WARM AND COLD FORGING

PRECISION FORGING
COLD HEADING
COLD EXTRUSION

Precision forging

Main characteristics:

- **Closed die forging**
- **Temperature is below the hot range, it is „warm” forging (T~0,5*T_m °K)**
- **Close tolerances, acceptable surface finish – „near net shaping process”**
- **Good material yield**
- **Good mechanical properties**

Economic considerations

- Precision forging is more costly than conventional forging, …but!
- Savings in material and machining costs are significant
- Forming complex shapes is possible
- Precision forging represents a higher value product than a conventional forging (higher added value)

Temperature of forging

Low alloy steels:

Cold forging	< 250 ^oC
Warm forging	540 … 815 ^oC
Hot forging	950 … 1150 ^oC

Controlled cooling may be necessary after forging to avoid distorsion and to control the microstructure of the workoiece

Tooling (1)

- Dimensions
  - Allowances (thermal contraction, machining)
  - Draft angles, no sharp corners – good material flow
- Workability
  - High deformation levels – needs good formability
  - Try to avoid cracking!

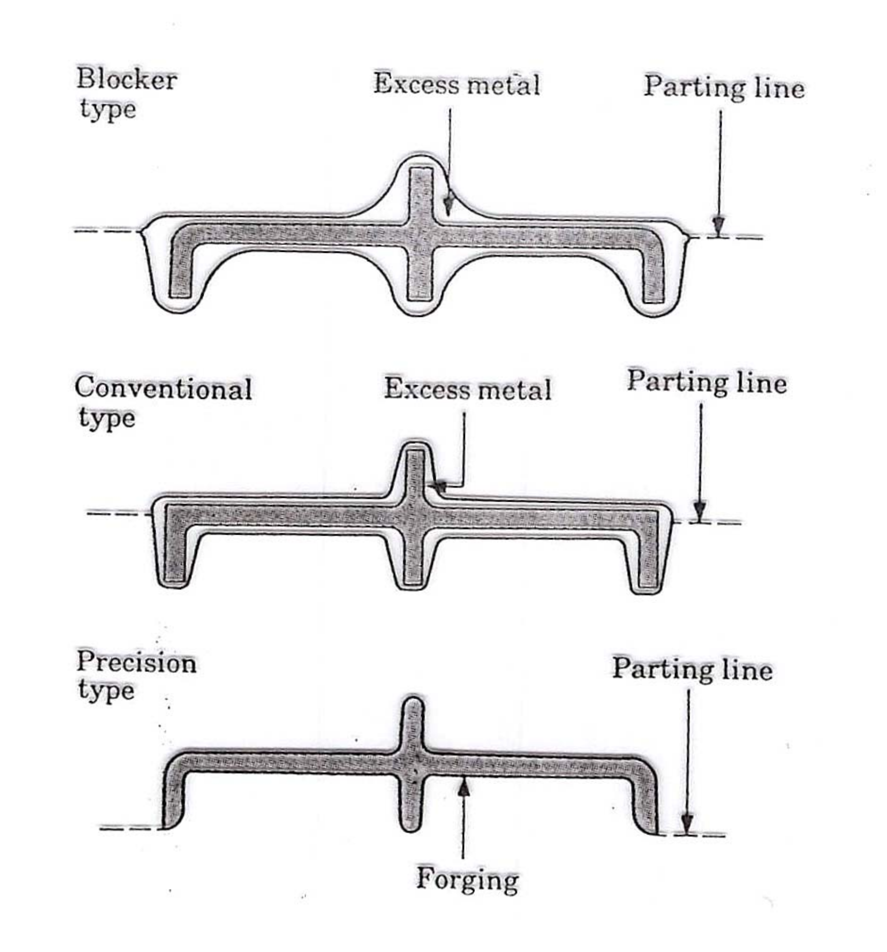
Tooling (2)

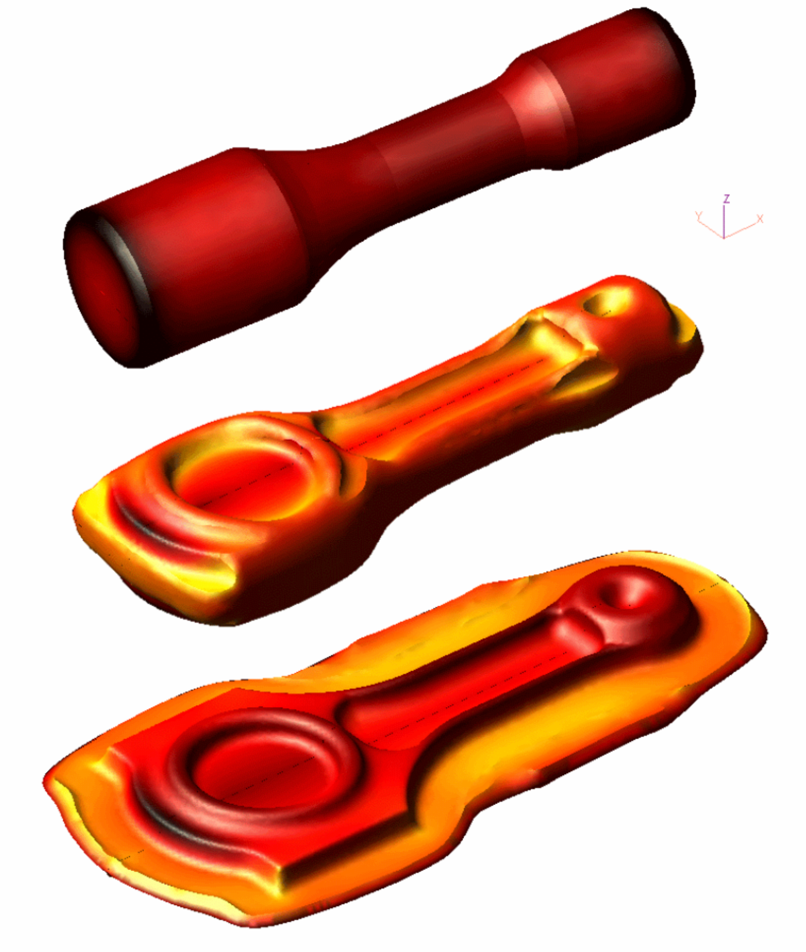
- Precision:
  - Tolerance bands of tool: 10…30% of the workpiece
  - High-precision machining (EDM)
  - Rigid alignment
  - Preform considerations (volume, weighting, appropriate shape)
- Conditions: good lubrication, remove contaminants, good control of billet and tool temperature

