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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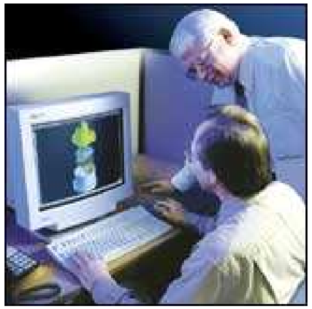



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Schedule

- Week 1-6th - Cutting tools and methods
- Week 7-13th - Machine tools
- Week 14th - Test

- HomeWork 1 - Tool drawing
- HomeWork 2 - Operation planning
- HomeWork 3 -

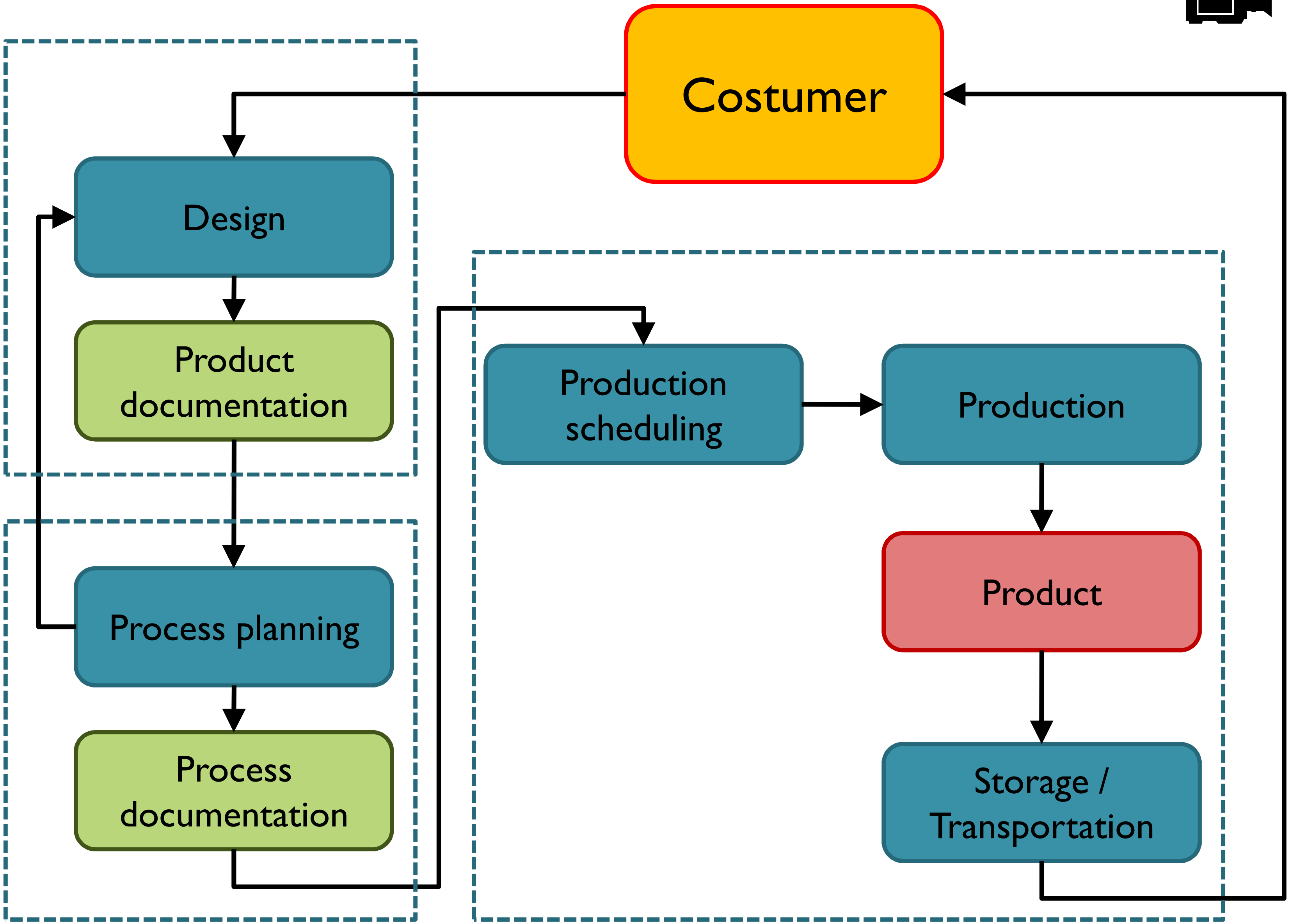
Useful links

- http://www.sandvik.coromant.com/en-gb/knowledge/pages/default.aspx
- http://www.kennametal.com/kennametal/en/resources/calculators.html
- http://mmu.ic.polyu.edu.hk/handout/0102/0102.htm
- http://www.mitsubishicarbide.net/contents/mht/enuk/html/product/technical_information/index.html
- www.turning.fw.hu

01

BASICS OF CUTTING

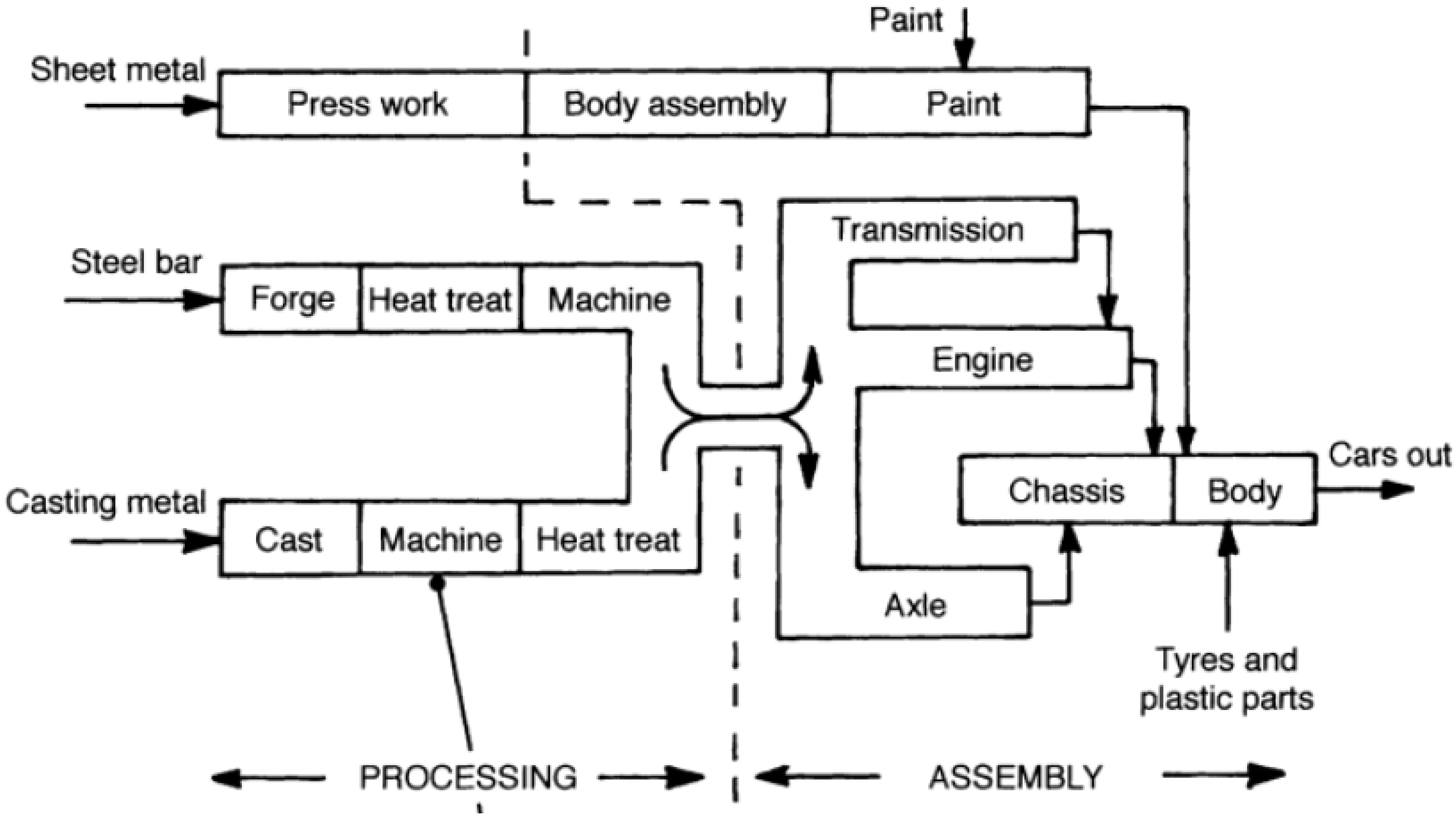
Production process



Manufacturing methods

Forming	Cutting methods	Assembly
Sheet metal processing	Welding	Packaging
Moulding	Heat treatment	Testing and Measuring
Forging	Painting	

