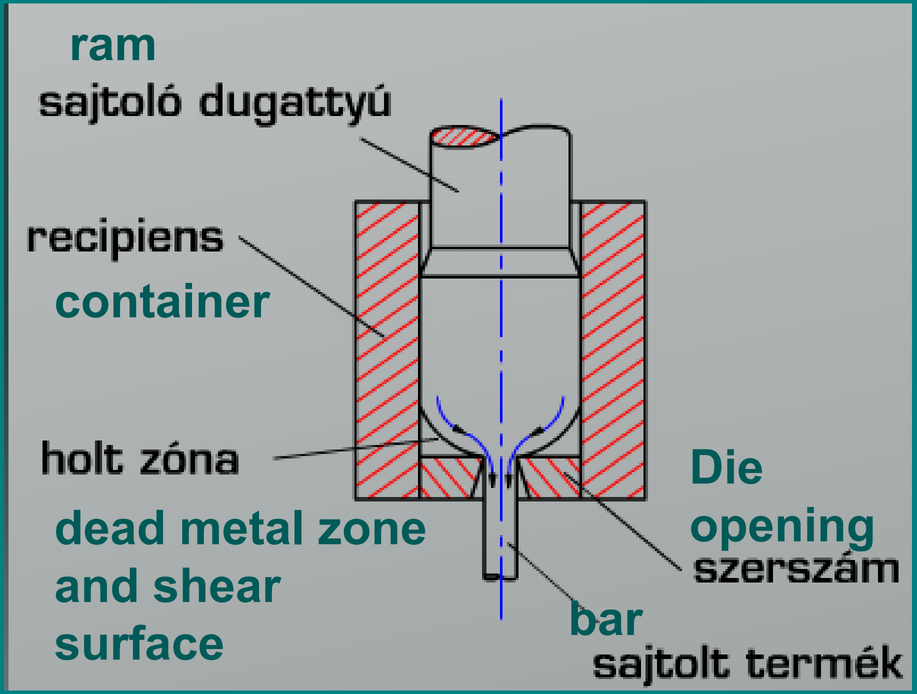
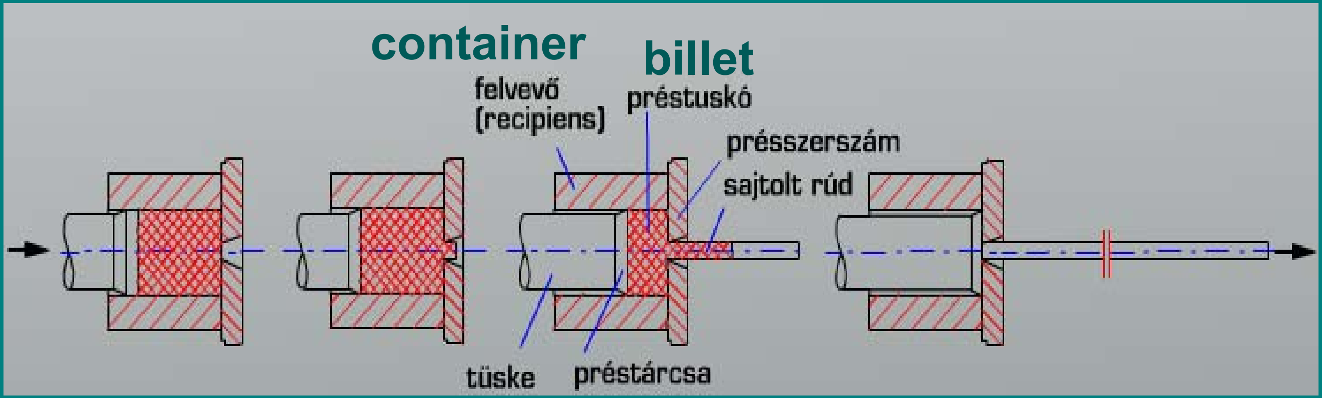
Extrusion of complex shapes

Hot extrusion

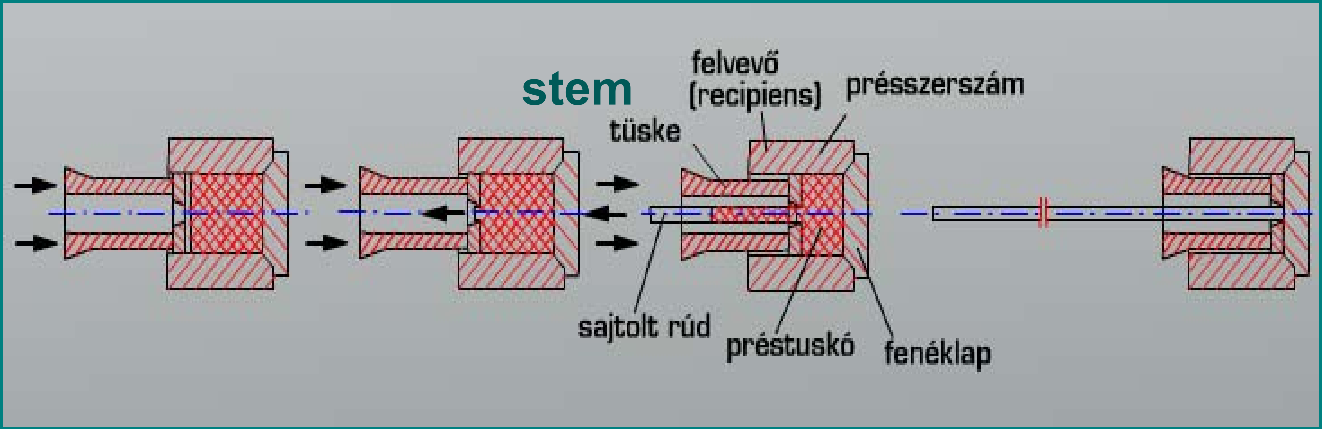
- Hot extrusion is the process of forcing a heated billet to flow through a shaped die opening
- It is used to produce long, strait metal products of constant cross section
- Products: bars, solid and hollow sections, tubes, strips