Forging equipment

- **Billet separation: shearing or sawing**
- **Heating:**
  - Furnace – oxide formation
  - Induction heating
  - Resistance heating
- **Presses:**
  - Hammers
  - Crank presses
  - Hydraulic presses

Comparison of forgings



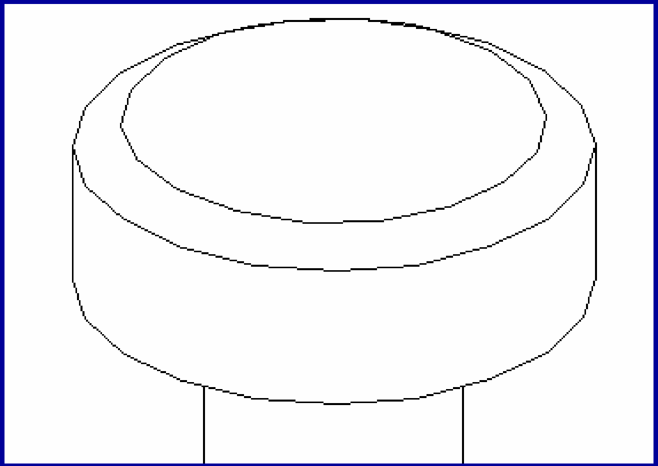


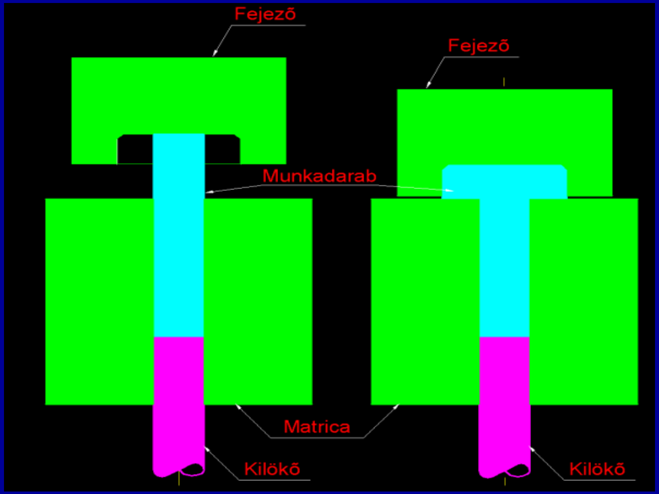
Cold forging

- **Processes:**
  - Upsetting
  - Cold forging of components
- **Effect of cold working on material properties**
  - the ductility of the material drops, strengths and hardness increases (because of higher dislocation density - strain hardening)
  - the microstructure changes, crystals (grains) become elongated in the direction of major deformation

Cold heading

- To upset the metal in a portion of wire or rod blank
- The cross-sectional area of the initial material is increased as the height of the workpiece is decreased
- variants:
  - Free (head formed between flat punch and die)
  - Closed (head formed in punch and die)