Manufacturing process



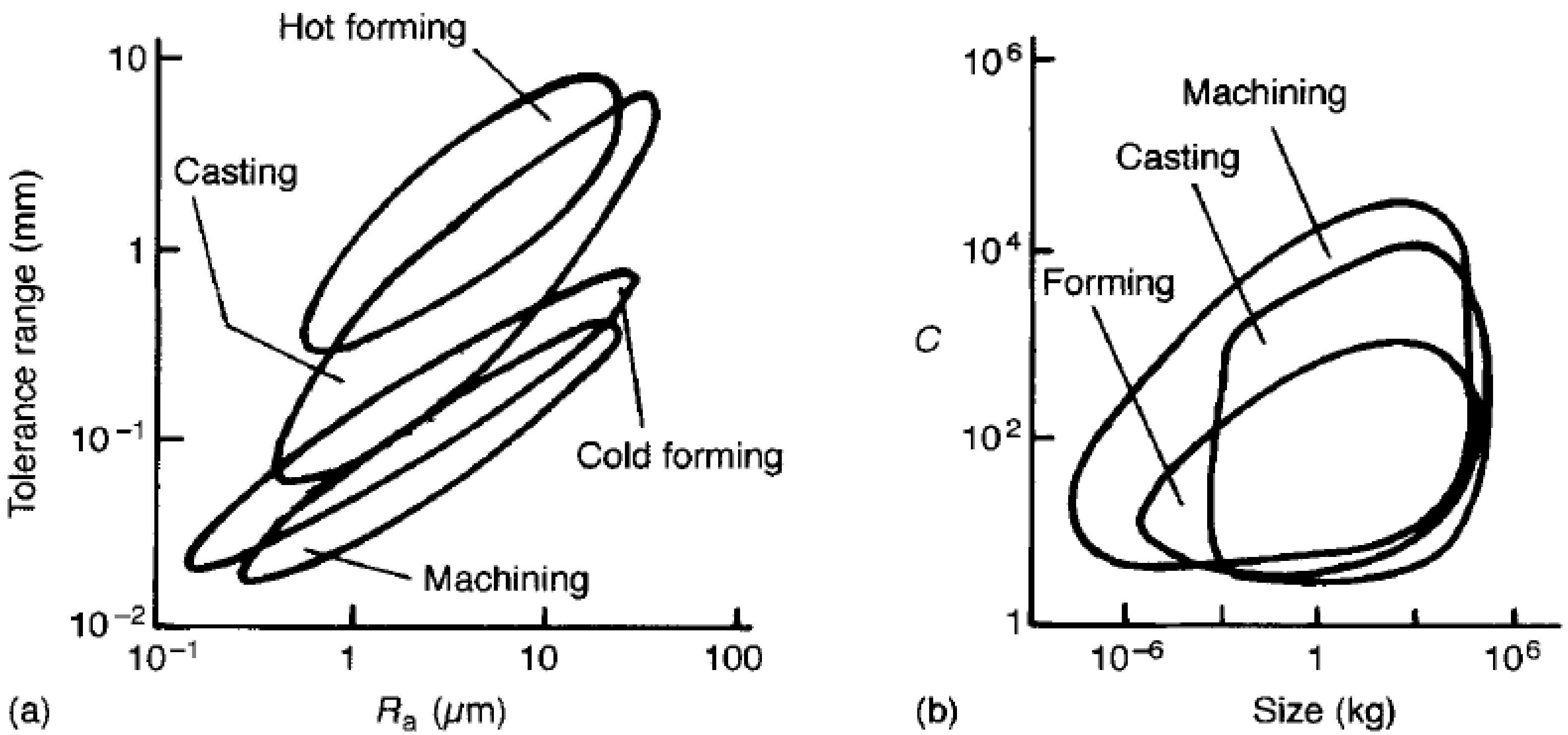


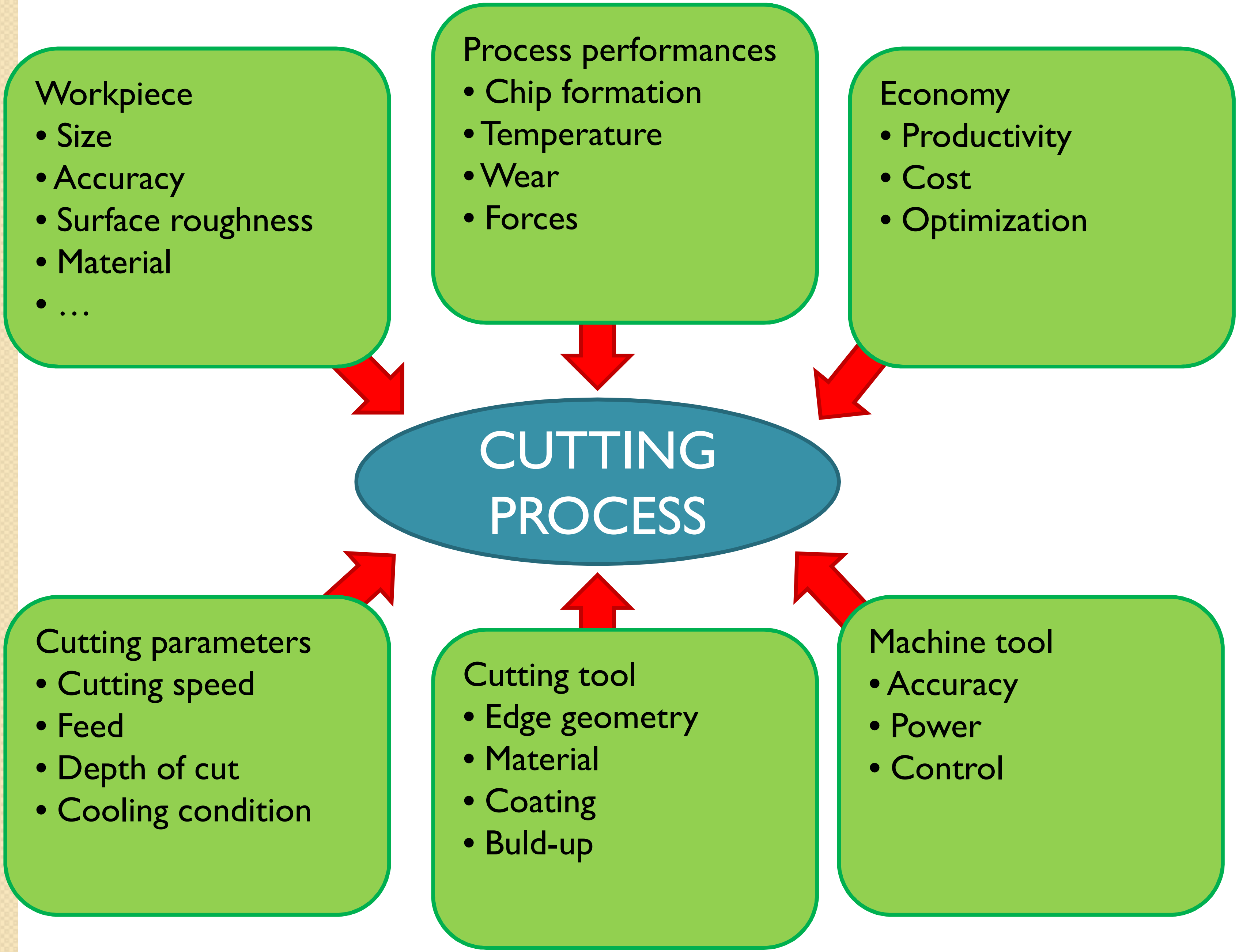
Fig. 1.2 (a) Typical accuracy and finish and (b) complexity and size achievable by machining, forming and casting processes, after Ashby (1992)

Advantages of cutting technology

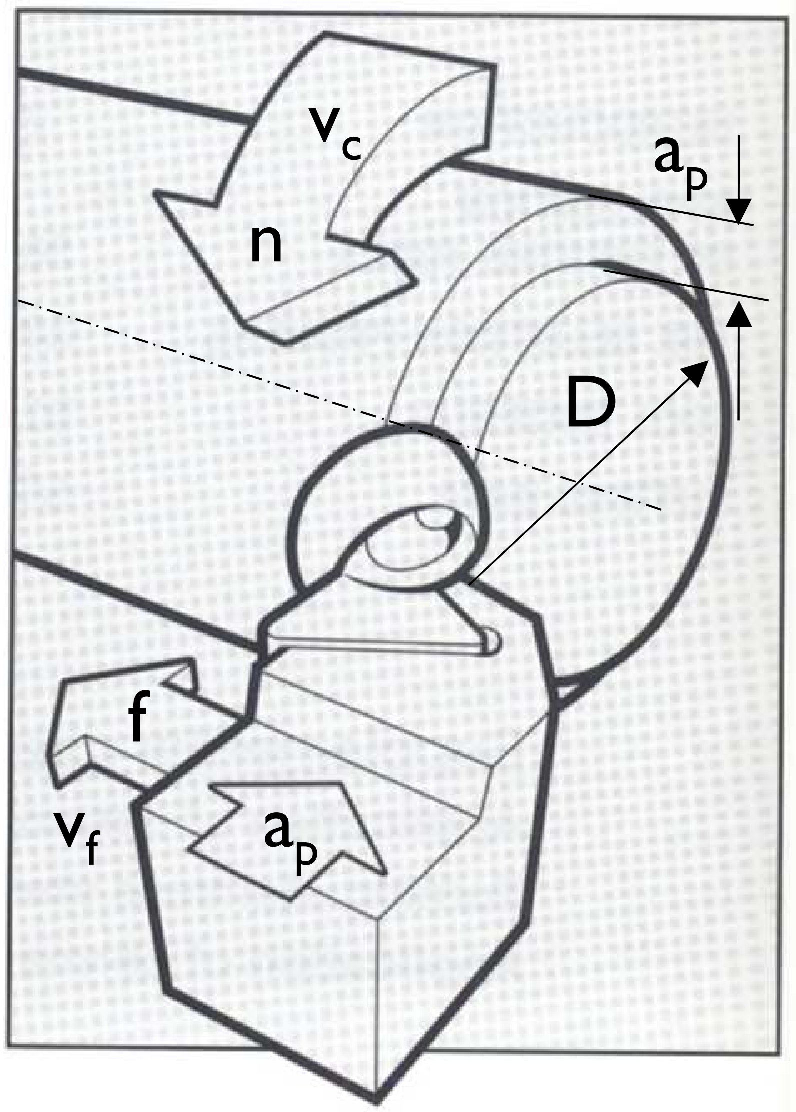
- Good for piece production (cost, time)
- Accurate, guud surface quality
- Good for every material
- Good for complex parts
- Homogenous material structure
- Easy to automate

Disdvantages of cutting technology

- High energy demand
- Waste material (chip)
- Different machine tools
- Lot of equipments
- CNC control
- Risk of accident
- Polution (coolant liquid, chip, noise…)
- High cost


Workpiece
• Size
• Accuracy
• Surface roughness
• Material
• …
Process performances
• Chip formation
• Temperature
• Wear
• Forces
Economy
• Productivity
• Cost
• Optimization
CUTTING PROCESS
Cutting parameters
• Cutting speed
• Feed
• Depth of cut
• Cooling condition
Cutting tool
• Edge geometry
• Material
• Coating
• Buld-up
Machine tool
• Accuracy
• Power
• Control

Cutting parameters (in case of turning)



n – Spindle speed [1/min]

v_c – Cutting speed [m/min]

$$n = \frac{1000 \cdot v_c}{D \cdot \Pi} \qquad v_c = \frac{D \cdot \Pi \cdot n}{1000}$$

f – Feed [mm]

v_f – Feed speed [mm/min]

$$v_f = n \cdot f$$

a_p – Depth of cut [mm]

Material removal rate:

$$Q = a_p \cdot f \cdot v_c [mm^3 / \min]$$

Primary motion

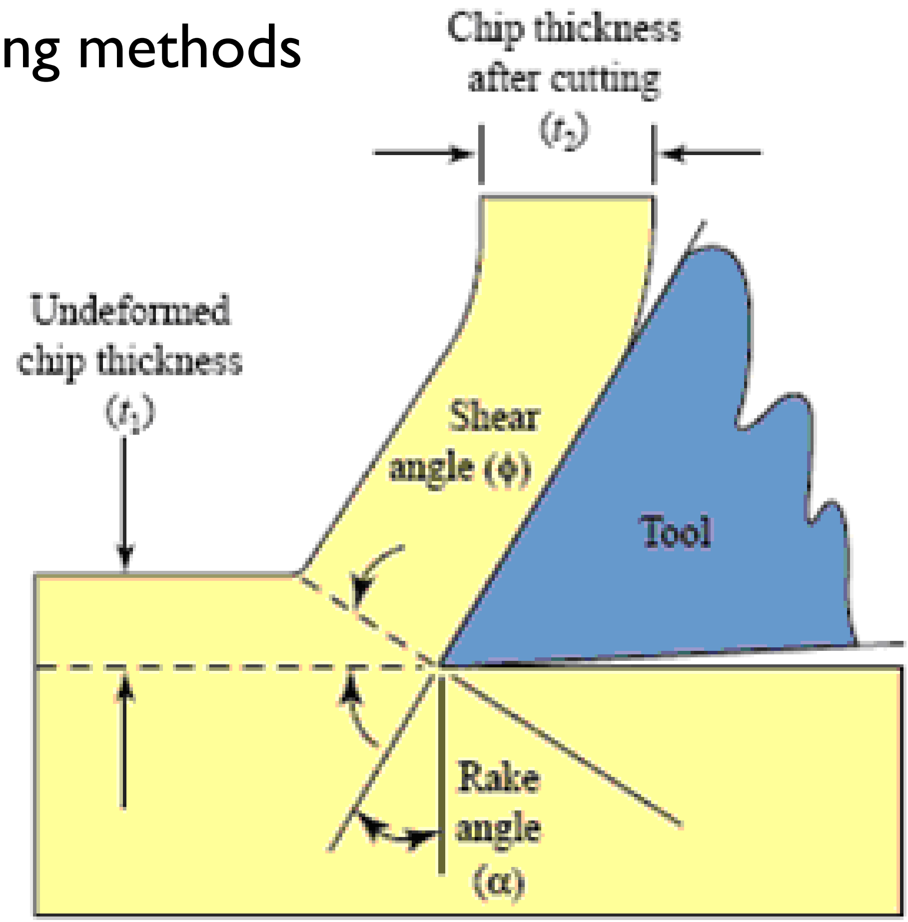
- **Ensures the cutting speed**
- Linear OR Rotational
- Continous OR Periodical
- Done by the Tool OR by the Workpiece

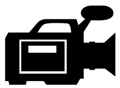
Feed motion

- **<u>Ensures the feed speed</u>**
- Continous OR Periodical (double stroke)
- Done by the Tool OR by the Workpiece

Cutting

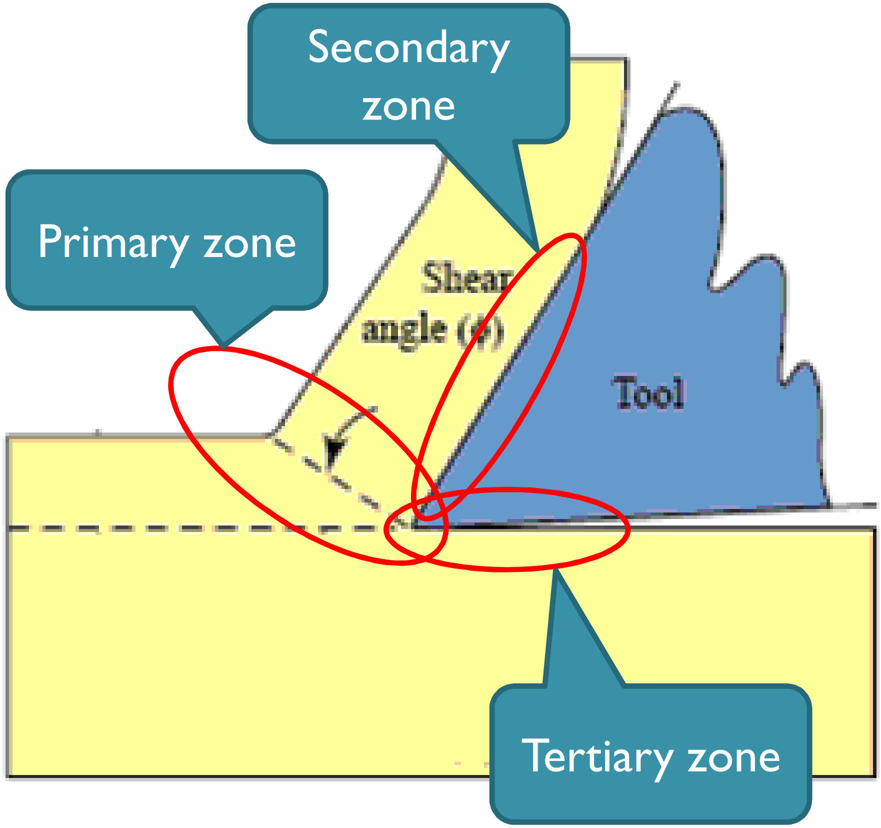
- Hard tool – Tool materials
- Cutting edge – Edge geometry
- Relative motion – Cutting methods