Nonlubricated hot extrusion

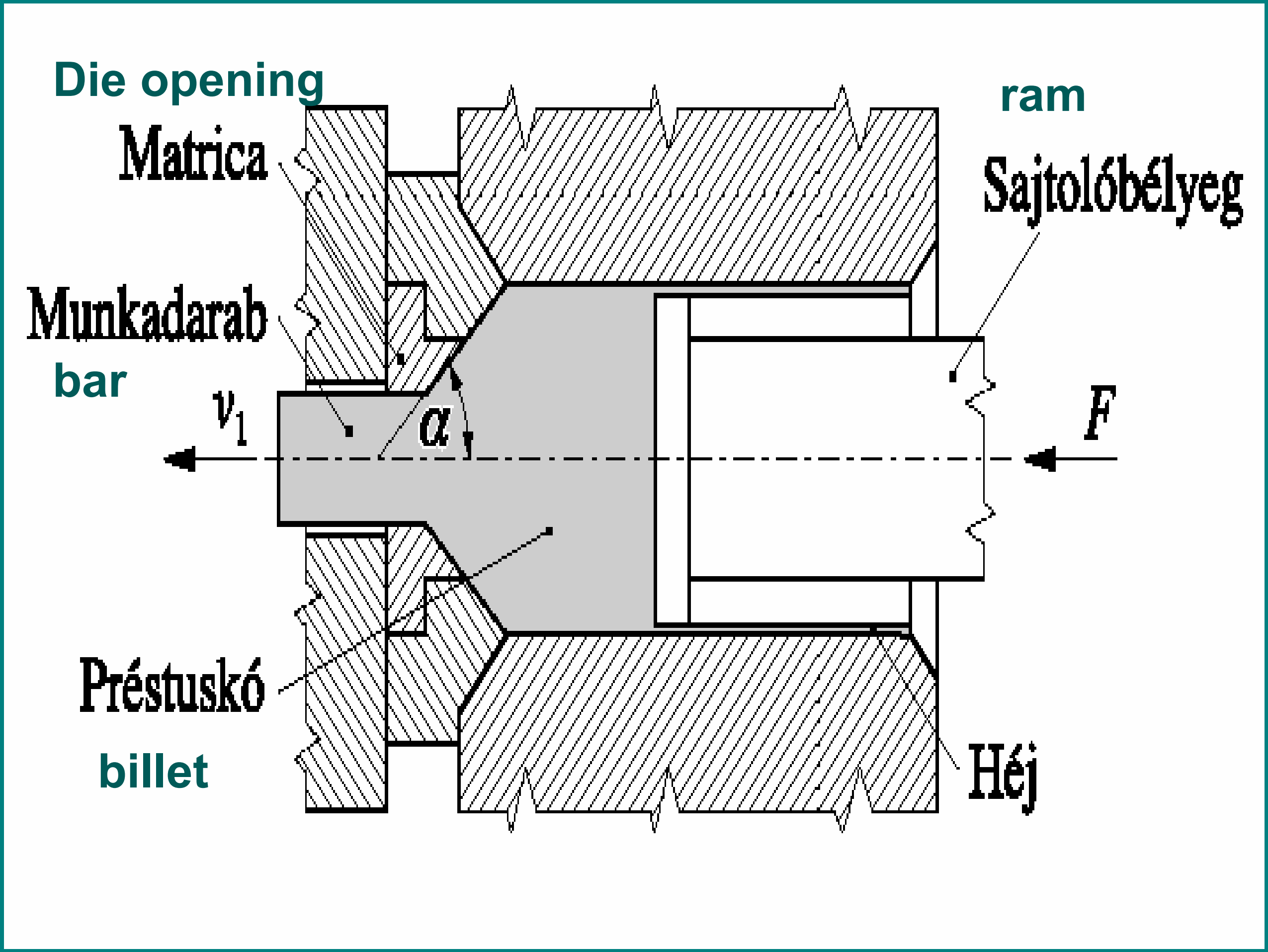


Direct or forward extrusion

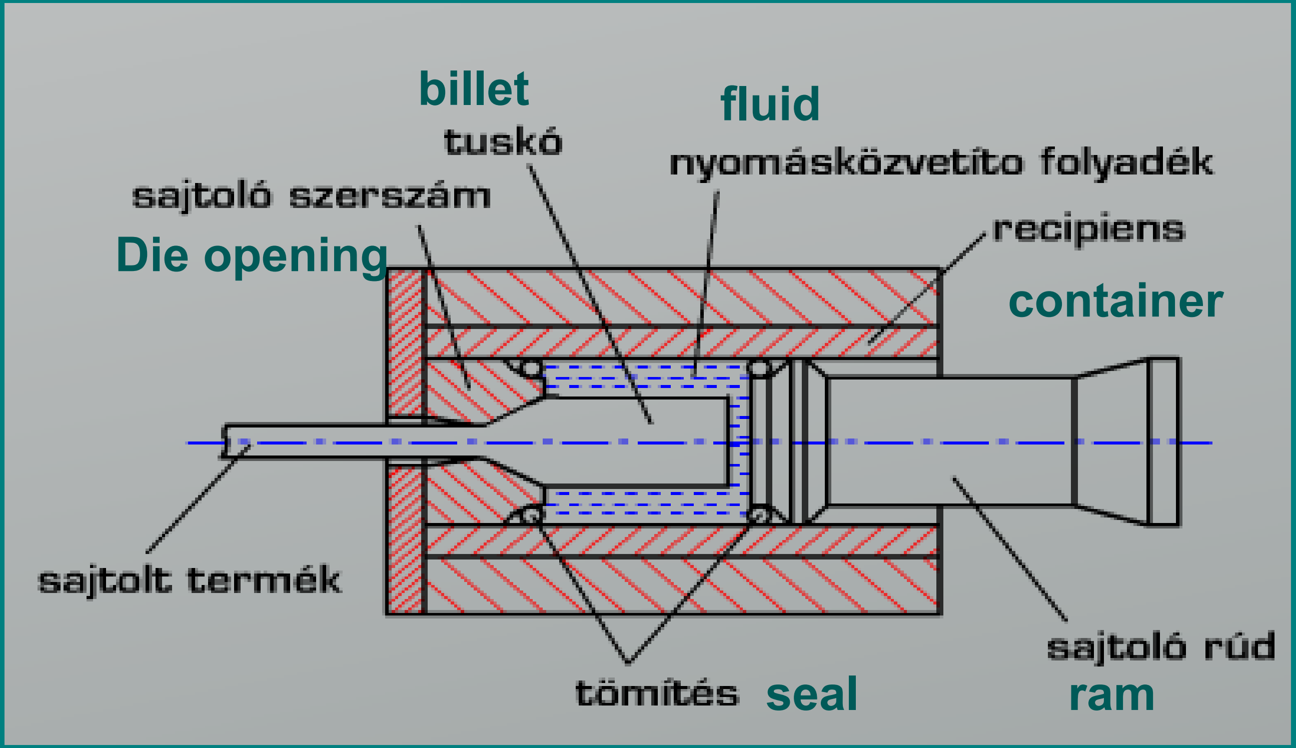


Indirect or backward extrusion

Lubricated hot extrusion



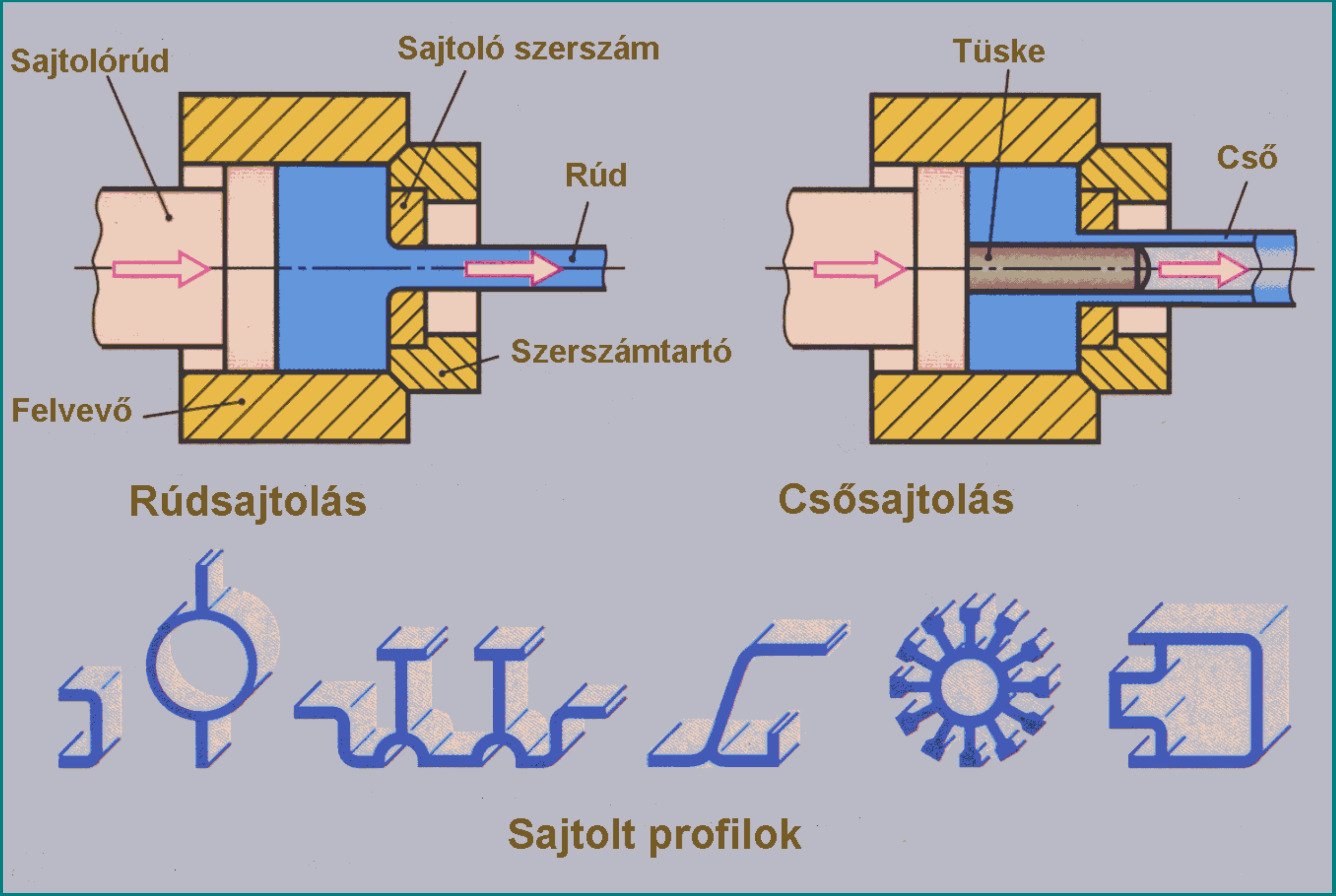
Hydrostatic extrusion



Hydrostatic fluid is forcing to flow the billet through the die opening

It is used for materials which can not be formed by other extrusion processes

Extruded Profiles



Comparison of processes

	Non-lubricated	Lubricated	Hydro-static
Characteri-sation of process	The material flows by internal shear	Lubricant film between billet and container	Fluid around the billet
Billet material	Aluminium alloys	Cu,Ti alloys, steels	Special alloys
Lubricants	No	Grease or glass	High pressure oil

Comparison of processes: forward and backward extrusion

- Advantages of backward extrusion:
  - Reduction in maximum load
  - Billet length is not limited by friction
  - No heat is generated by frictionűincreased tool life
- Disadvantages:
  - Impurities in the billet surface affect the surface of extruded bar
  - The length of extruded bar or tube is limited by the length of the stem

Materials for hot extrusion

Material	Temperature (°C)	Application
Aluminium and Al alloys	300-595	Pipes, wire, bars, structural sections
Copper and Cu alloys	595-995	Wire, rod, bars for electrical conductors
Steels	995-1300	Limited application, simpler sections