Limits of deformation

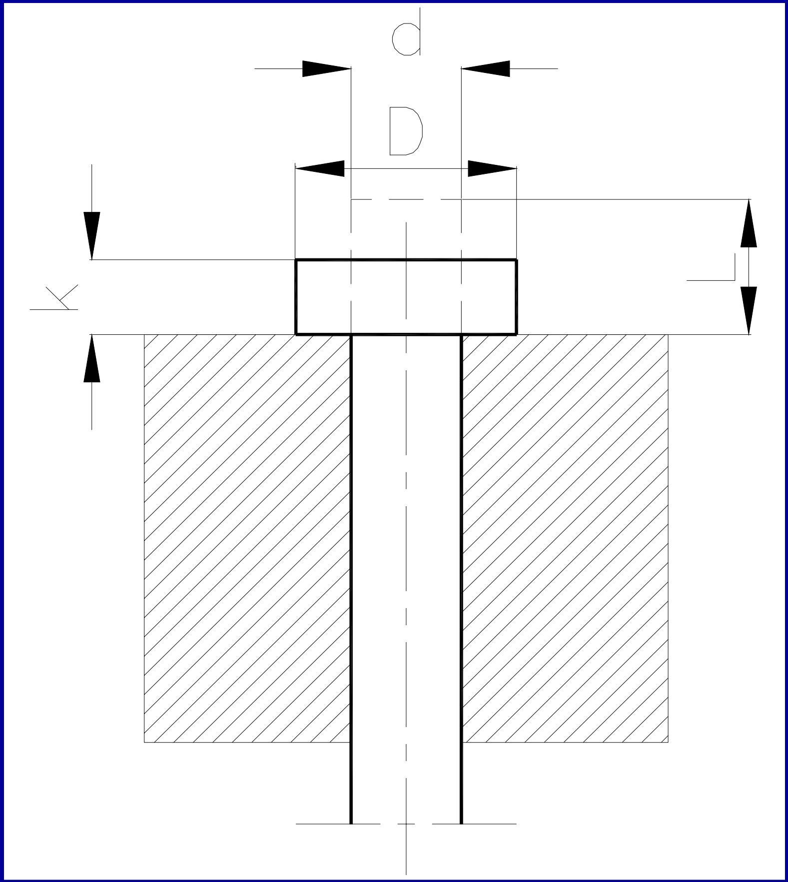
Material dependent:

$$\frac{L}{d} \leq 2{,}3$$

$$\frac{\mathrm{D}}{\mathrm{d}} \Rightarrow 2 \ldots 2.7$$

Material independent:

$$\frac{D}{k} \Rightarrow \quad 2 \ldots 3$$



Calculation of force

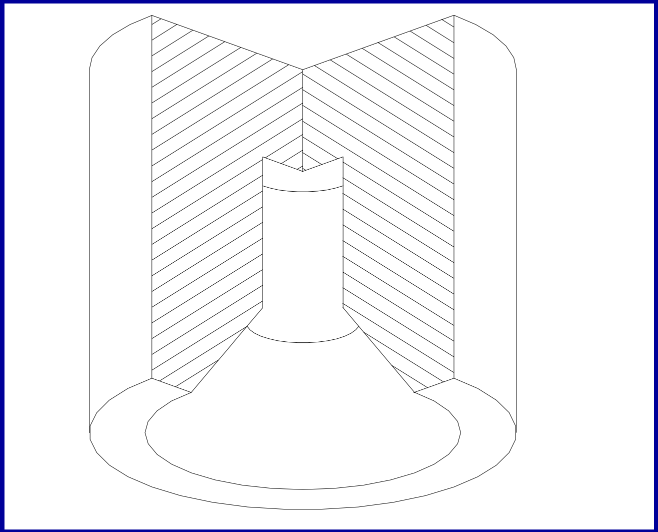
$$F = k_f A \left(1 + \frac{2\mu}{3h} R\right)$$

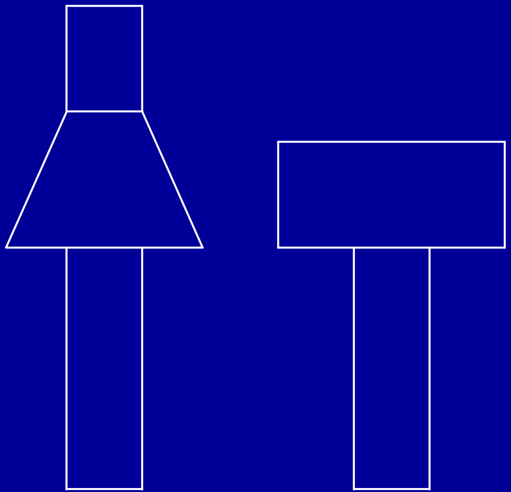
Where:

k_f	flow stress
A	cross-sectional area
R	radius of head
h	height of head
μ	coefficient of friction