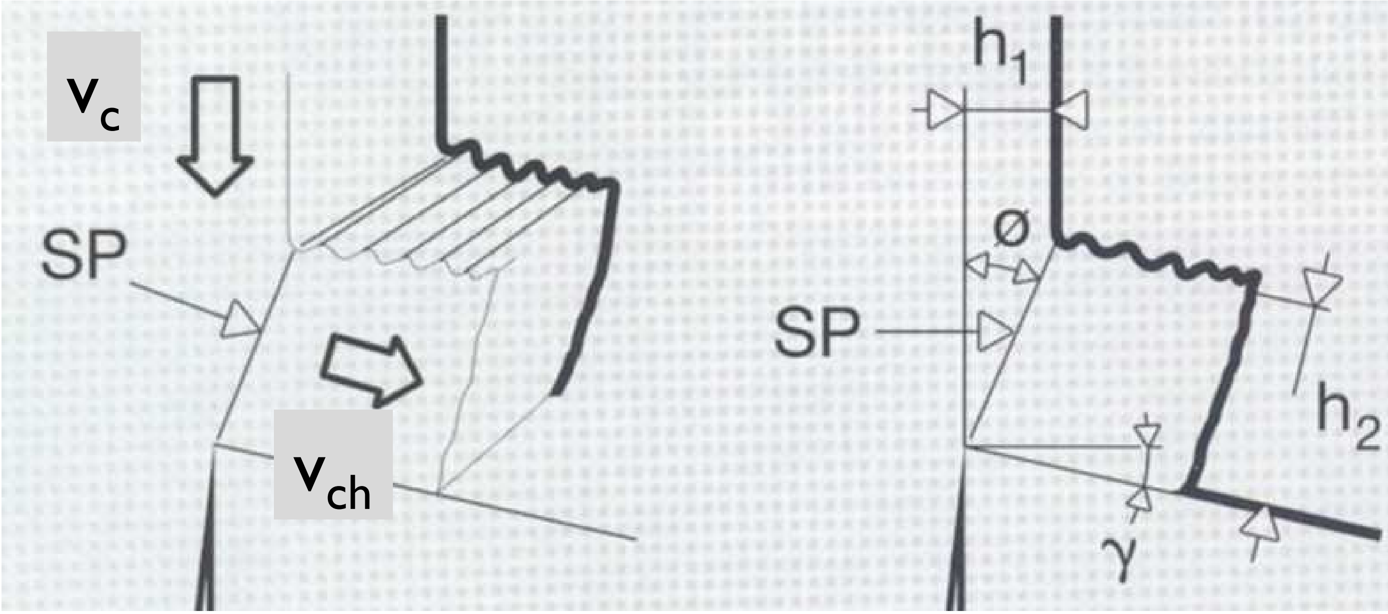




Deformation zones

- Primary zone:
  - Shear of the material
  - Shearing force
- Secondary zone
  - Friction between the chip and the tool
- Tertiary zone
  - Friction between the tool and the part
  - Plastic deformation





1. Elastic deformation
2. Plastic deformation
3. Shearing
4. Welding of chip elements

Chip contraction:

$$\lambda = \frac{h_2}{h_1}$$

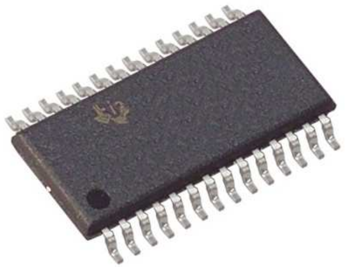
Steels: 1.5 – 6
Cast iron: 1.5 – 2.5

SP – Shear plane
Φ – Shear plane angle
γ – Rake angle
h1 – Undeformed chip thickness
h2 – Deformed chip thickness

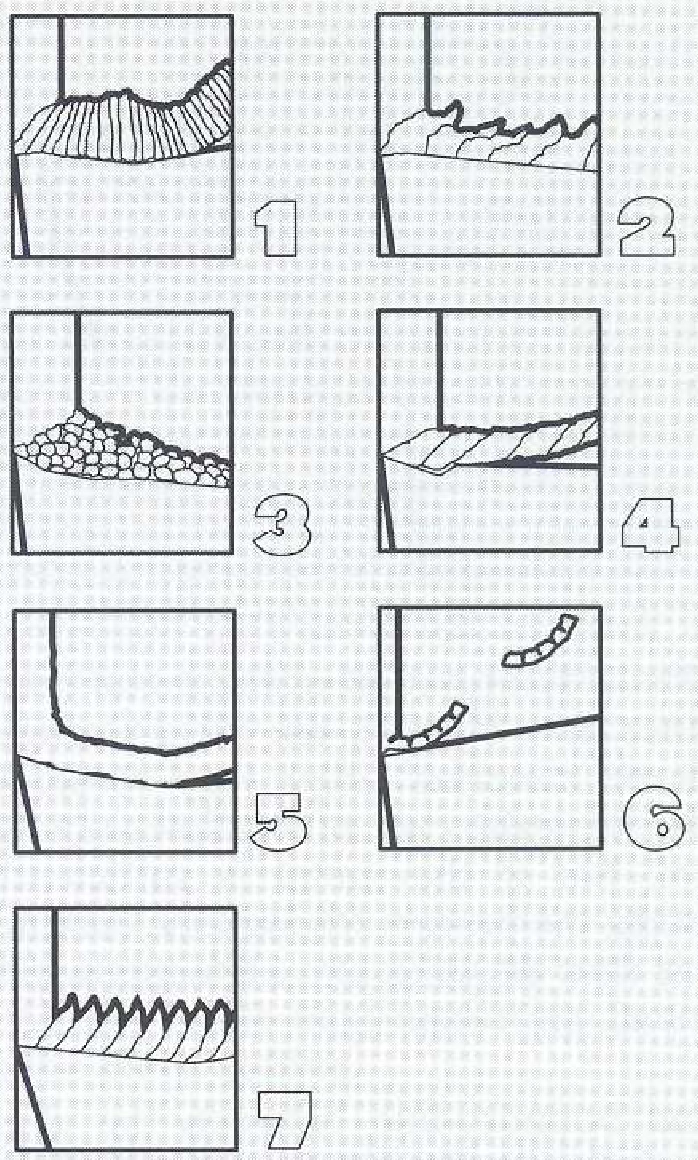
$$h_1 \cdot v_c = h_2 \cdot v_{ch}$$

Chipformation

- Continous chip
- Discontinous segmented chip
  - C
- Breaked chip
  - C
  - 6
  - Short spiral



Chipformation



(1) continuous, long chipping, such as most steels

(2) lamellar chipping, such as most stainless steels

(3) short chipping, such as most cast-irons

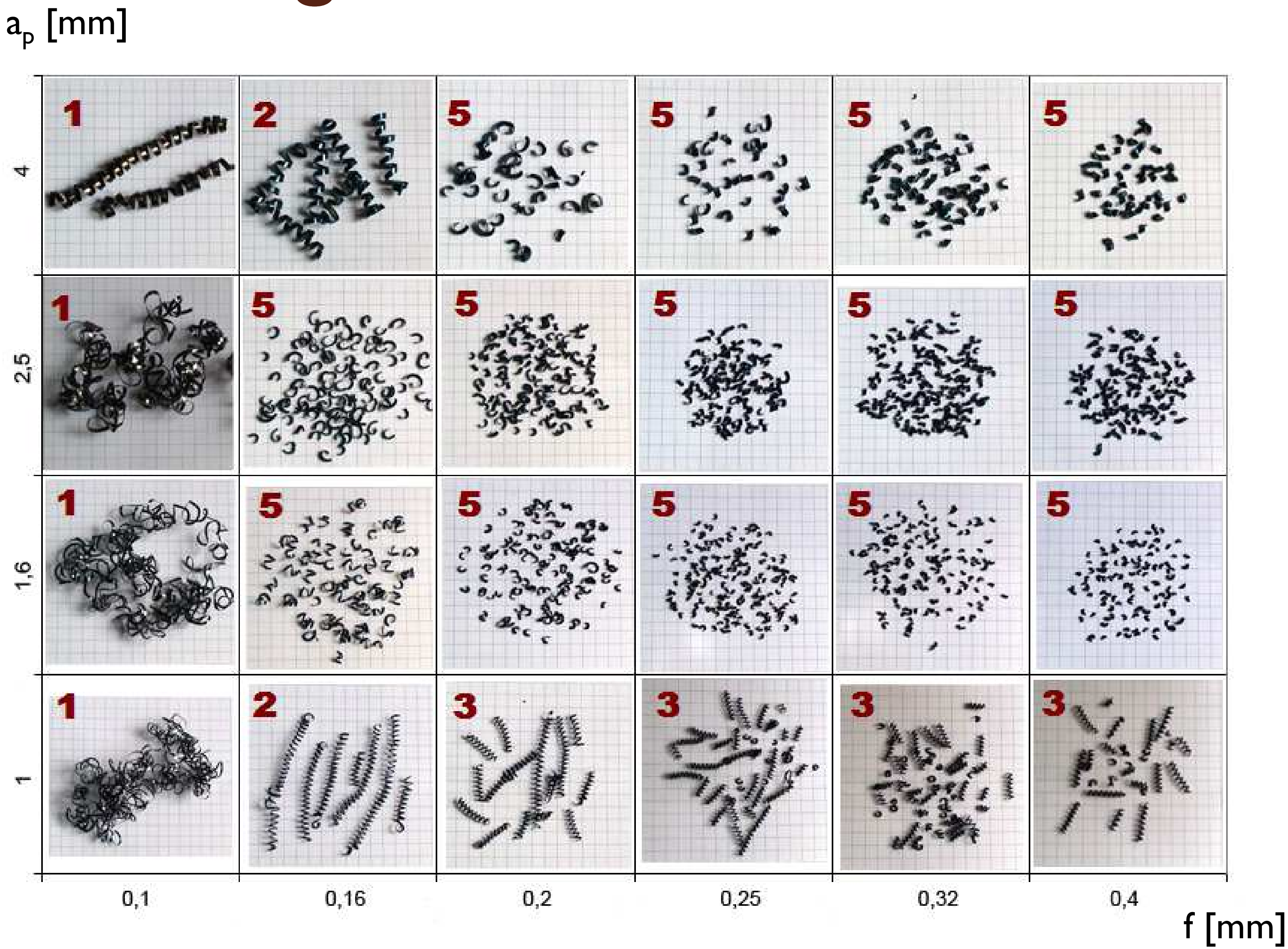
(4) varying, high force chipping, such as most super alloys

(5) soft, low force chipping, such as aluminium

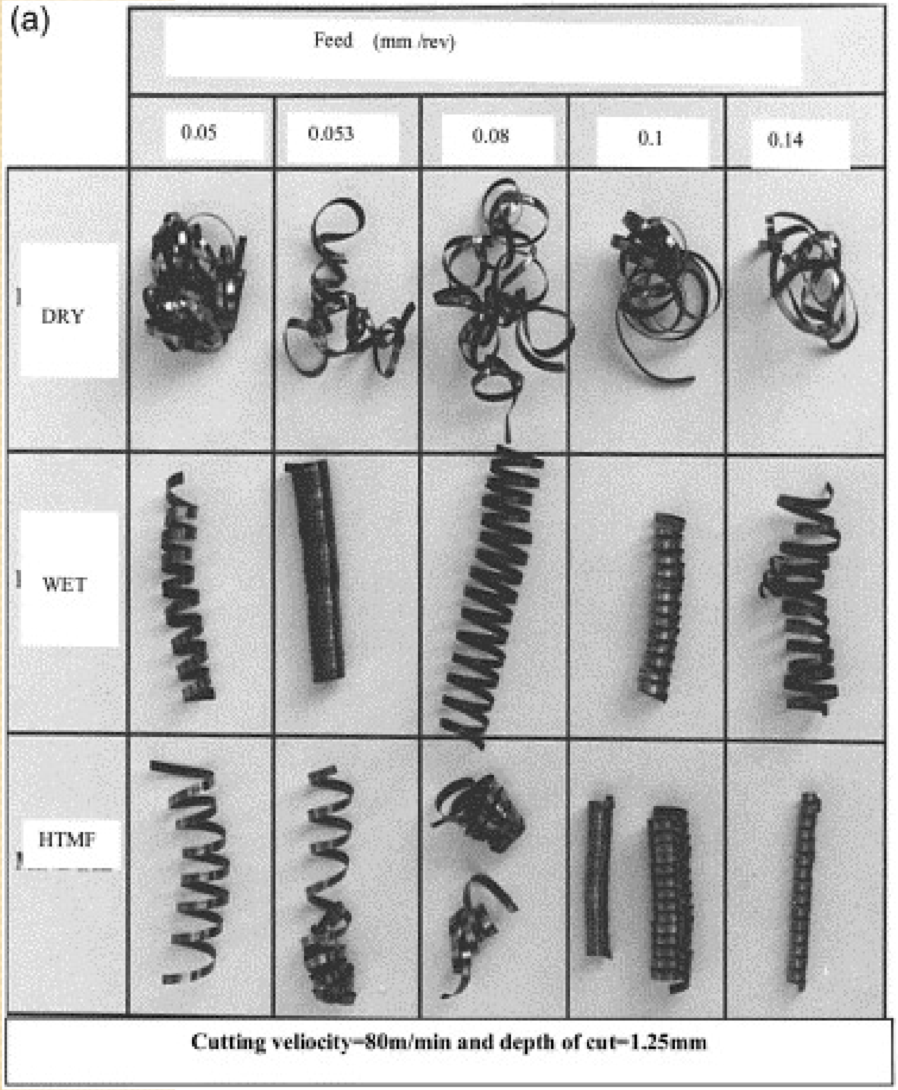
(6) high pressure/temperature chipp-ing, such as hard materials