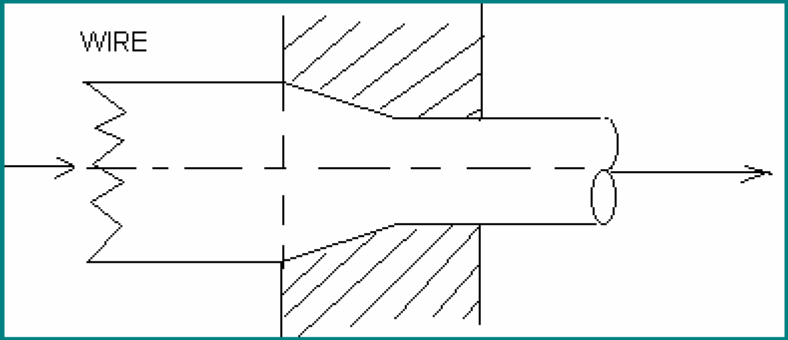
Drawing of rods, wires and tubes

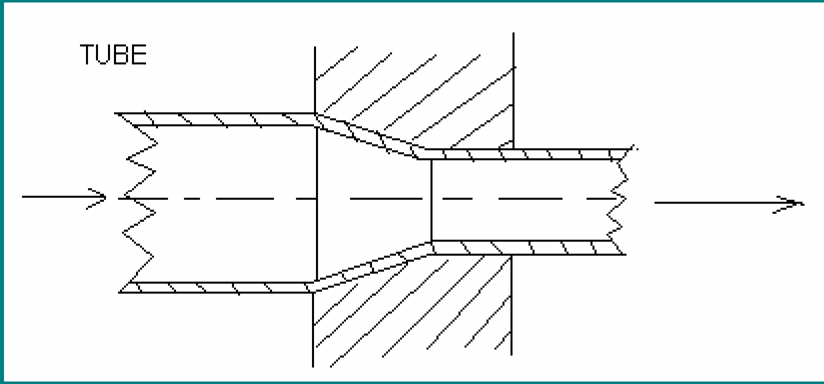
Principle of rod and tube drawing

- Drawing tool is a conic die
- Distinction between wire and rod:
  - Wire D < 5 mm; Rod D > 5 mm
- Wire drawing: continuous uncoiled => drawing => re-coiled
- Rod drawing:
  - single-die machines (drawing bench)
  - these benches do not require coiling of the as-drawn product

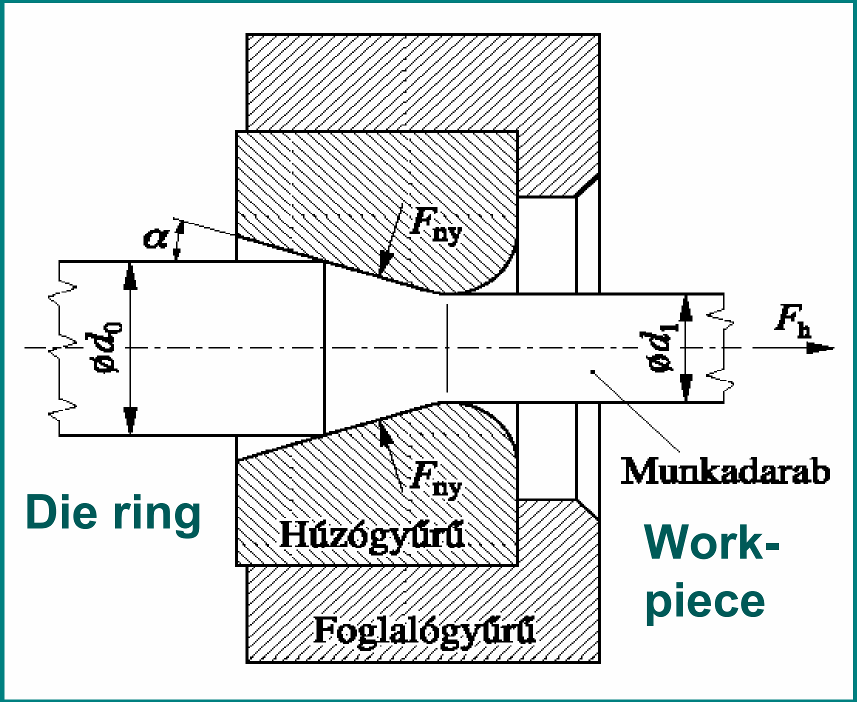
The drawing process:

- The deformation made by indirect compression
- The dies are made of tool steel, cemented WC or diamond
- For tube drawing we have to use inner dies if we want to reduce the wall thickness
- Drawing processes are very productive, because of high working speed



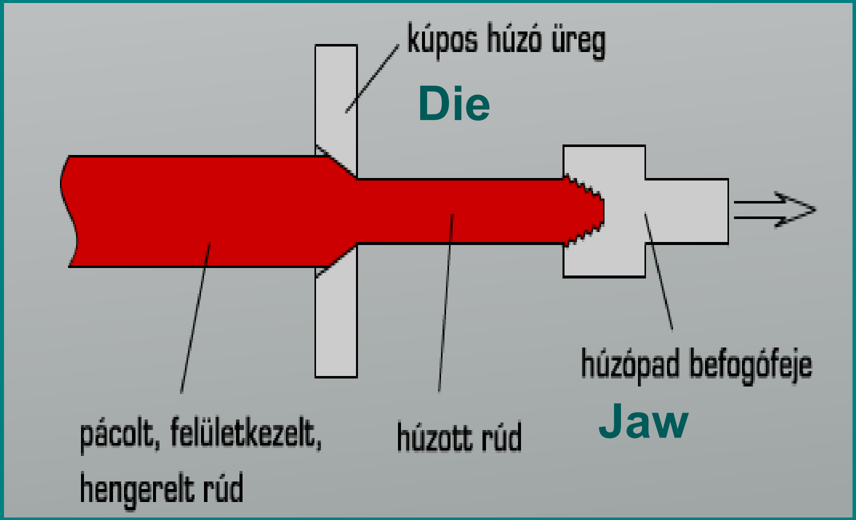


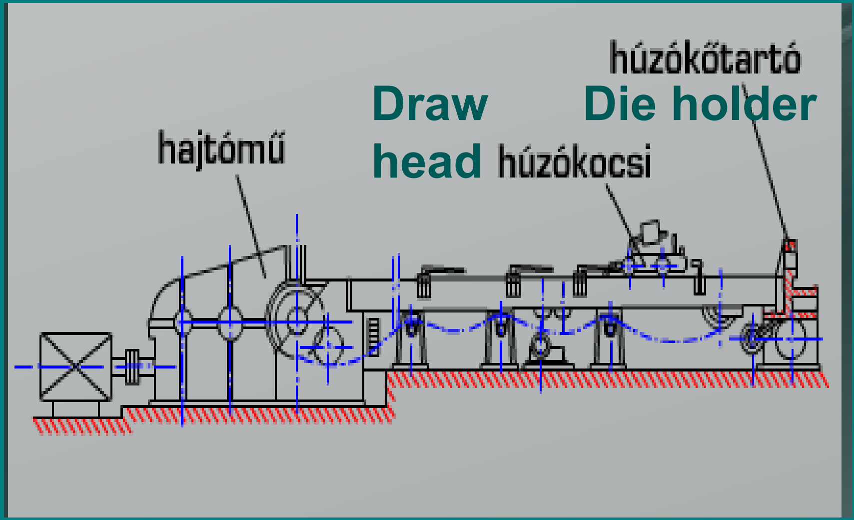
Tooling of rod and wire drawing



Cross-sectional area of a rod, bar, and wire is reduced by pulling metal through a die by means of tensile force applied to the exit side of the workpiece