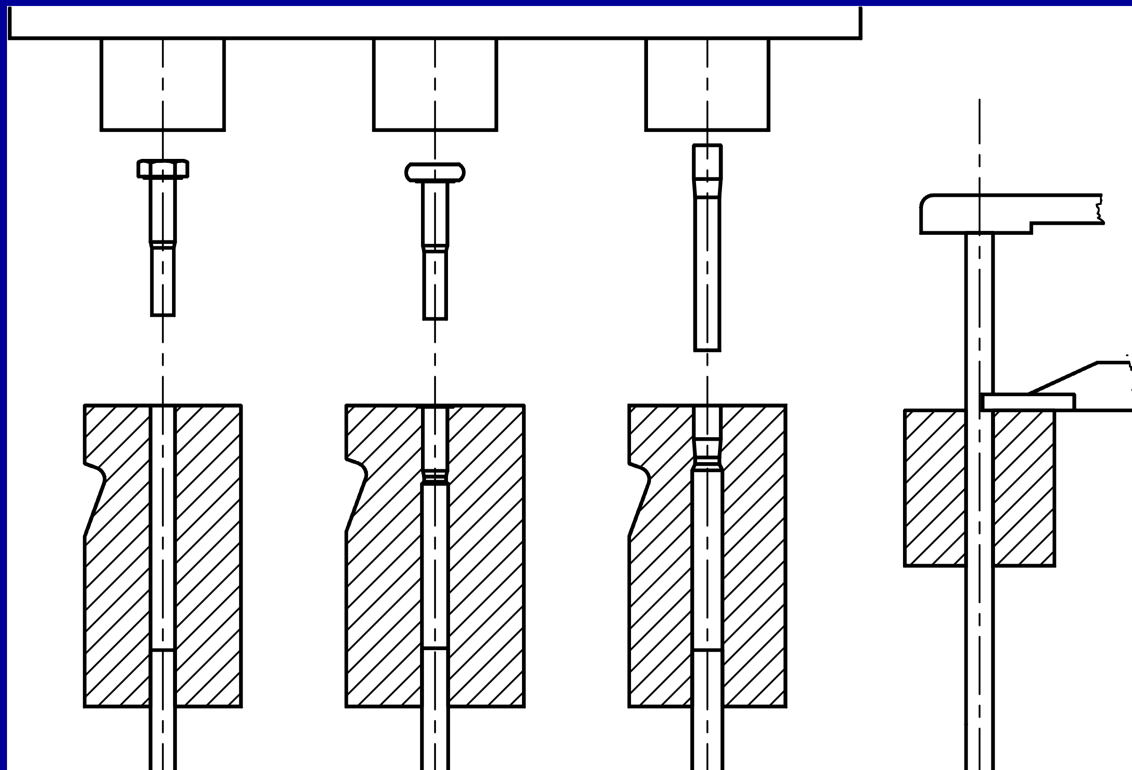
Two-stroke upsetting

- If L/d > 2,3 then two operations are needed:
  - Preforming
  - Finish heading
- Preforming head: conic-cylindrical
- Finish: closed heading punch