(7) segmental chipping, such as tita-nium

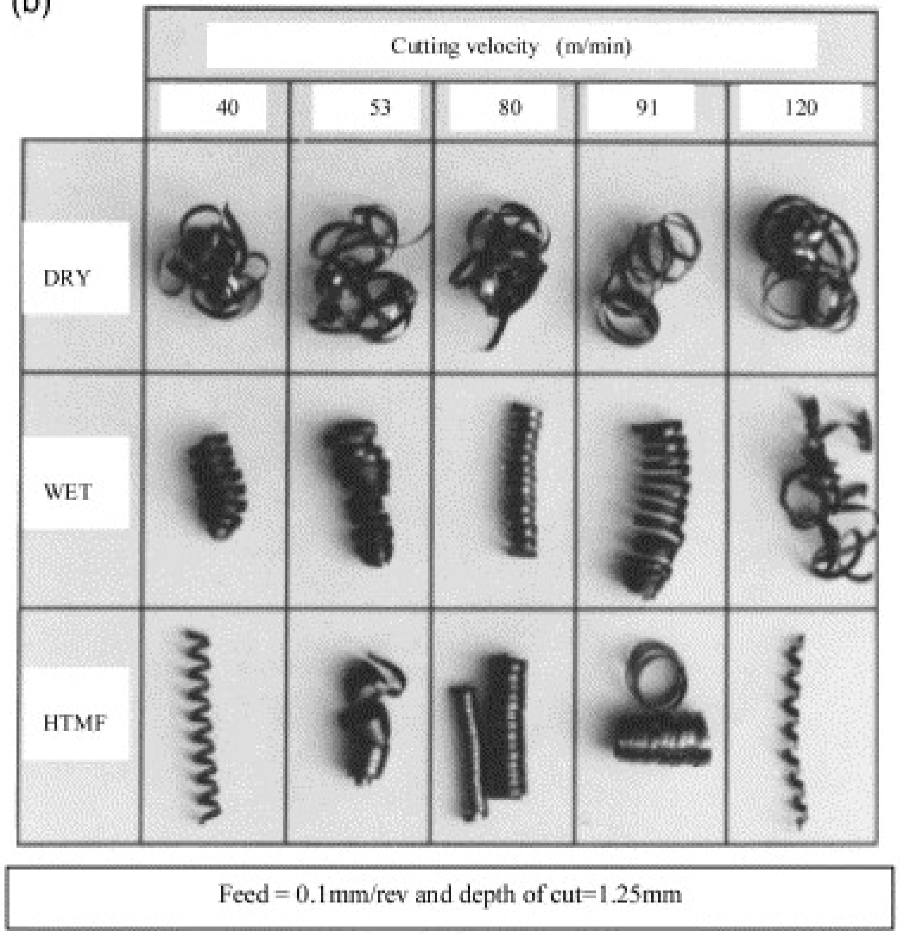
Turning test



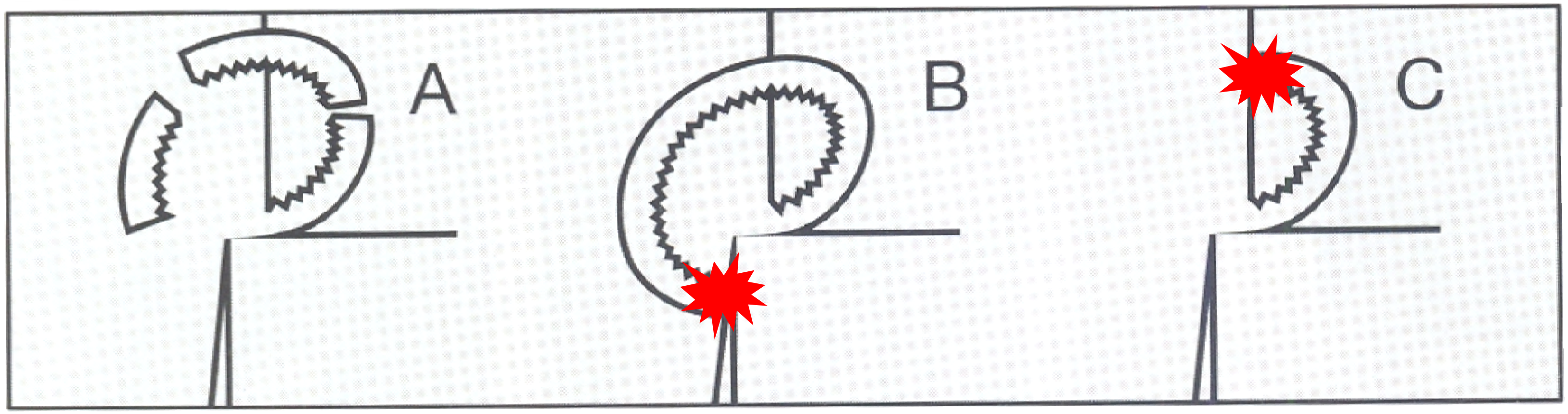
(a)


Feed (mm /rev)
0.05
0.053
0.08
0.1
0.14
DRY
WET
HTMF
Cutting veliocity=80m/min and depth of cut=1.25mm

(b)


Cutting velocity (m/min)
40
53
80
91
120
DRY
WET
HTMF
Feed = 0.1mm/rev and depth of cut=1.25mm

Chip breaking



Three ways to break a chip

<u>A – Self breaking</u>

Cutting conditions (v_c, *f*, *a*, *coolant*)

Tool geometry

Workpiece material (S, Pb)

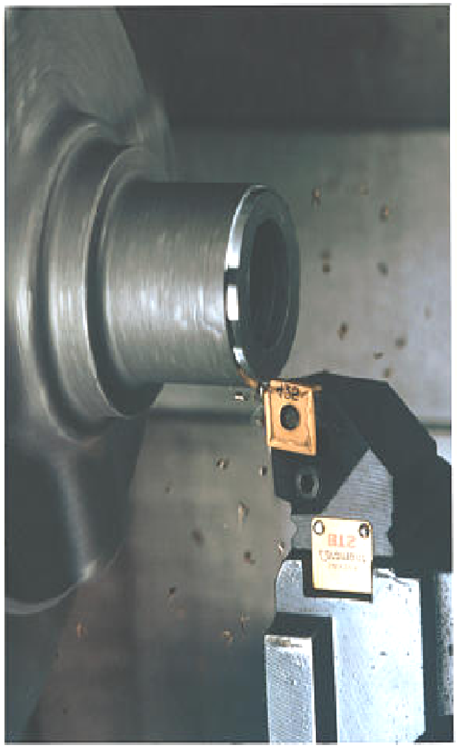
B – Stopped by the tool

C – Stopped by the workpiece

Cutting tools' classification

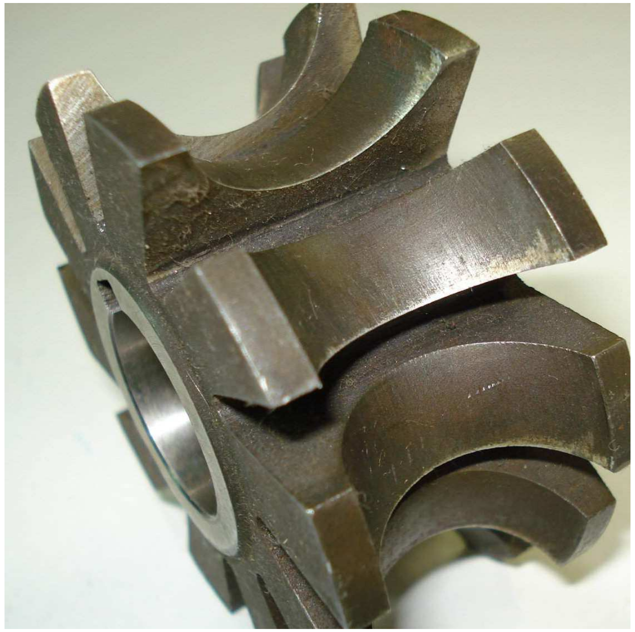
- Cutting method: turning tool, drilling tool, milling cutter…
- Edge geometry: regular or unregular (statistical)
- Number of edges: 1, 2, many, much
- Edge shape: simple or shaped
- Build-up: solid (monolite), assembled (brazed, fixed by screw…)
- Edge material: steels, hard materials, super hard materials

Example



- Turning tool
- Regular edge geometry
- Number of edges: 1
- Simple edge
- Assembled built-up
- Hard material (sintered carbide)

Example



- Milling cutter
- Regular edge geometry
- Number of edges: 10
- Shaped edge
- Solid built-up
- Steel material (HSS)

Example

- Grinding tool
- Unregular edge geometry
- Number of edges: infinity
- Simple edge
- Solid built-up
- Composite

Parts of a cutting tool

Tool shank

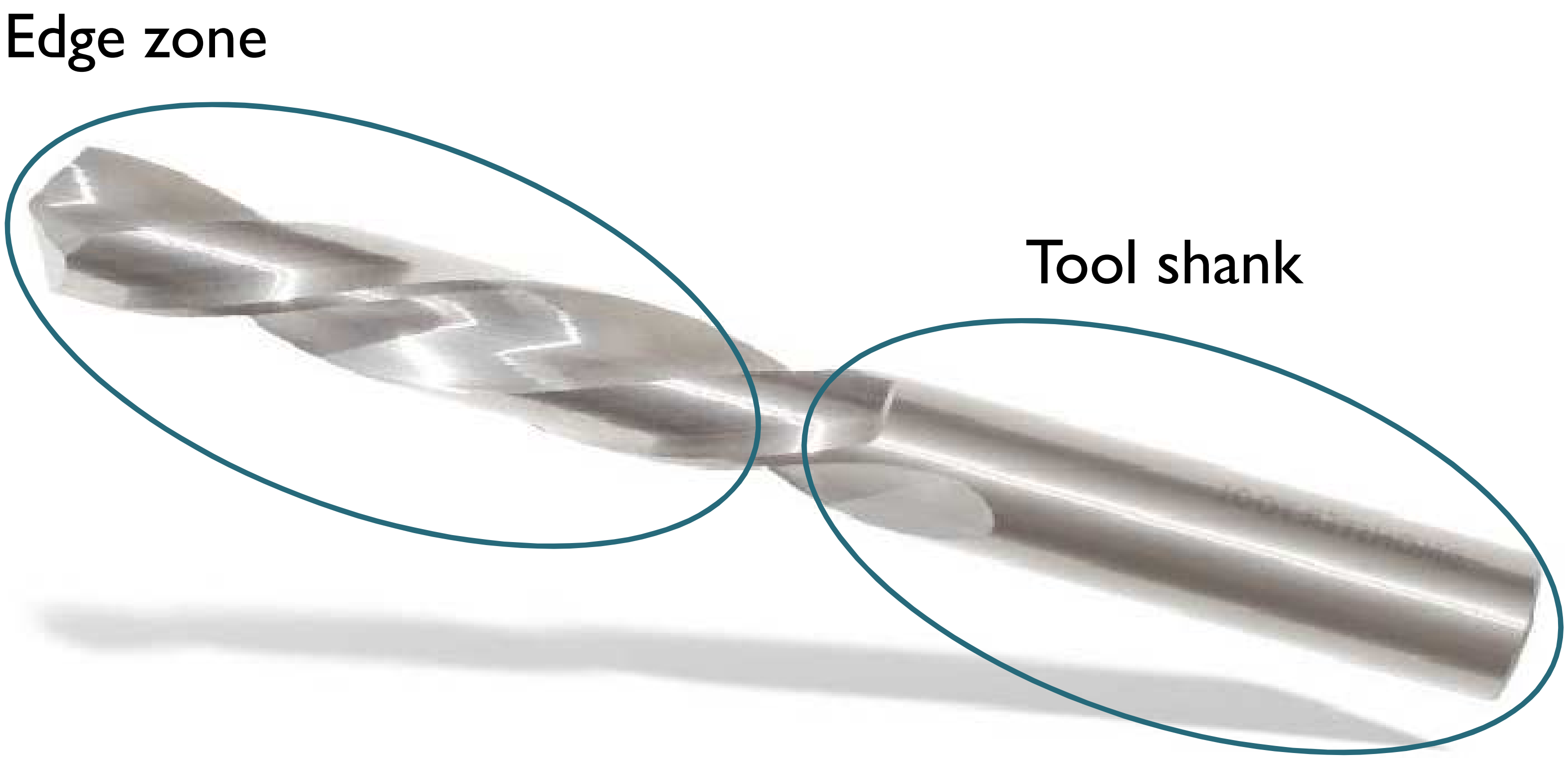
Edge zone

Cutting edge(s)