Rod drawing bench





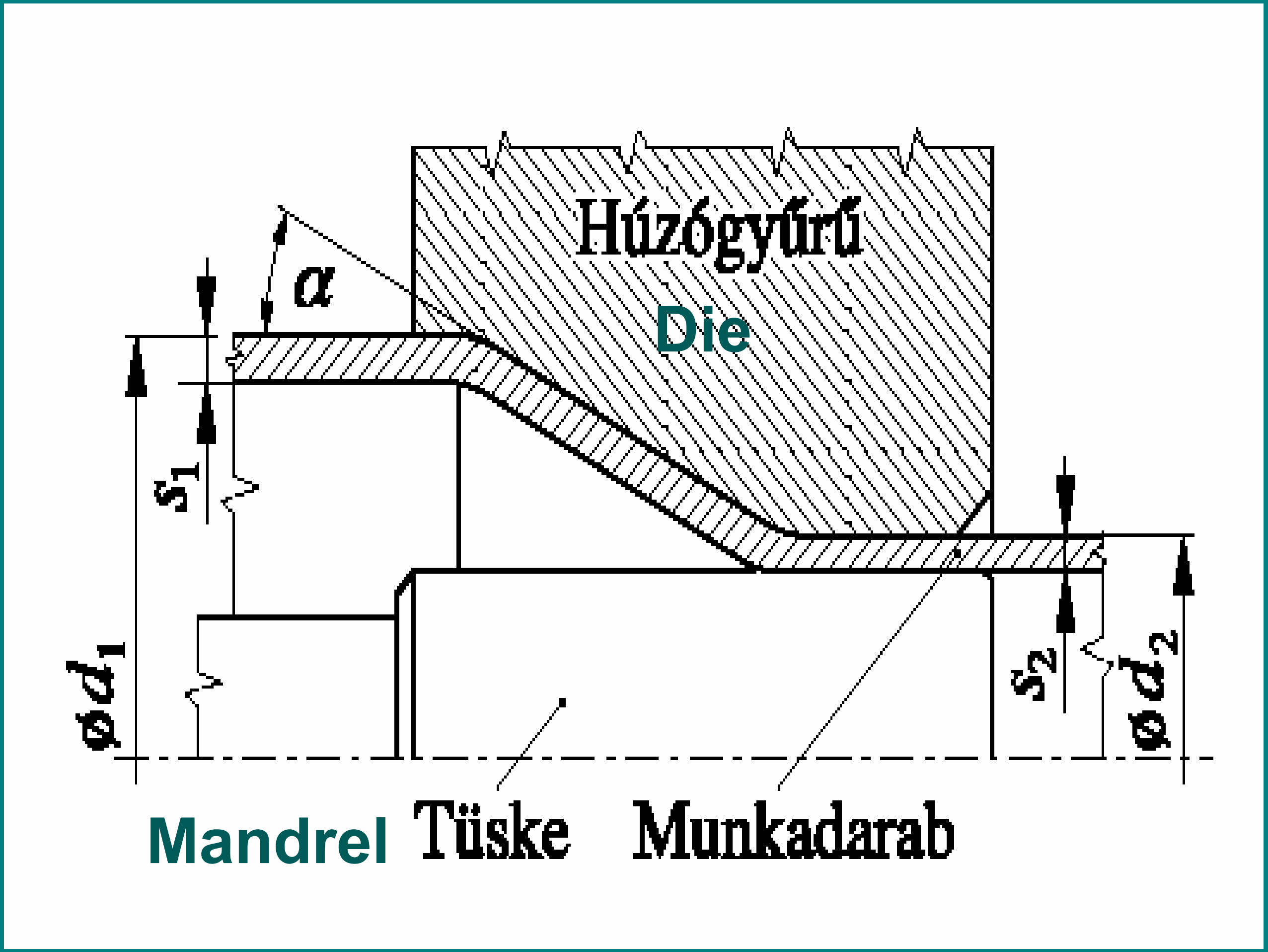
Conic die

Drawing bench

The pulling force cannot exceed the strength of the wire or rod being drawn

Area reduction per drawing pass is smaller than 30-35%

Tube drawing



Superplastic Sheet Forming

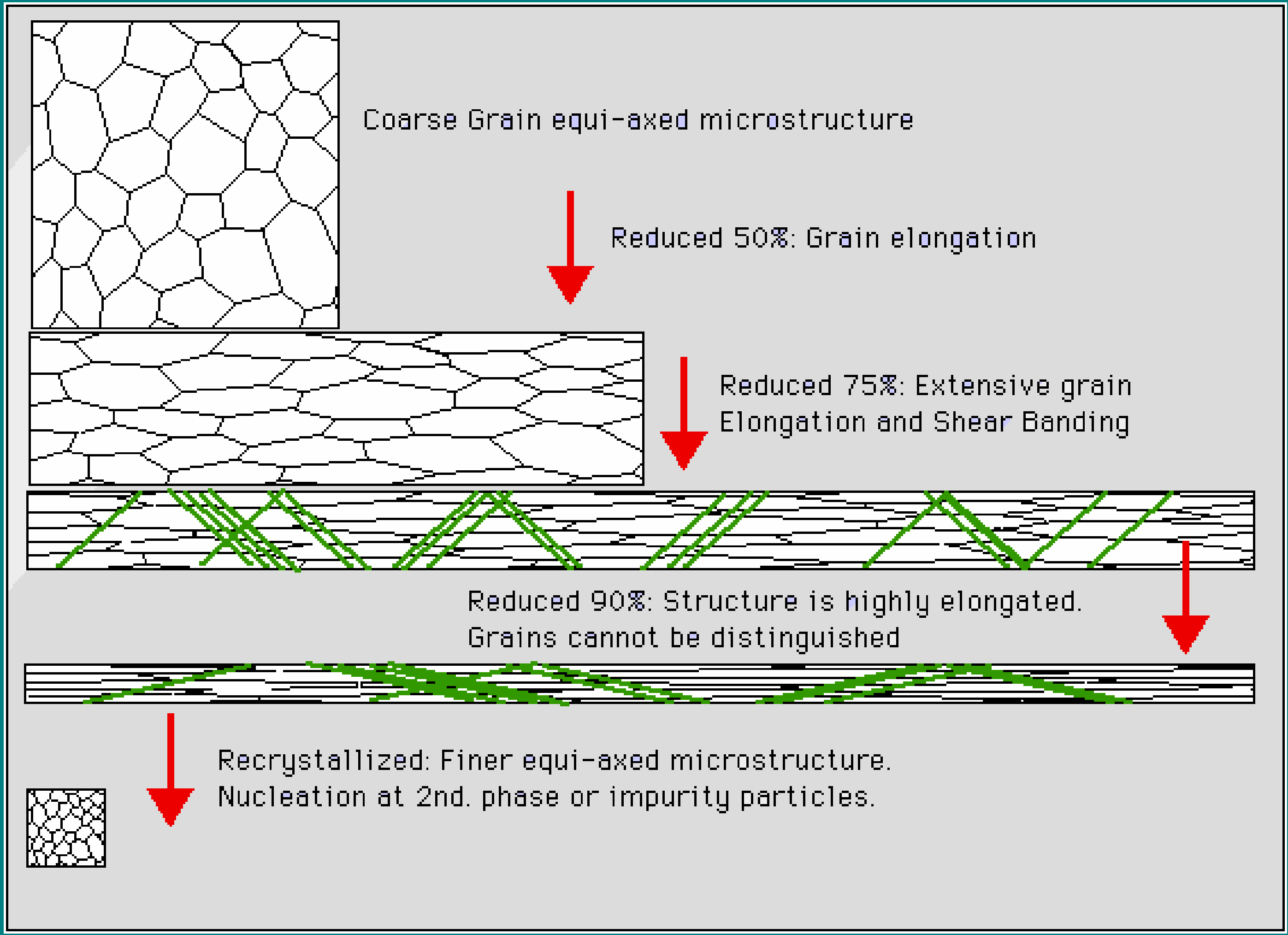
Principles (1)

