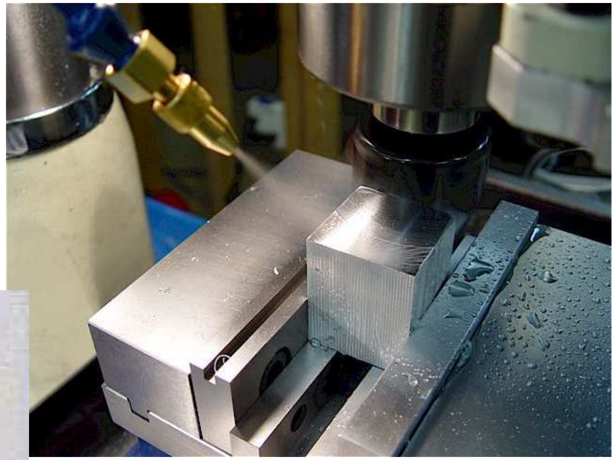

Temperature [°C]
550
500
450
140
120
100
80
0.1
0.15
0.2
0.25
0.3
Cutting speed [m/min]
Feed rate [mm/rev]

Coolant

- Aim / function:
  - Cooling - detract the heat
  - Lubricating - decrease the friction
  - Flushing - wash-out the chips

Coolant material

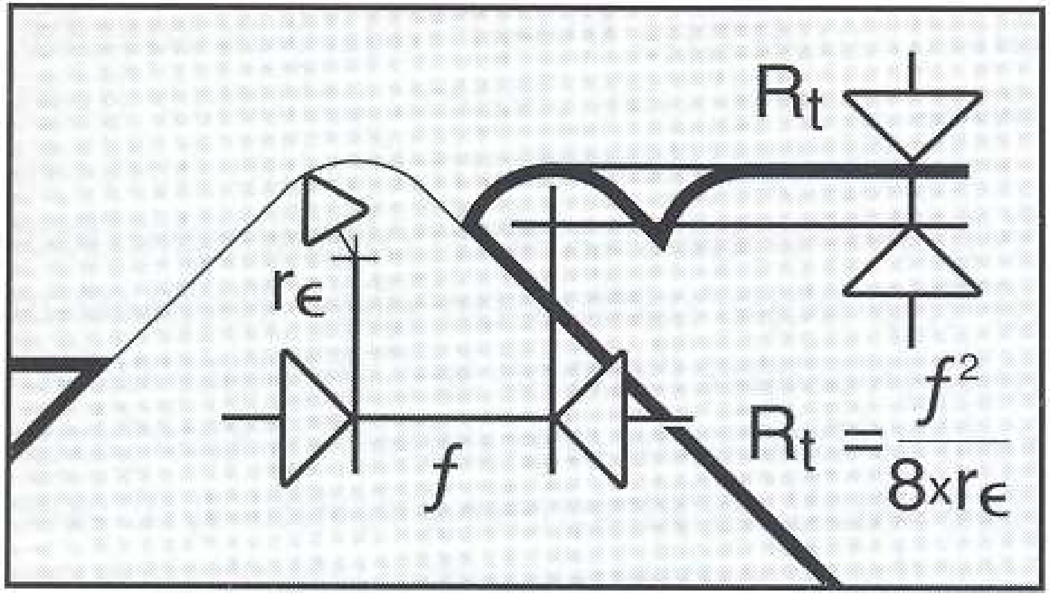
- Non (dry cutting)
- Air (C, F)
- Cool air (C, F)
- Oil (L)
- Water + oil (C, L, F)

Surface quality

- Accuracy
  - Size
  - Shape
  - Position
- Surface quality
  - Surface roughness
  - Surface integrity

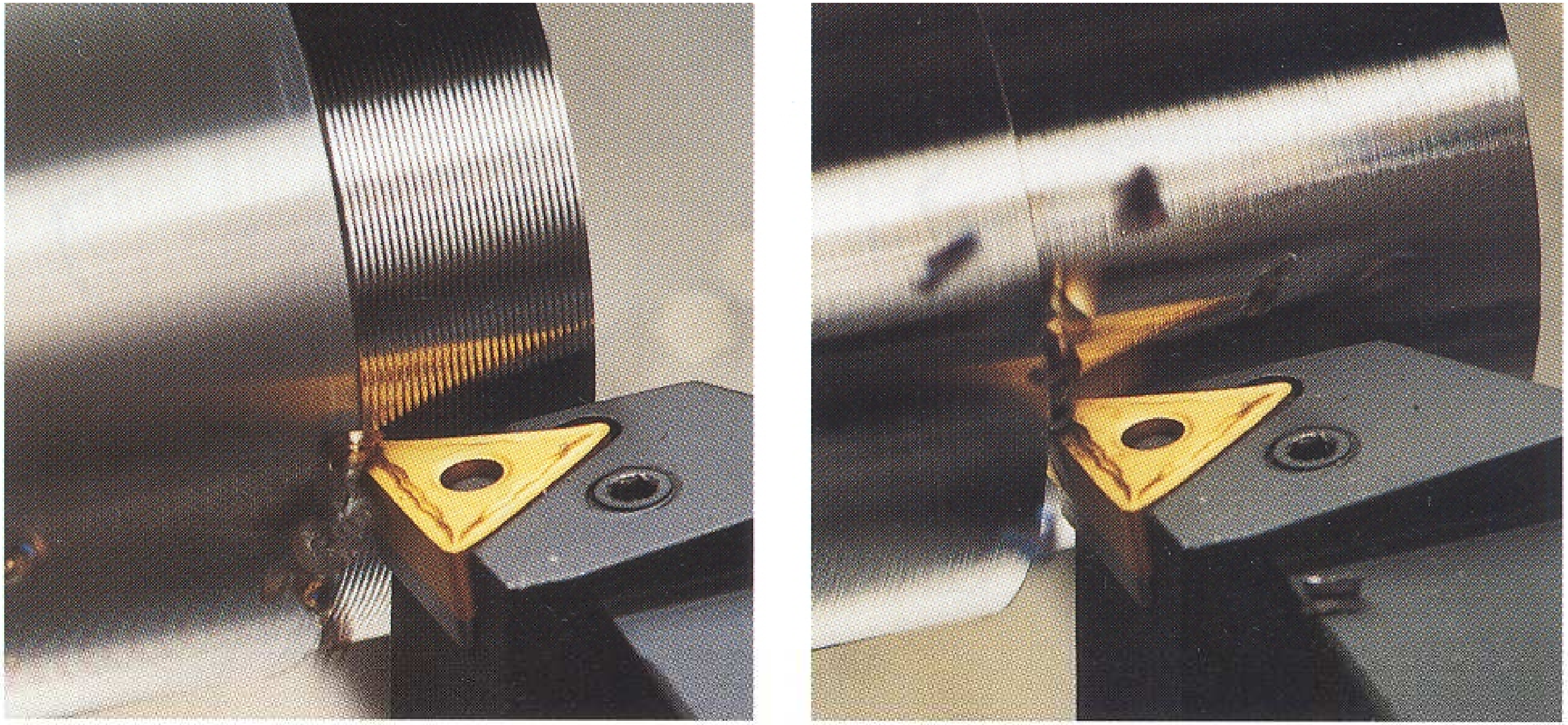
Surface roughness in turning



Main factors:

- Feed
- Nose radius

Rt ≈ 4 Ra



The nose radius affects surface texture and cutting edge strength