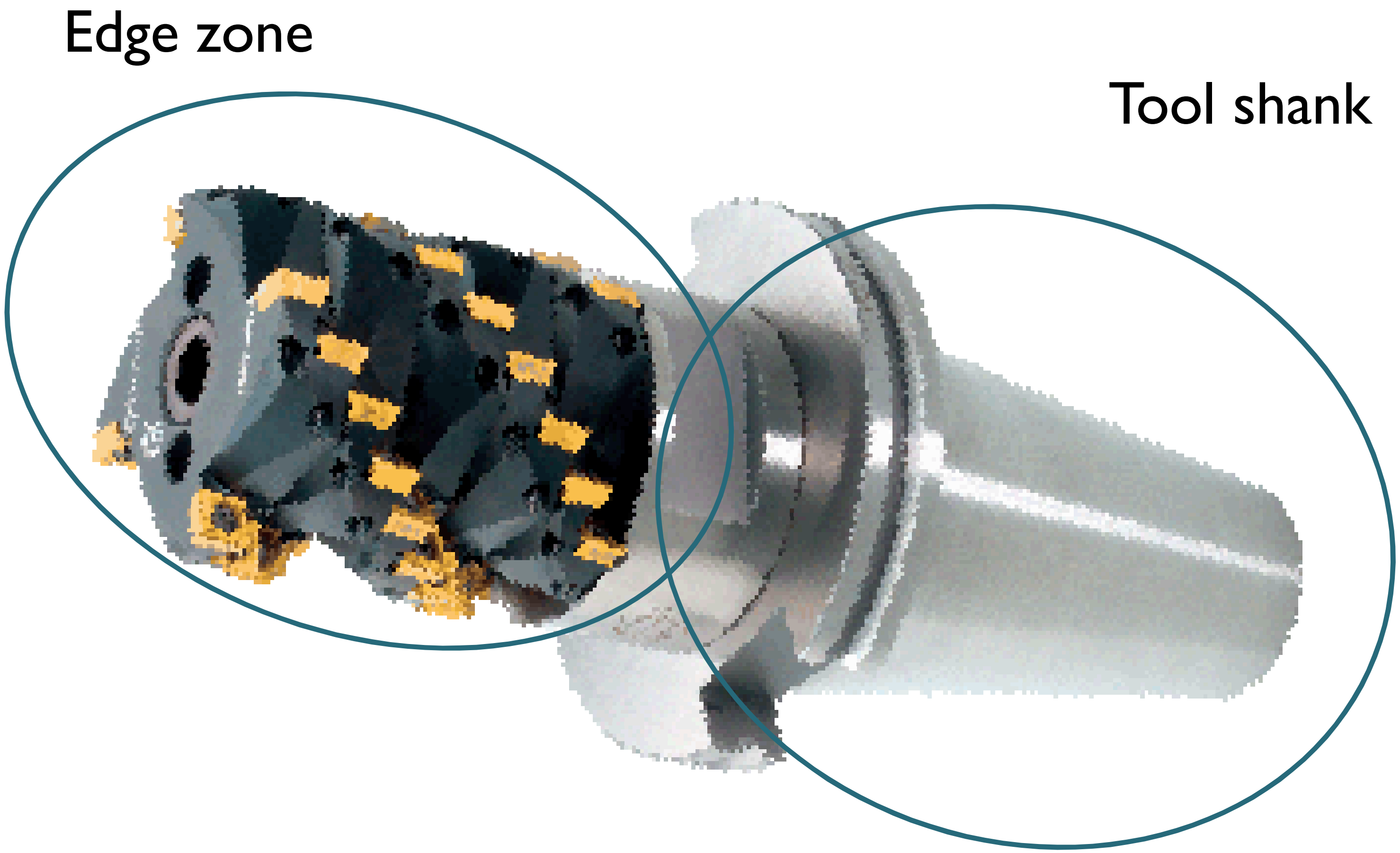
Tool length
Strength

Positioning
Fixing

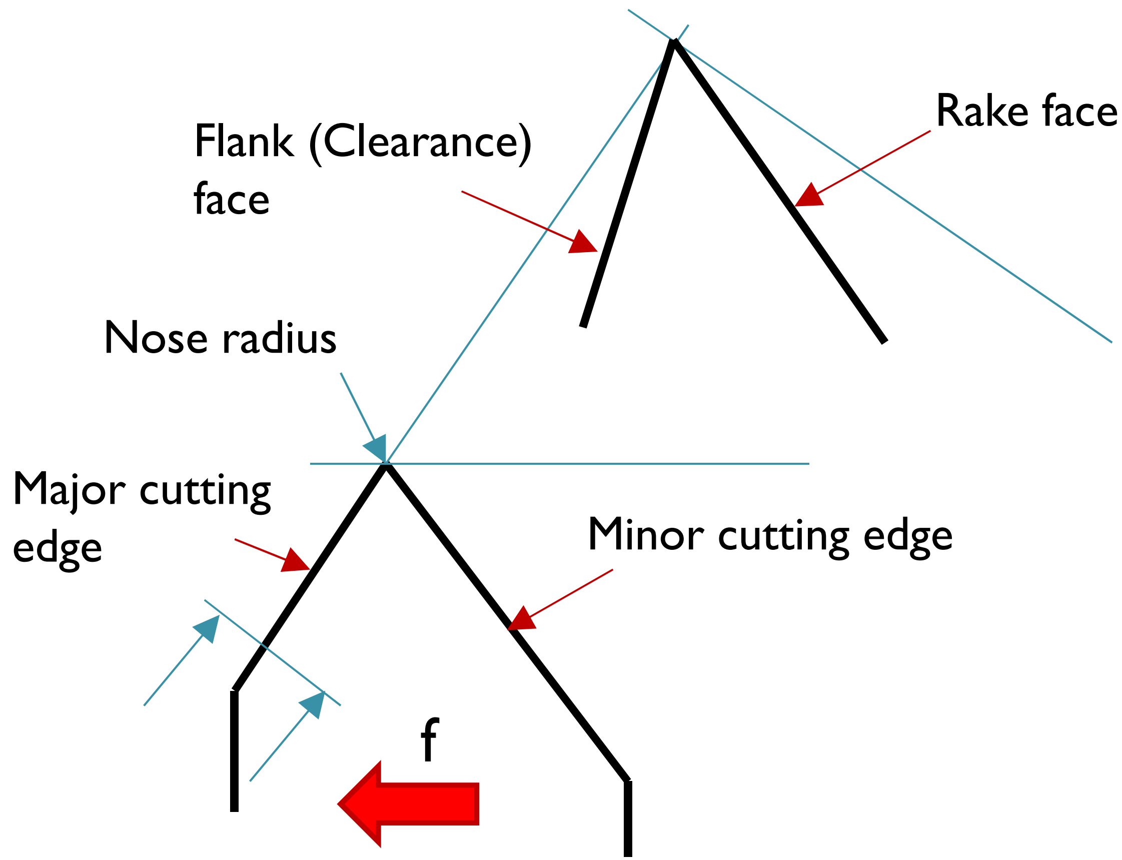
Parts of a cutting tool



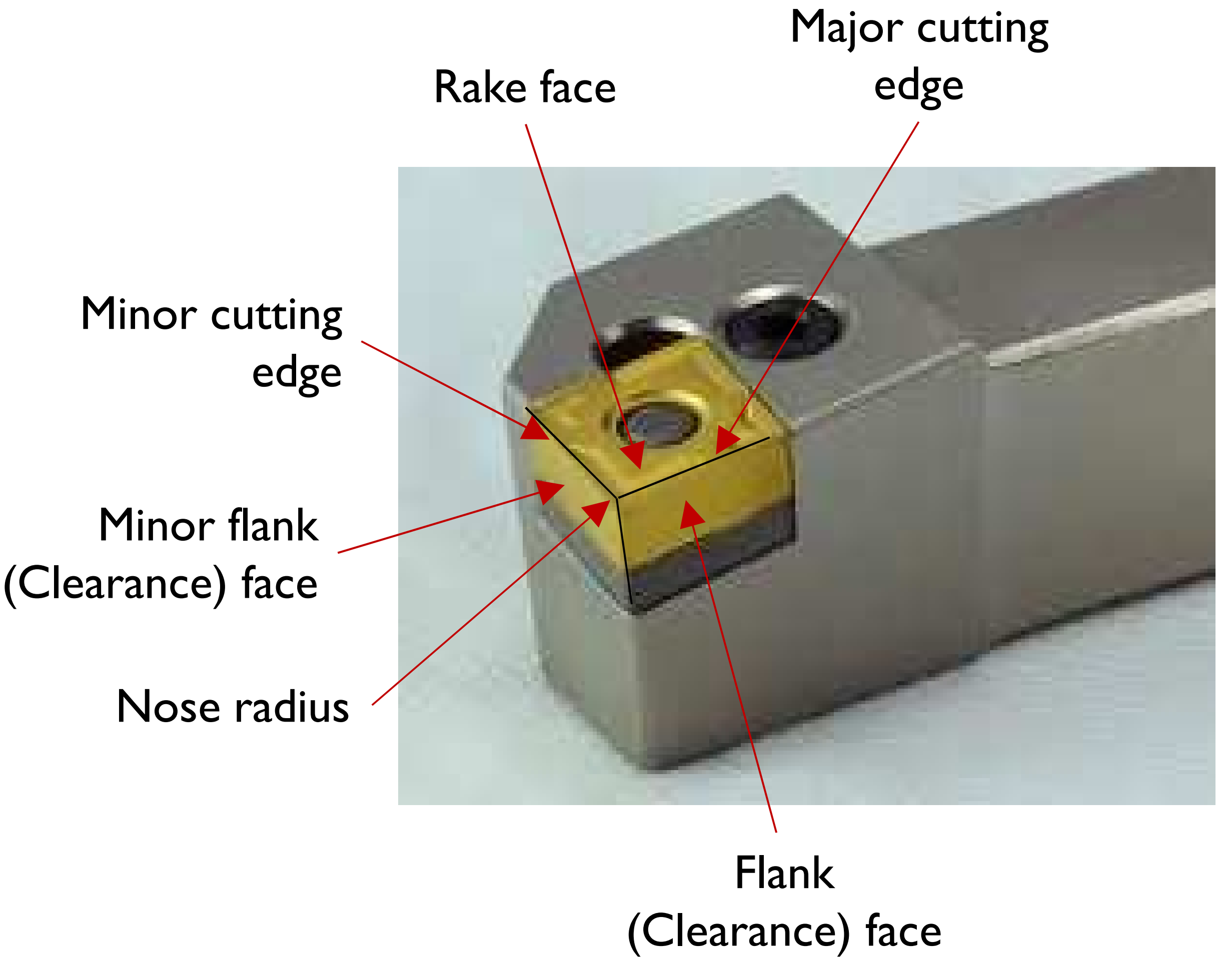
Parts of a cutting tool



Edge geometry



Edge geometry



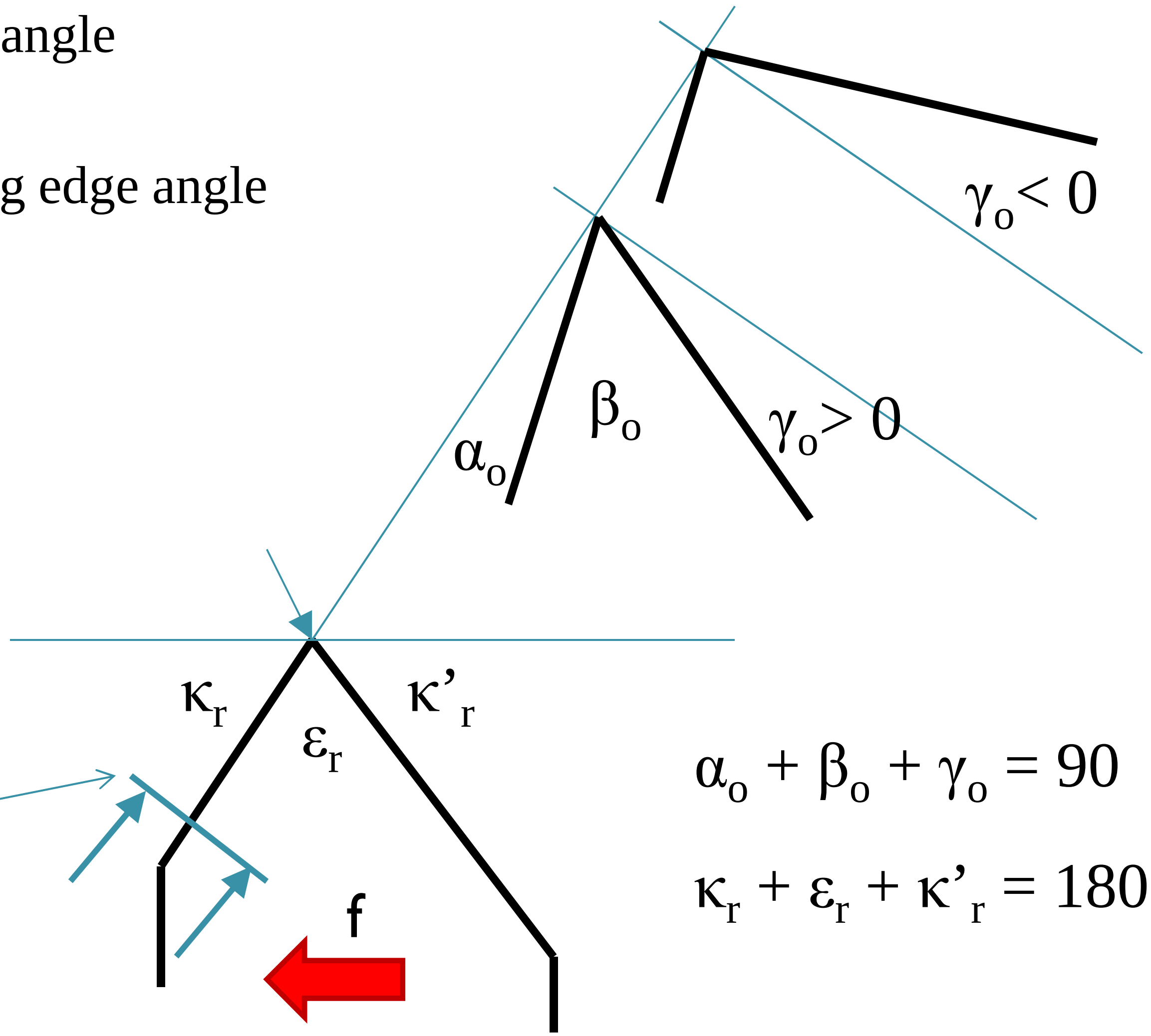
Edge geometry

κ_r – Cutting edge angle
ε_r – Nose angle
κ'_r – Minor cutting edge angle

α_o – Flank angle
β_o – Wedge angle
γ_o – Rake angle

r_ε – Nose radius

Perpendicular to the edge



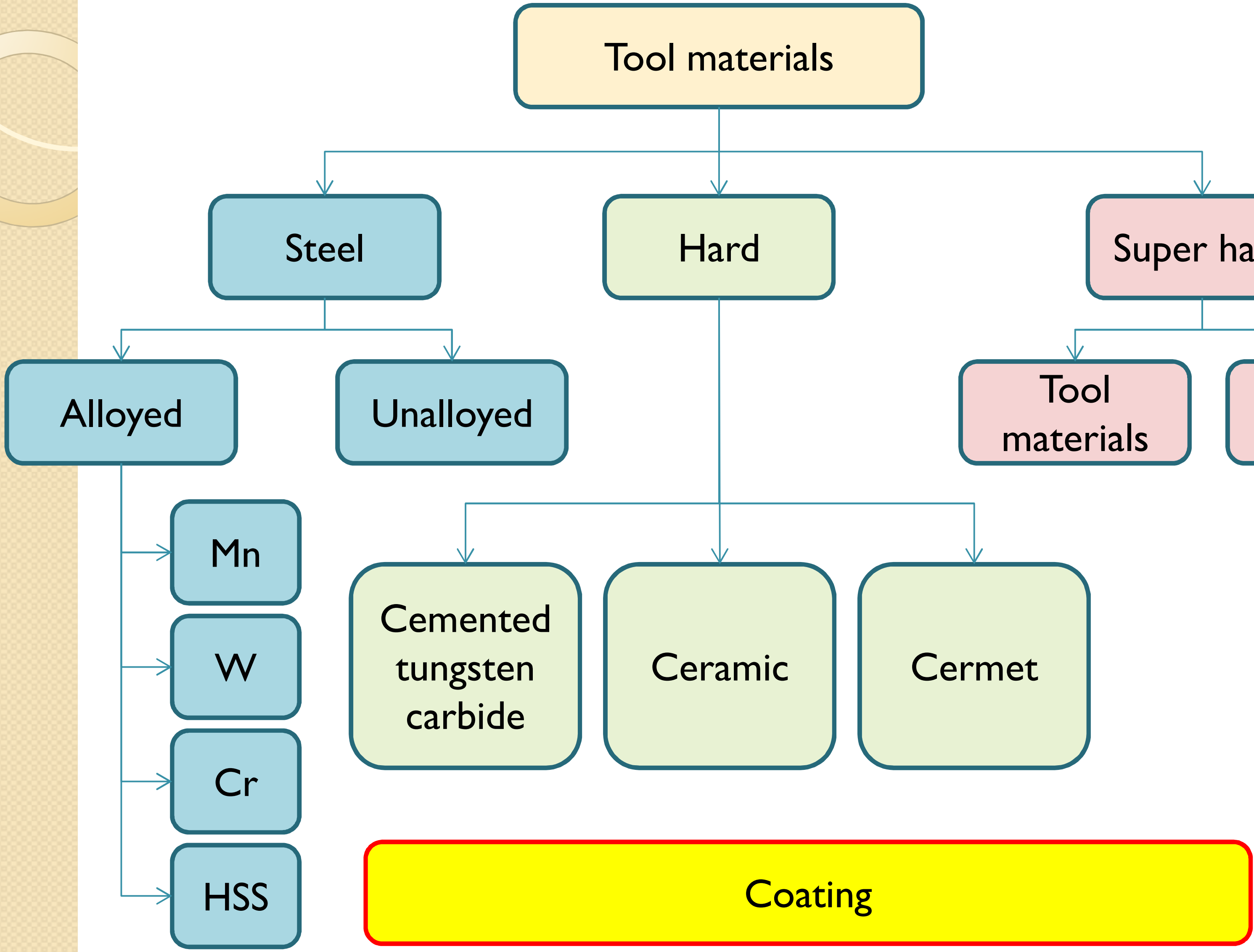
$$\alpha_o + \beta_o + \gamma_o = 90$$

$$\kappa_r + \varepsilon_r + \kappa'_r = 180$$

Definitions

Shank – It is main body of tool. The shank used to gripped in tool holder.
Flank – The surface or surface below the adjacent of the cutting edge is called flank of the tool.
Face – It is top surface of the tool along which the chips slides.
Base – It is actually a bearing surface of the tool when it is held in tool holder or clamped directly in a tool post.
Heel – It is the intersection of the flank and base of the tool. It is curved portion at the bottom of the tool.
Nose – It is the point where side cutting edge & base cutting edge intersect.
Cutting edge – It is the edge on face of the tool which removes the material from workpiece. The cutting edges are side cutting edge (major cutting edge) & end cutting edge (minor cutting edge)