- Superplasticity:
  - exceptional ductility – easy deformation under low tension or pressure
  - Tensile ductility (elongation): 200…1000%
- Types of superplasticity:
  - Micrograin
  - Transformation
  - Internal stresses

Principles (2)

- Conditions of micrograin superplasticity:
  - Very fine grain size (5…10 μm)
  - Relatively high temperature
  - Controlled, very low strain rate (0,0001…0,01 s^{-1})
- Only a limited number of commercial alloys are superplastic
- Forming methods are different from conventional forming processes

Producing fine grain size



Theoretical considerations

- **Flow stress curve:**

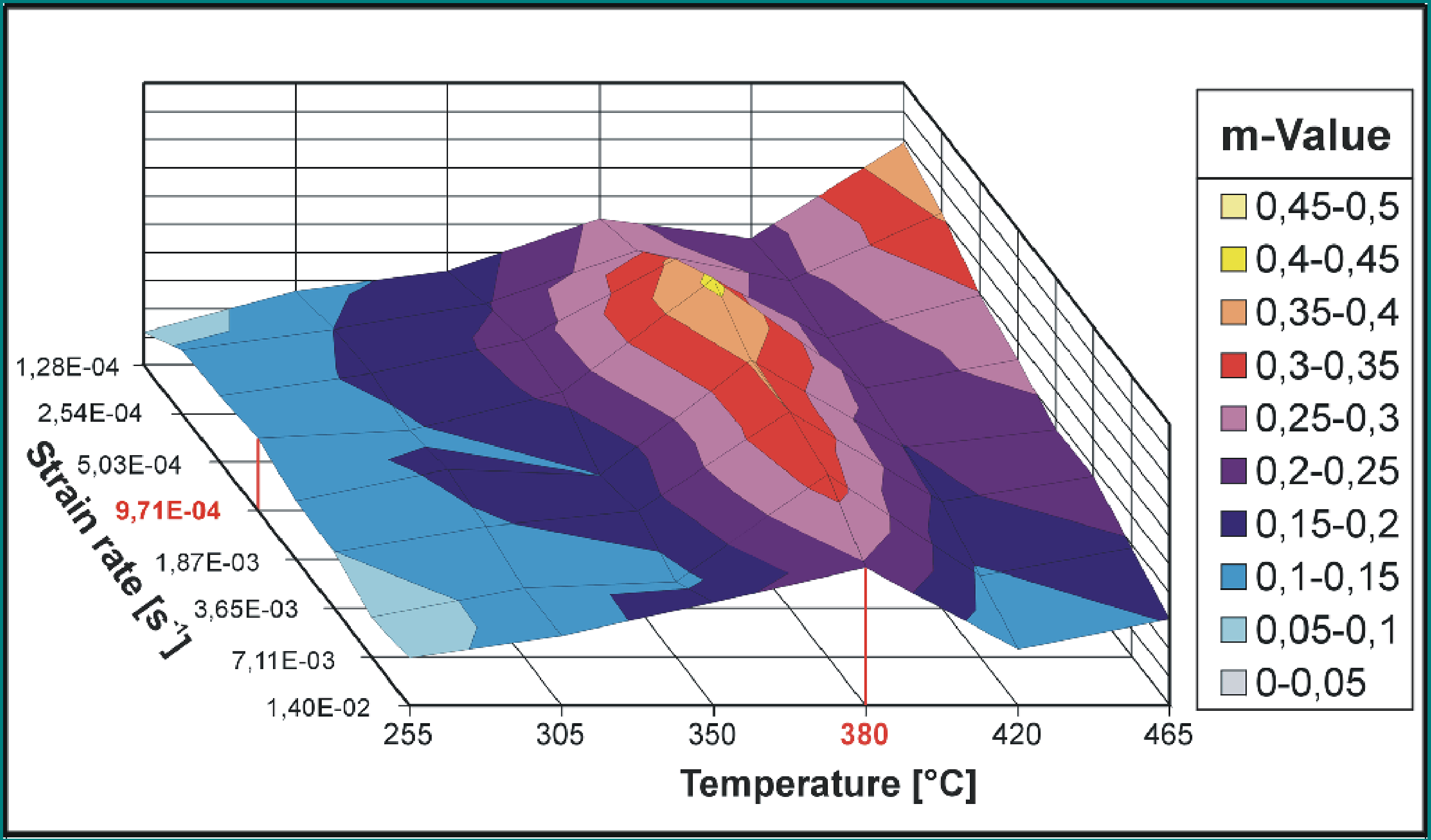
$$\sigma_f = c \cdot \varphi_e^n \cdot \dot{\varphi}_e^m \ (if\ T = const.)$$