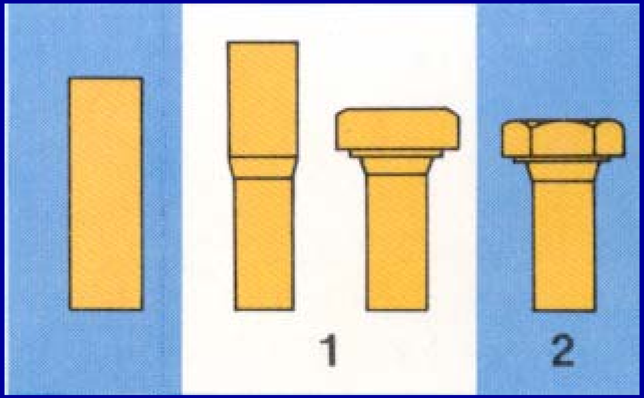


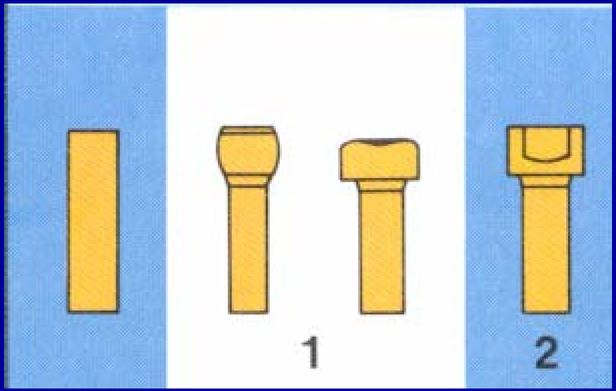
Example: screw

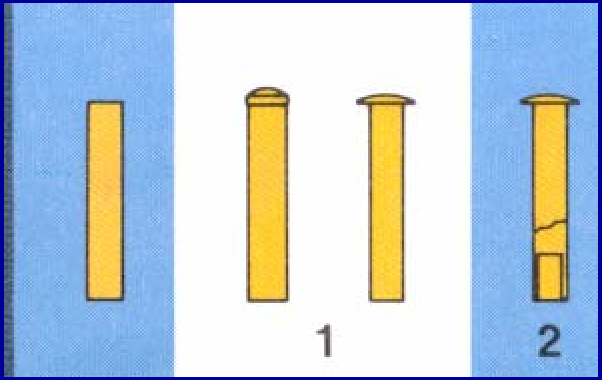


head shearing | heading | reduction | shearing

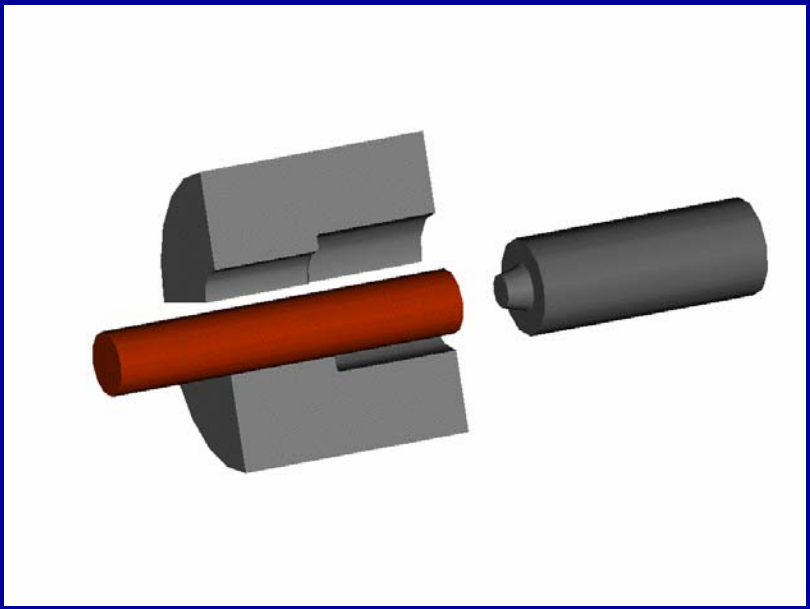