Tool angles **-** Tool angles have great importance. The tool with proper angle, reduce breaking of tool, cut metal more efficiently, generate less heat.
Noise radius – It provide long life and good surface finish sharp point on nose is highly stressed, and leaves grooves in the path of cut. Longer nose radius produce chatter.

Tool materials



Requirements

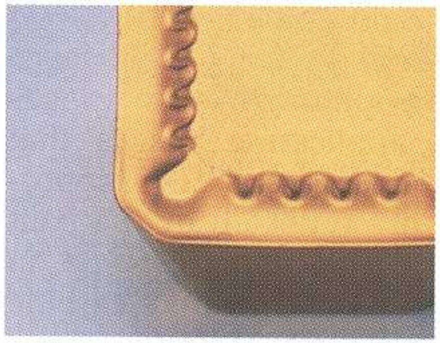
- Hardness
- Wear resistance
- Strength
- Toughness
- Heat resistance

Steel materials

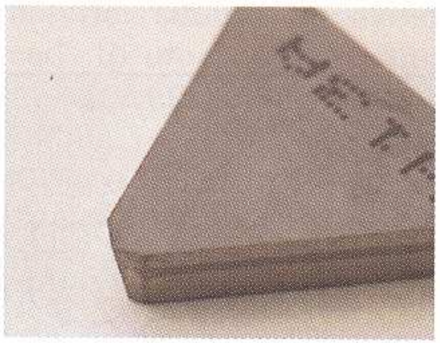
- Unalloyed tool steels
  - Fe + C; Hardening 66-67 HRc
- Alloyed tool steel
  - Mn (manganese), 60-62 HRc
  - W (tungsten), 62-64 HRc
  - Cr (chromium); 62-64 HRc
  - High speed steel (HSS) (W, Cr, V, Mo, Co); 63-70 HRc

Hard materials

- Cemented tungsten carbide
  - Powder production – Forming – Sintering (heat treatment) - Coating
  - Composite material: Co + WC, TiC
  - 87-92 HRA



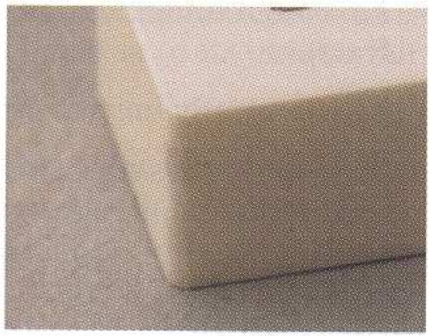
Coated cemented carbide



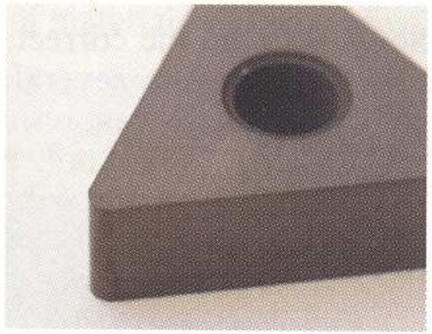
Uncoated cemented carbide

Hard materials

- Ceramic
  - Al_2O_3 / Al_2O_3+TiC / Si_3N_4
  - 90-96 HRA
  - Rigid but high heat resistance (1400°C)

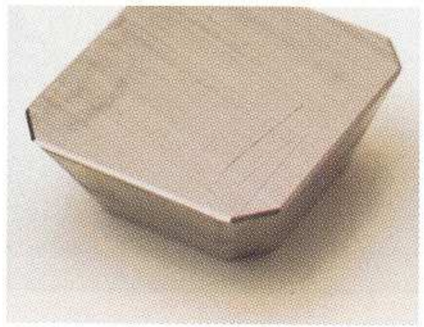


Pure-ceramic



Mixed ceramic

- CerMet – Ceramic metal
  - Mo, Ni + TiC, TiN, TiCN



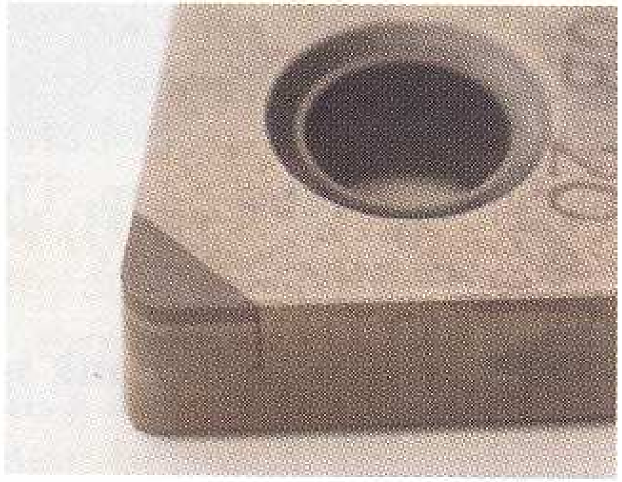
Cermet

Super hard material

- Diamond
  - Not for steels!!!