- **Where:**
  - **n: strain hardening exponent**
  - **m: strain rate sensitivity**
- **Uniform strain is dependent from n and m:**

$$\varepsilon_u = \frac{n}{1-m}$$

$$if\ m \rightarrow 1\ then\ \varepsilon_u \rightarrow \infty$$

Affect of temperature and strain rate on m-value



Characteristics of superplastic alloys

	Temp. C°	Strain rate s^{-1}	Grain size μm	m	ε %
Al-33Cu	400-500	$8*10^{-4}$	2	0,8-0,9	400-1000
Al-6Cu-0,5Zr	450	10^{-3}	5	0,3	1000
Ti-6Al-4V	840-870	10^{-4} …10^{-3}	6	0,75	750-1100

Superplastic forming processes

- Blow or vacuum forming
- Deep drawing
- Forging
- Extrusion
- Dieless drawing

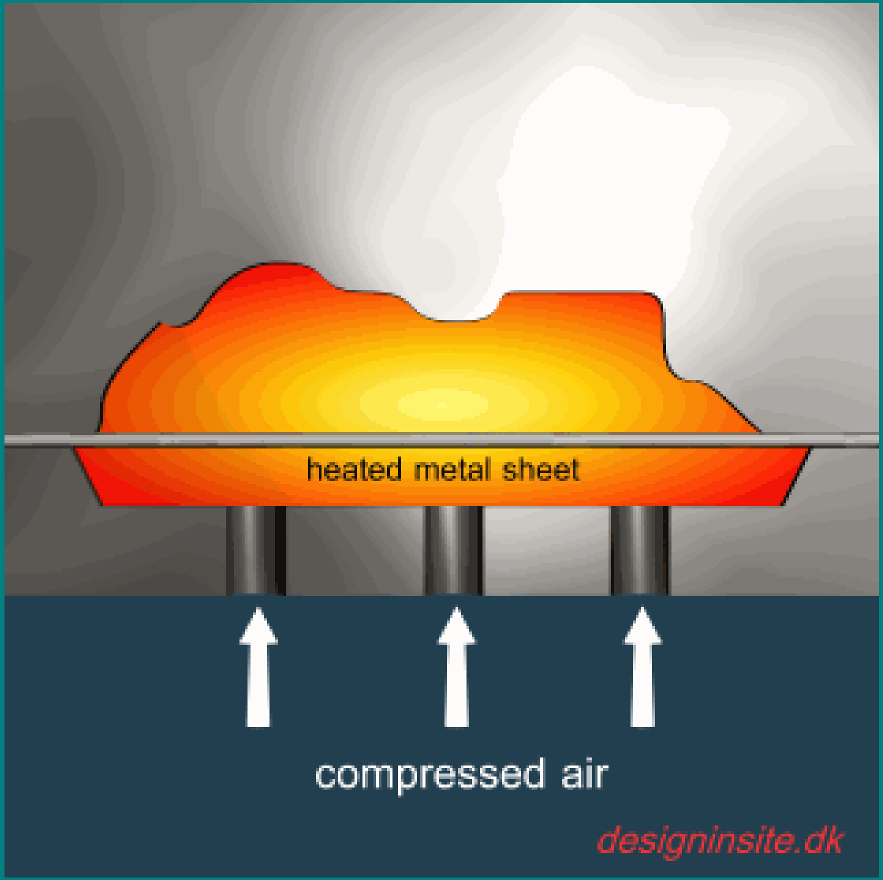
Blow forming

Free form of sheet metal

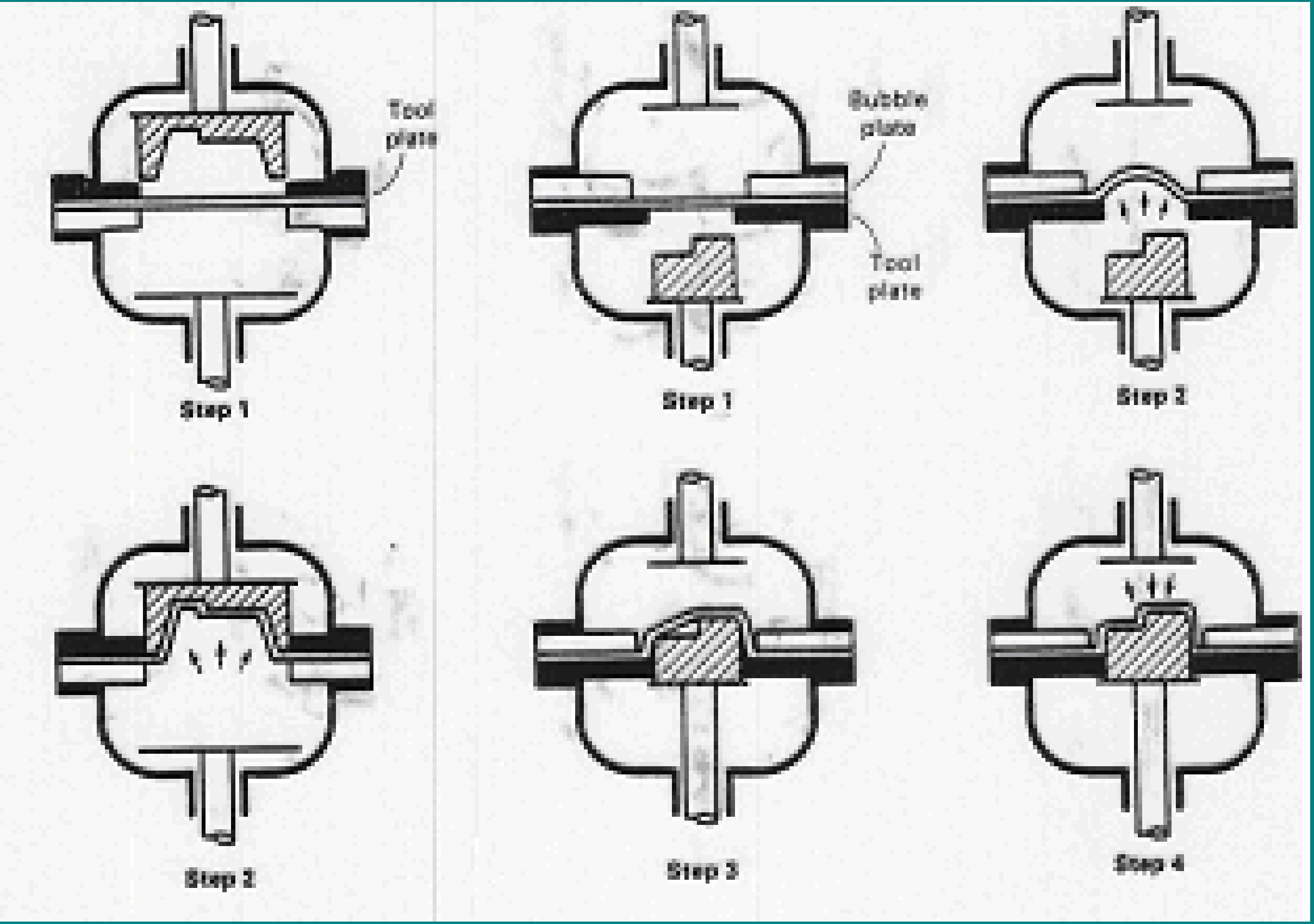
Used for automotive body parts

Temperature: constant

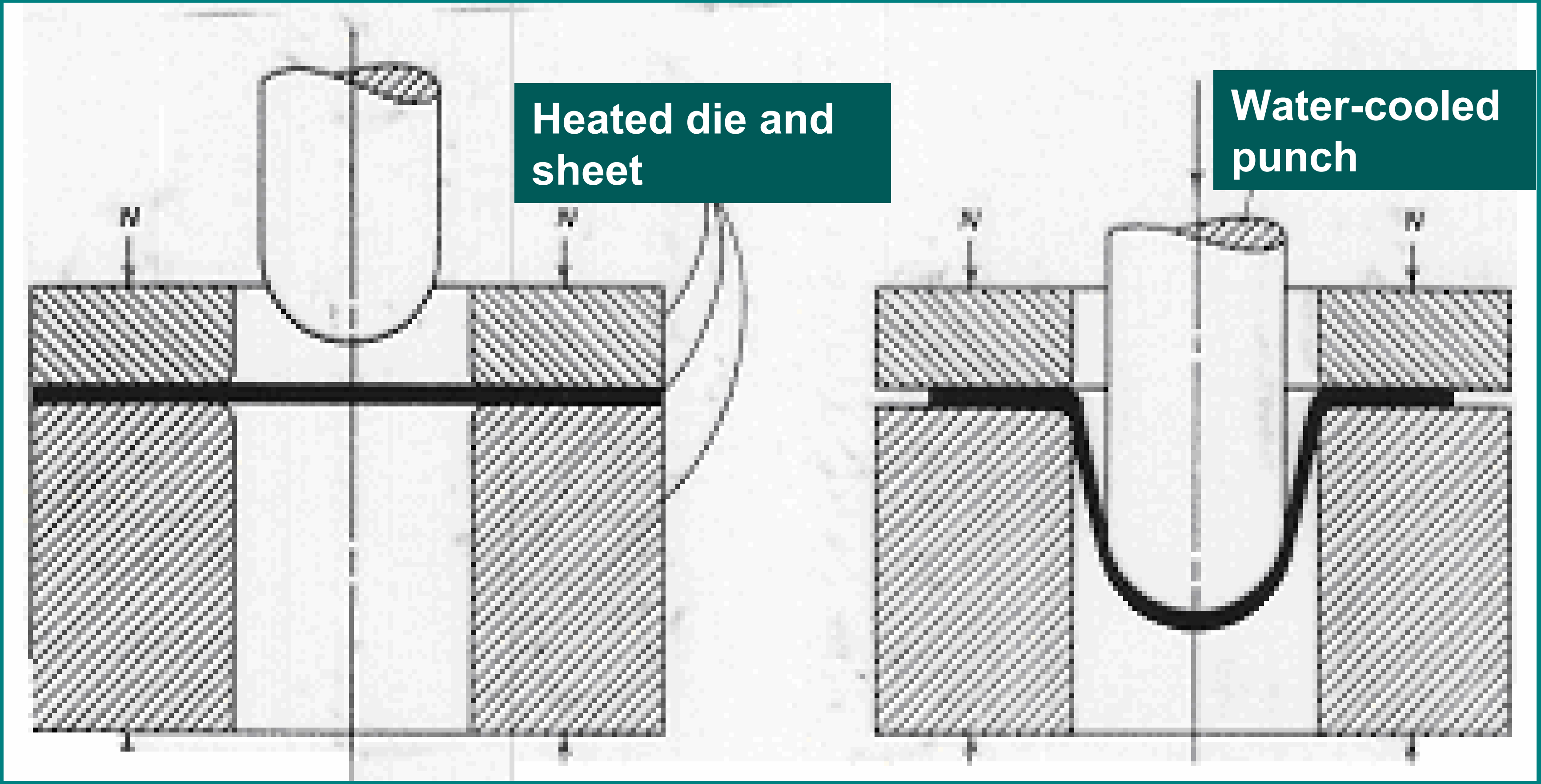
Time: 10…30 min



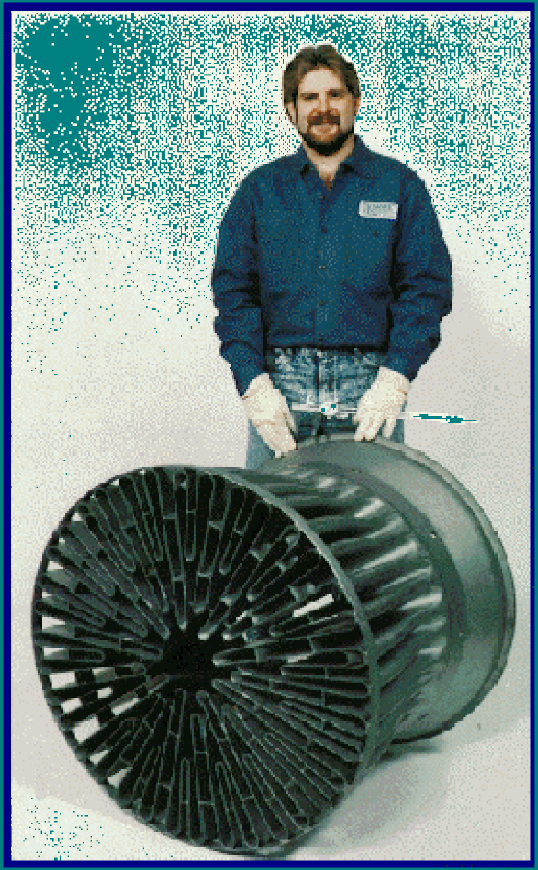
Thermo-forming: moving die + gas pressure



Superplastic deep drawing



Components produced by SP forming



Summary

- The SPF is unique in terms of the complexity of parts that can be produced
- Main characteristics:
  - High ductility of materials
  - Non-conventional manufacturing methods
- SPF processes are being increasily used for a wide range of applications