Example: screws and bolts

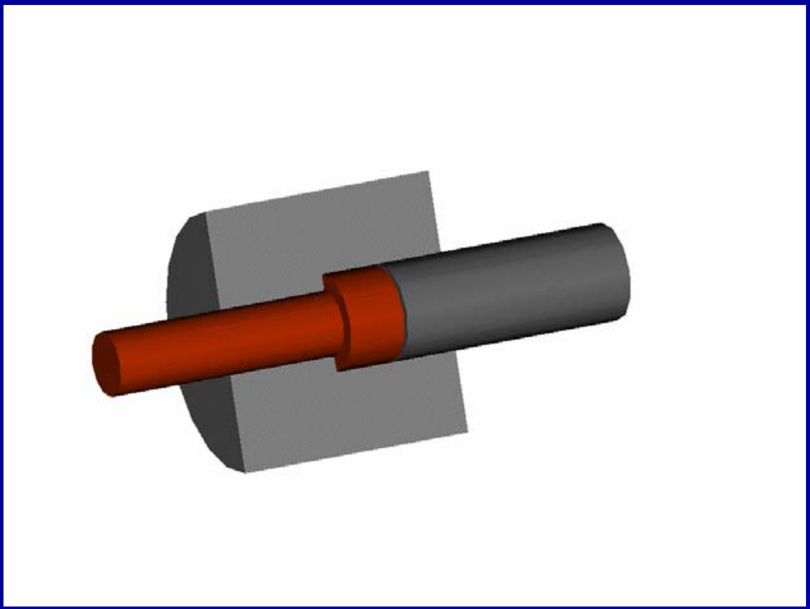






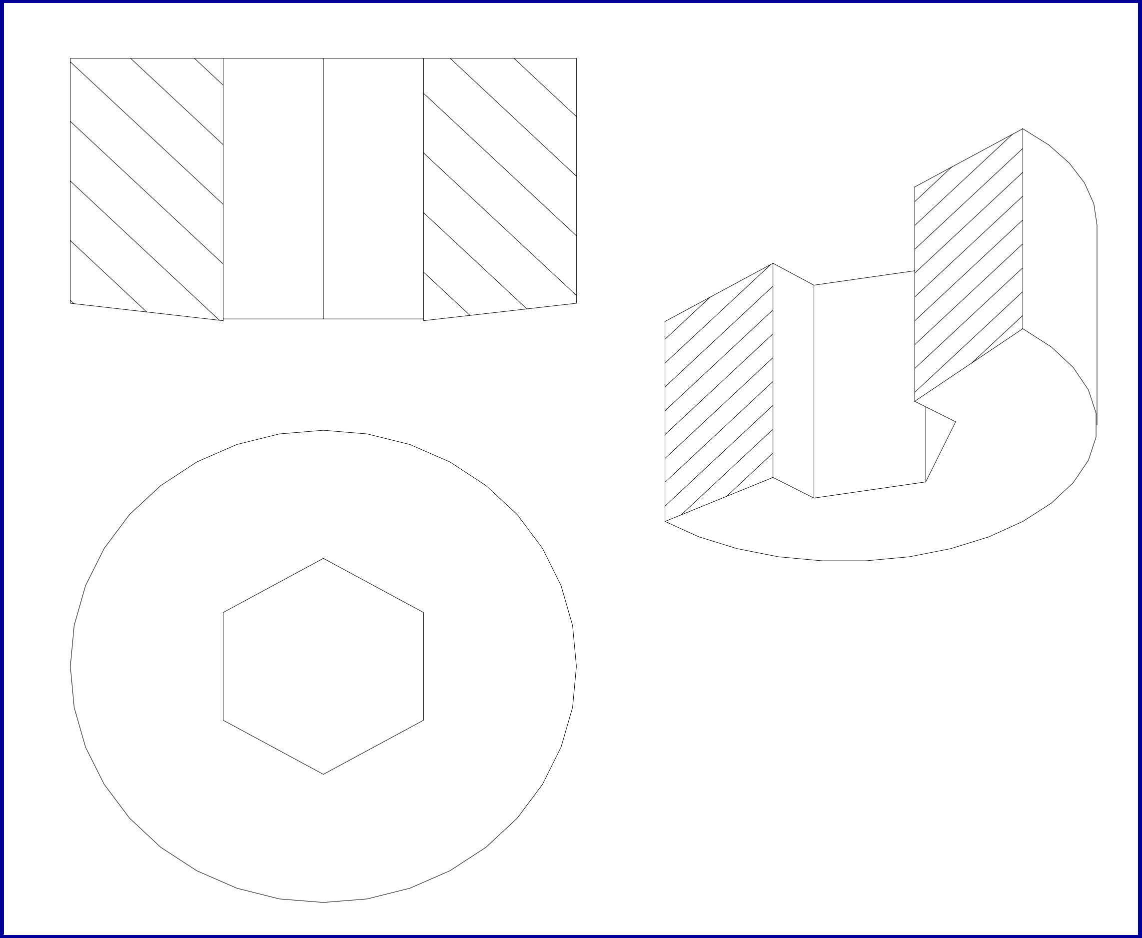
Example: heading





- Closed-die cold heading
- Die can be opened for feeding and removing the workpiece