Polycrystalline diamond

- CBN – Cubic boron nitride
  - For hardened steel (65 HRc)



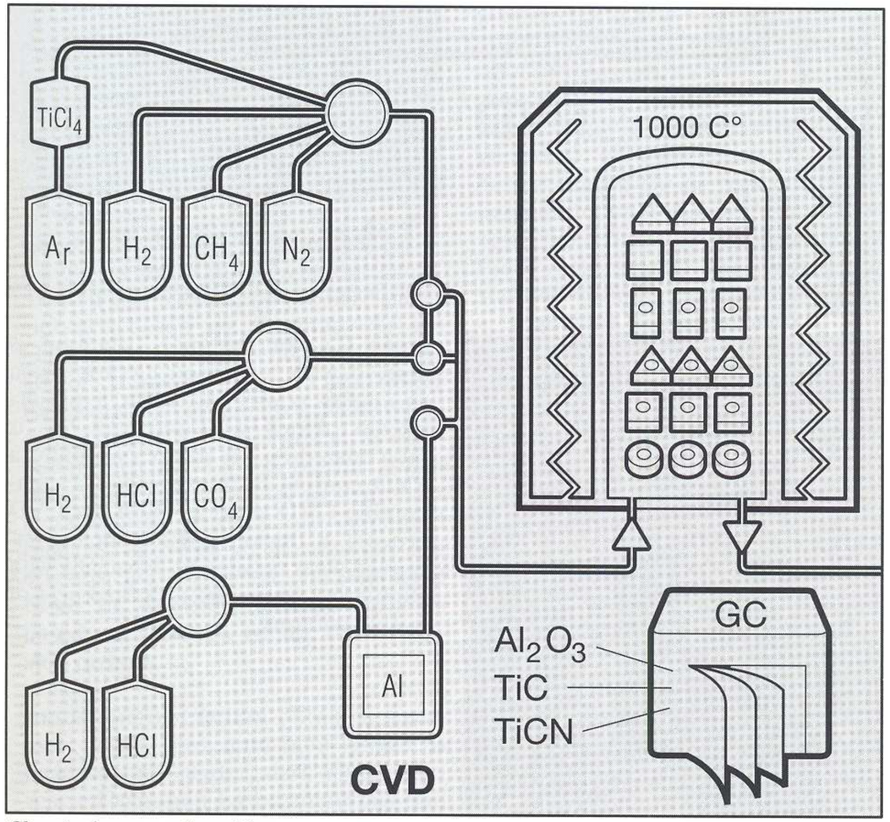
Cubic boron nitride

Coating technology

- Aim:
  - Increase the wear and heat resistance
  - Decrease the friction coefficient and heat
- Technologies:
  - CVD
  - PVD
- Thichness: 2-12 μm