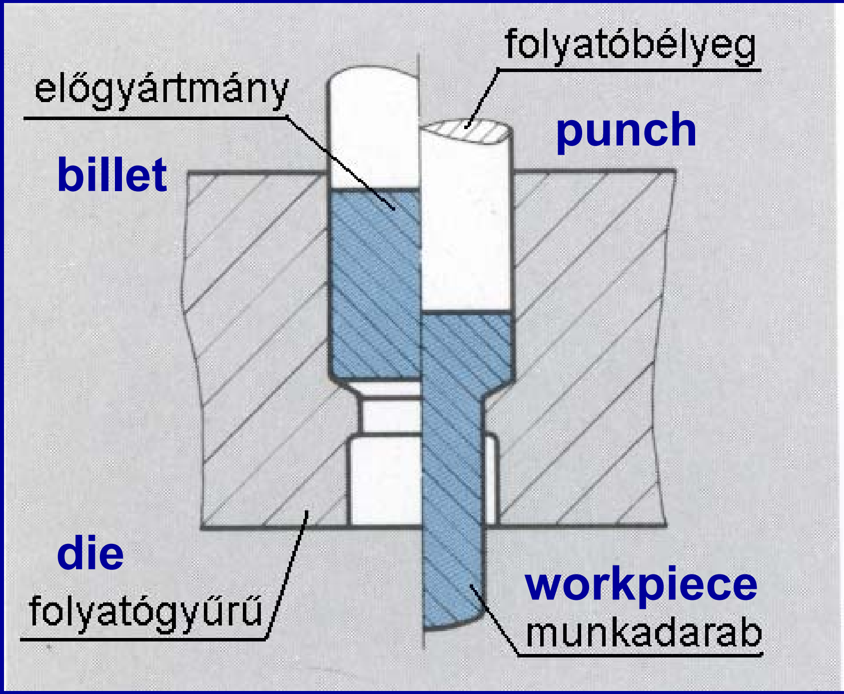
Head shearing



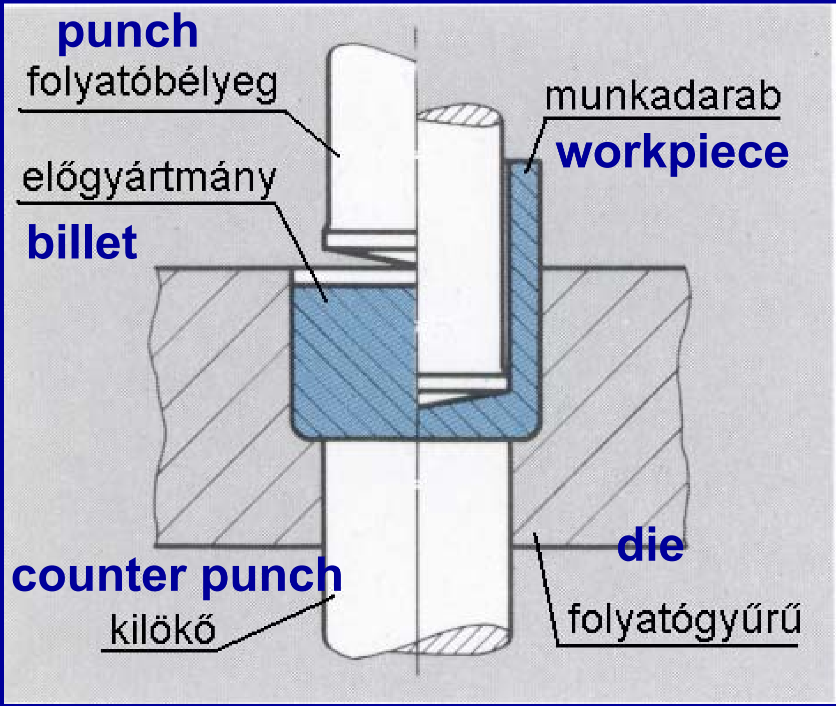
Cold extrusion of parts

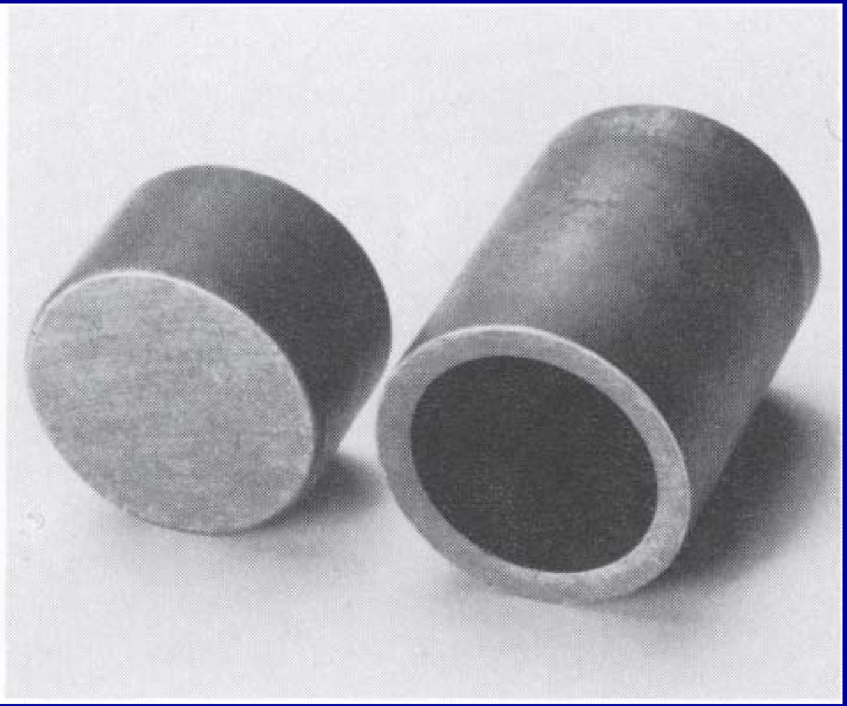
- Principle: a punch applies pressure to the preform or billet, causing the work metal to flow in the required direction
- Process variants:
  - Direct – indirect or forward – backward
  - Extrusion of rod, can and hollow part
  - Single or combined operations