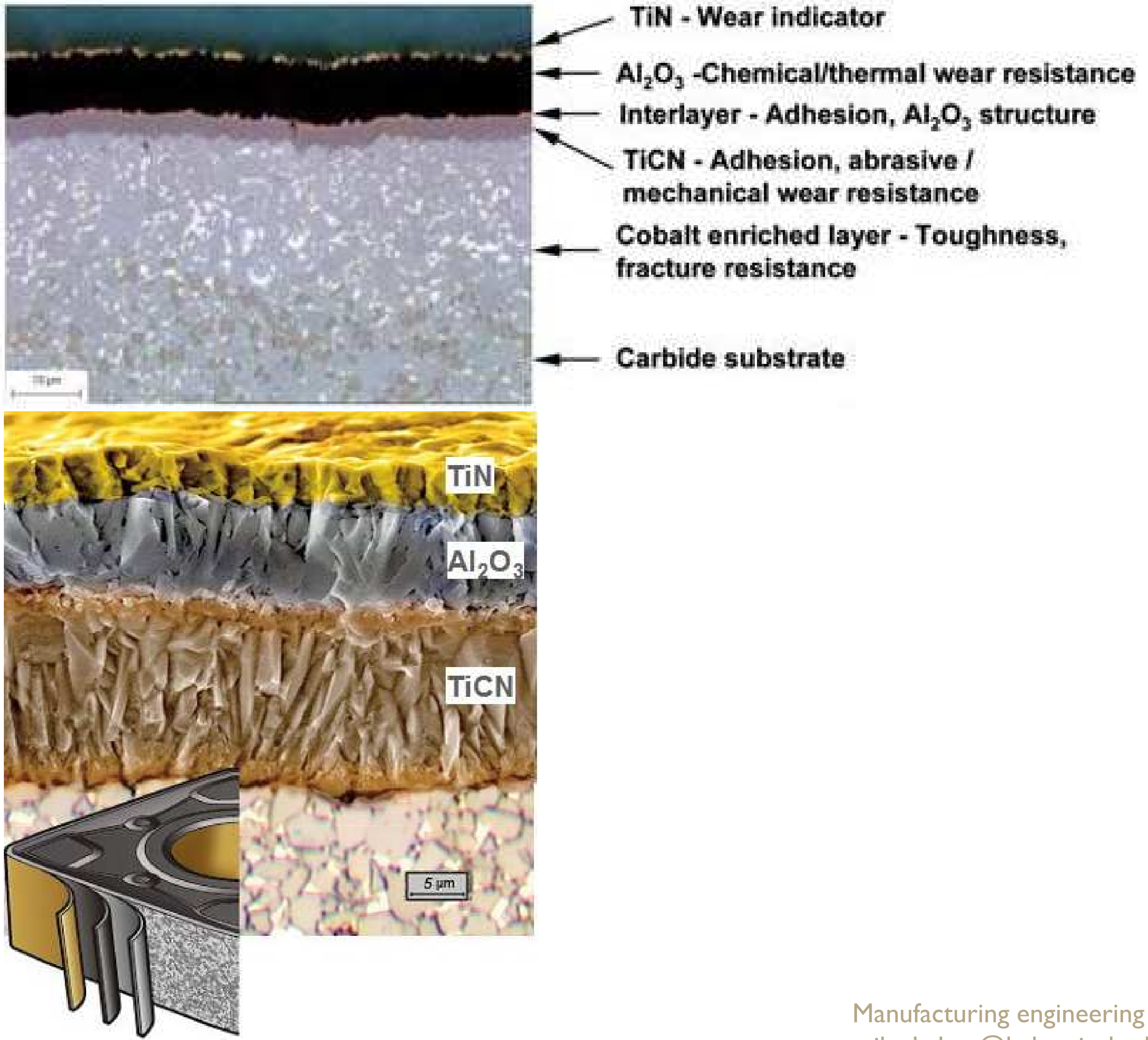
CVD – Chemical vapour deposition

- Multi-layer coating
- Chemical reaction of gases



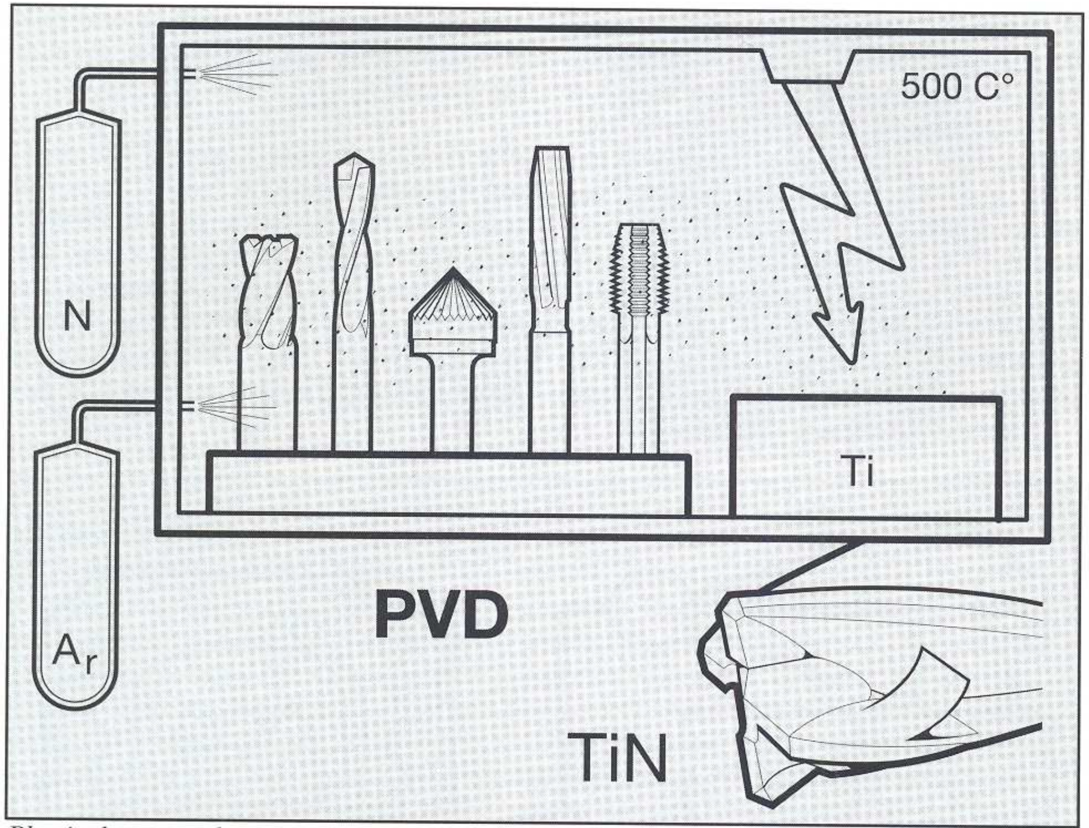
Chemical vapour deposition

Multi layer coating



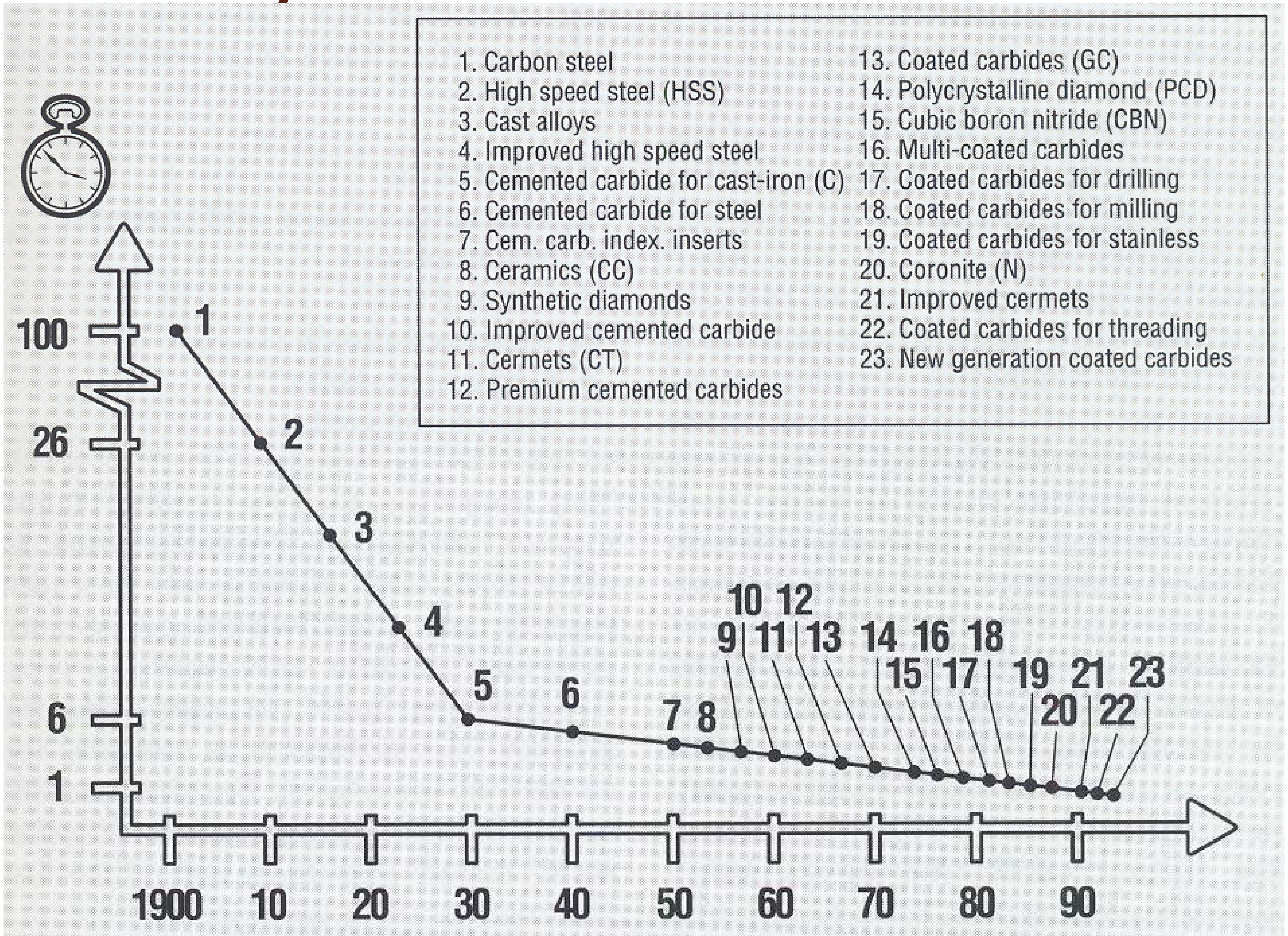
PVD – Phisical vapour deposition

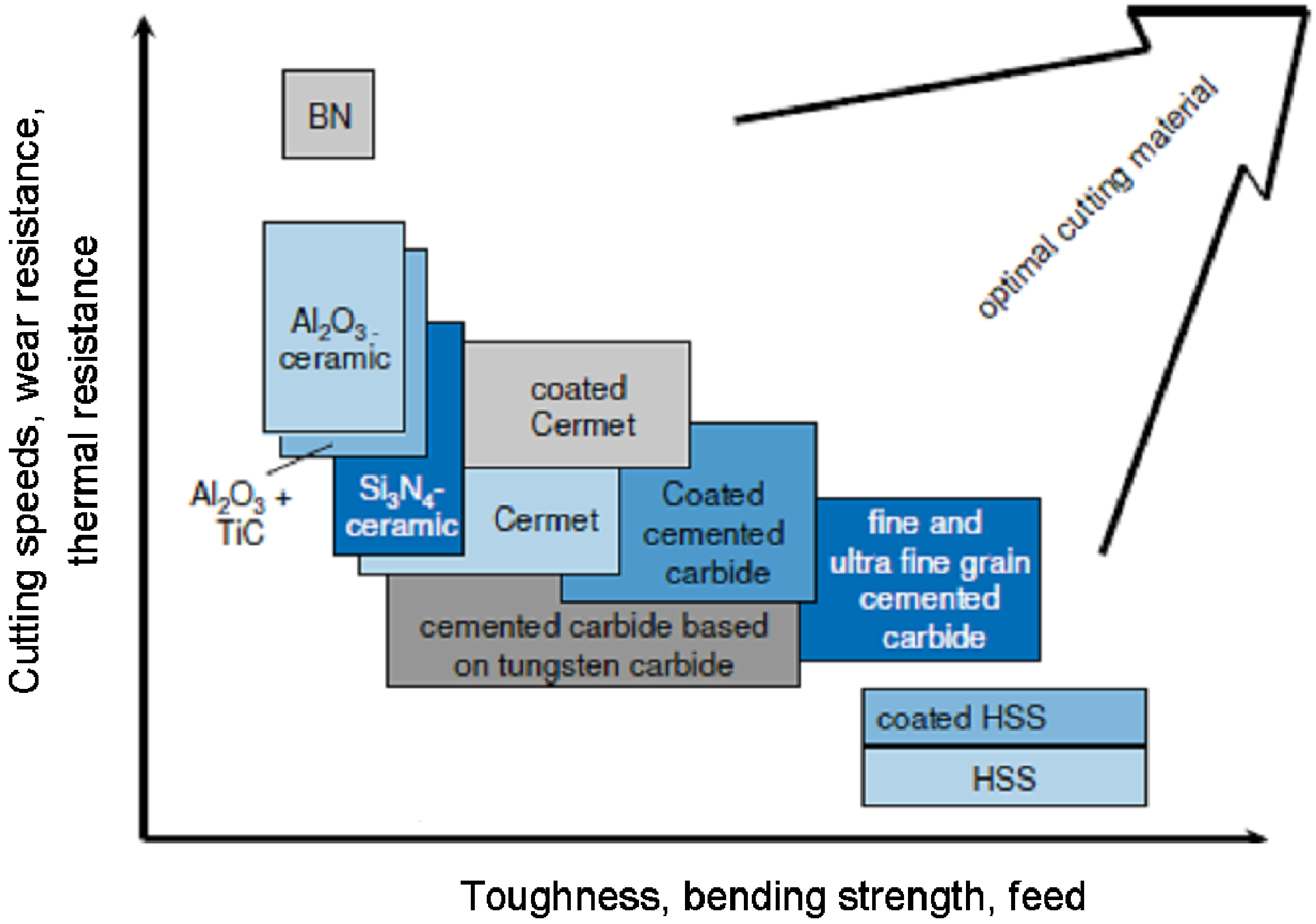
- Environment frendly
- Not so expensive
- Flexible



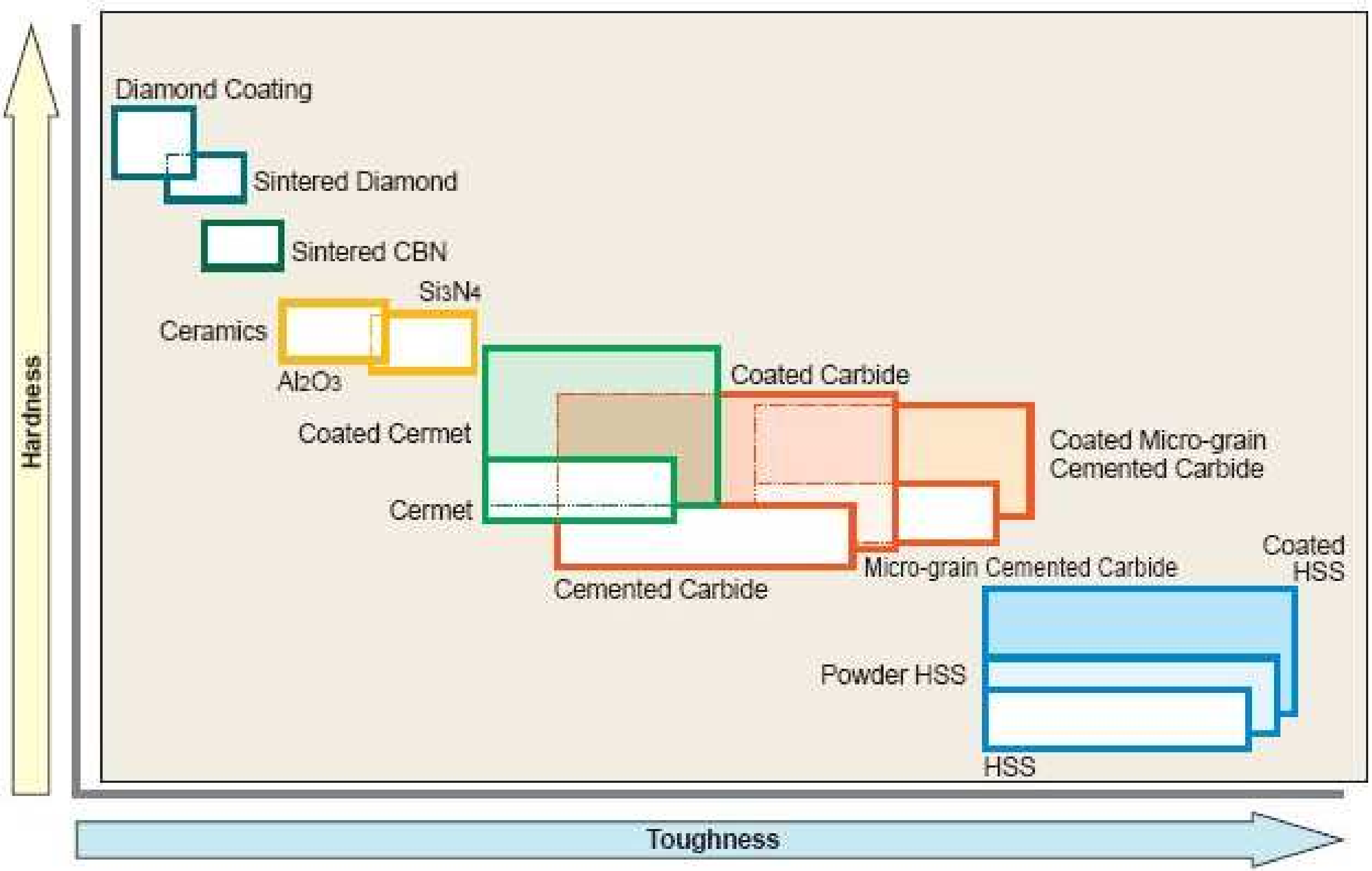
Physical vapour deposition

History


1. Carbon steel
2. High speed steel (HSS)
3. Cast alloys
4. Improved high speed steel
5. Cemented carbide for cast-iron (C)
6. Cemented carbide for steel
7. Cem. carb. index. inserts
8. Ceramics (CC)
9. Synthetic diamonds
10. Improved cemented carbide
11. Cermets (CT)
12. Premium cemented carbides
13. Coated carbides (GC)
14. Polycrystalline diamond (PCD)
15. Cubic boron nitride (CBN)
16. Multi-coated carbides
17. Coated carbides for drilling
18. Coated carbides for milling
19. Coated carbides for stainless
20. Coronite (N)
21. Improved cermets
22. Coated carbides for threading
23. New generation coated carbides
100
26
6
1
1900
10
20
30
40
50
60
70
80
90

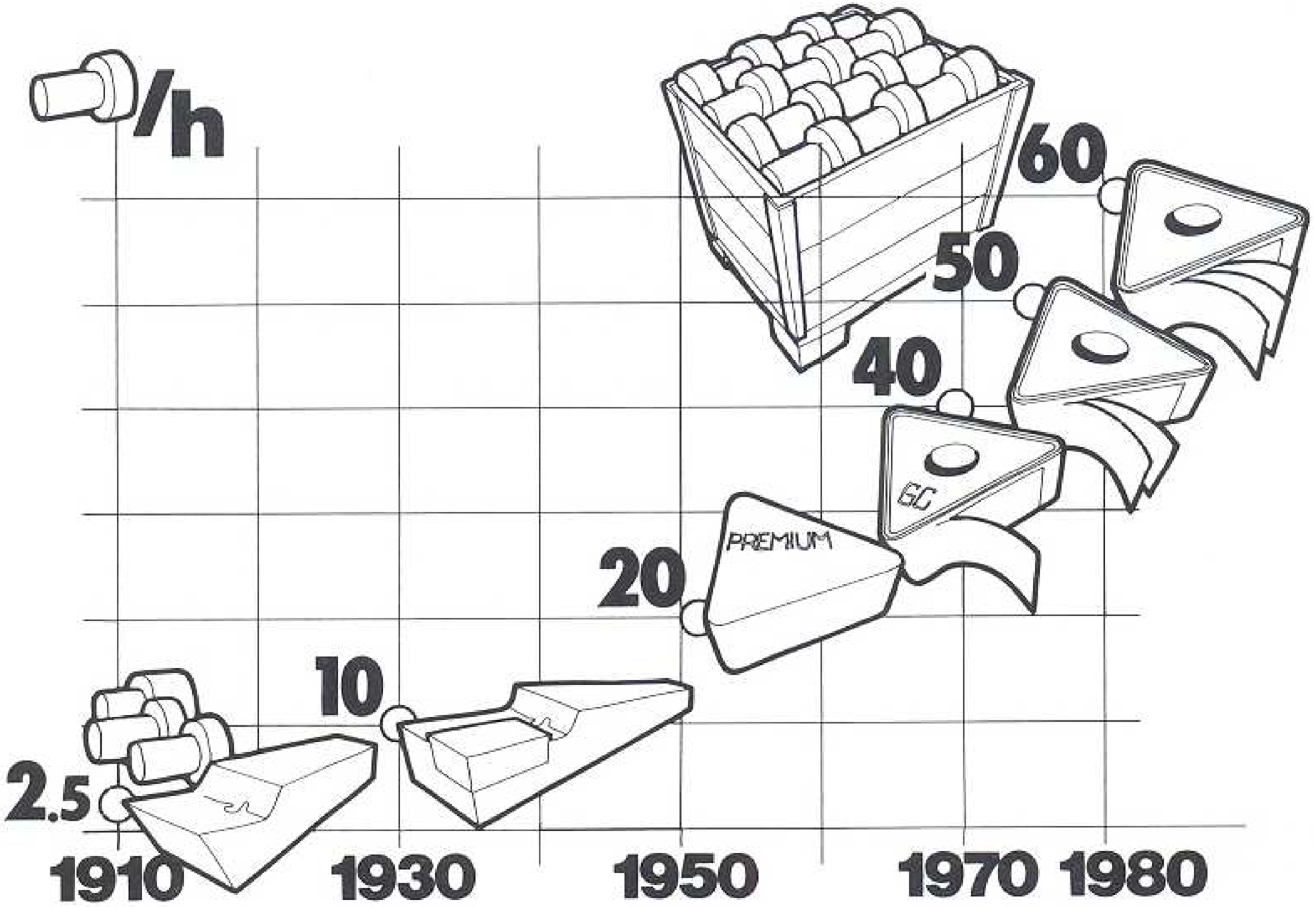

Cutting speeds, wear resistance, thermal resistance
BN
Al_2O_3-ceramic
Al_2O_3 + TiC
Si_3N_4-ceramic
coated Cermet
Cermet
Coated cemented carbide
fine and ultra fine grain cemented carbide
cemented carbide based on tungsten carbide
coated HSS
HSS
optimal cutting material
Toughness, bending strength, feed

Summary



Hardness
Diamond Coating
Sintered Diamond
Sintered CBN
Si3N4
Ceramics
Al2O3
Coated Carbide
Coated Cermet
Coated Micro-grain Cemented Carbide
Cermet
Micro-grain Cemented Carbide
Cemented Carbide
Coated HSS
Powder HSS
HSS
Toughness

Increasing productivity



Production of components per cutting edge changed considerably, with that of HSS to cemented carbide

Increasing cutting parameters