Forward extrusion of rod

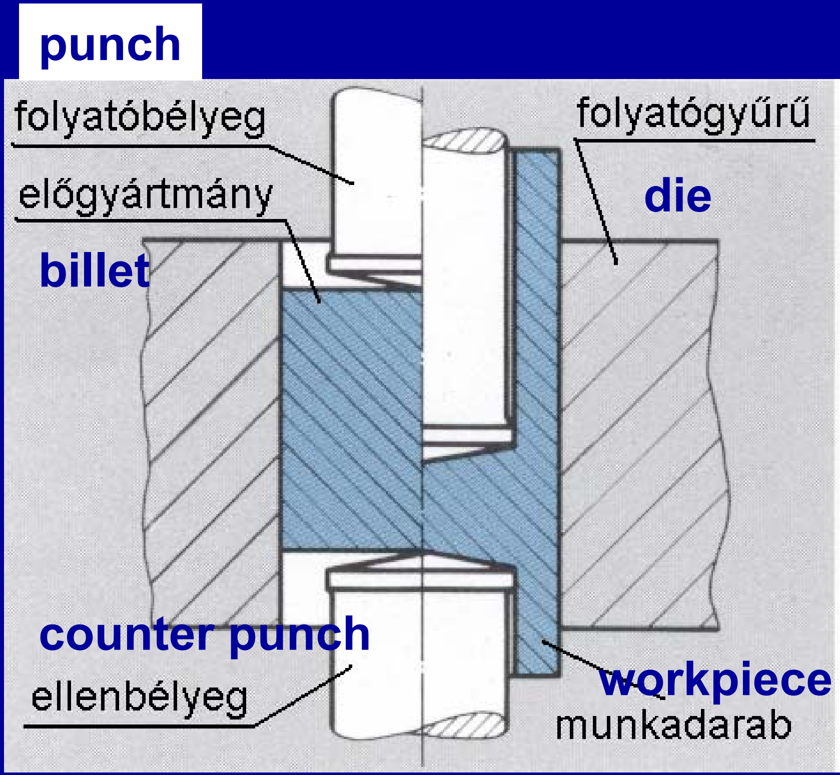


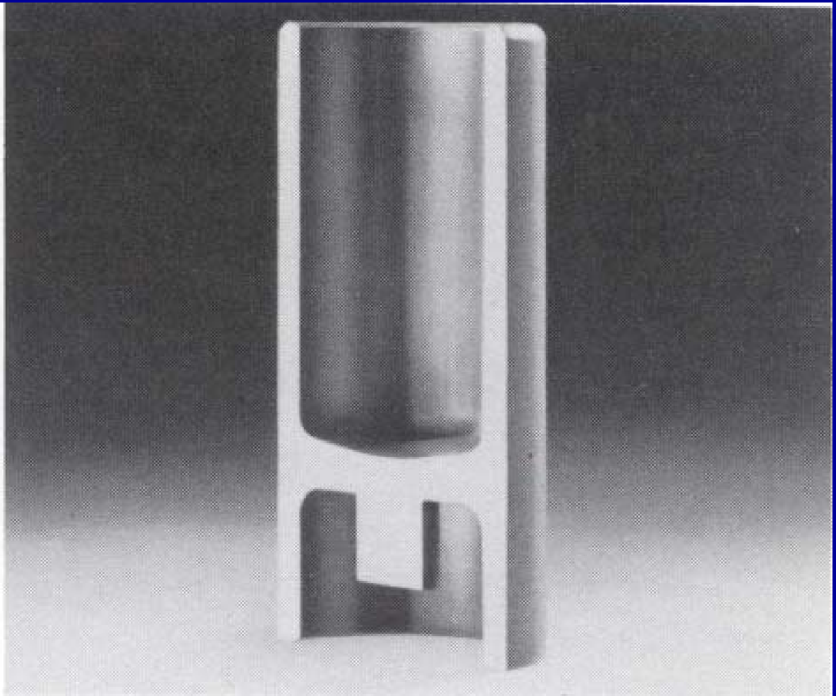
Backward extrusion of can



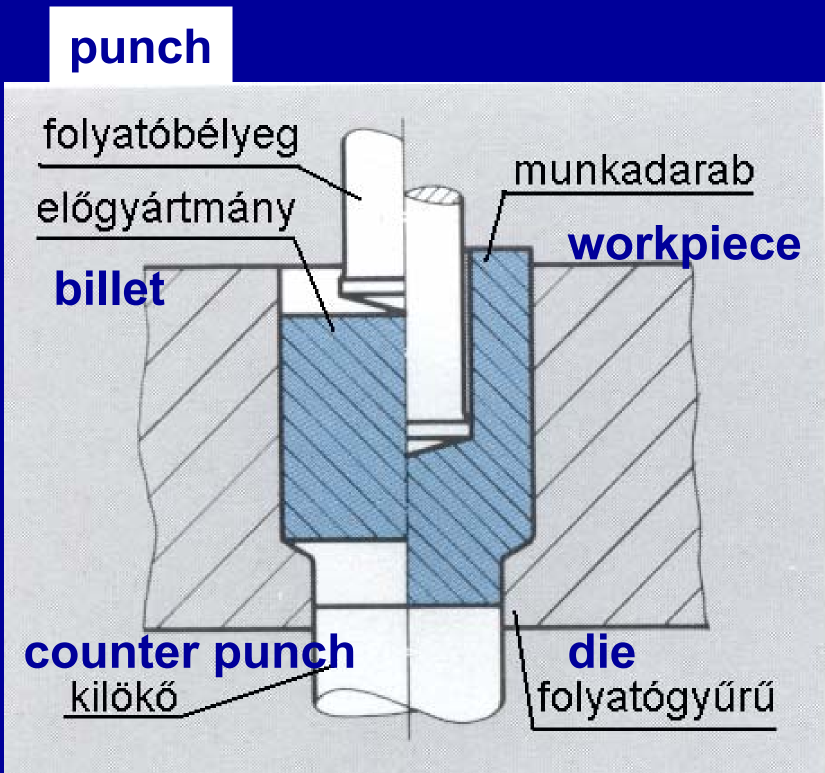


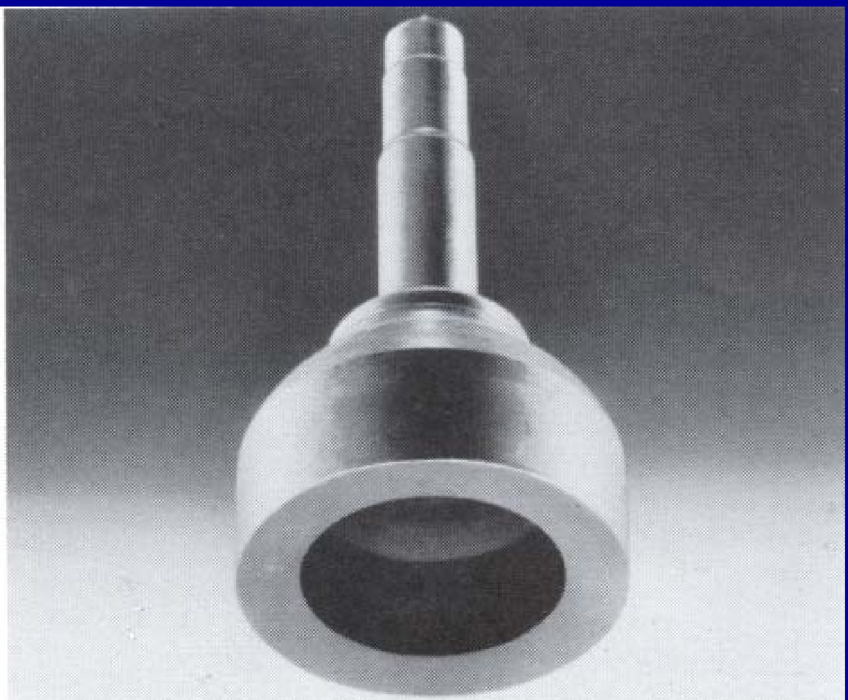
Combined : forward and backward extrusion of can





Combined: forward extrusion of rod, backward extrusion of can





Cold extrusions

- Forward extrusion of rod
- Back extrusion of can
- Forward extrusion of can

Extrusion pressure and force

- **Extrusion pressure:**

$$p = \frac{k_{fm}\varphi}{\eta}$$

where:

k_{fm} **mean flow stress**

φ **logarithmic strain: $\ln(A_o/A_1)$**

η **coefficient of extrusion (0,4…0,7)**

Extrusion pressure and force

- Punch load (force)

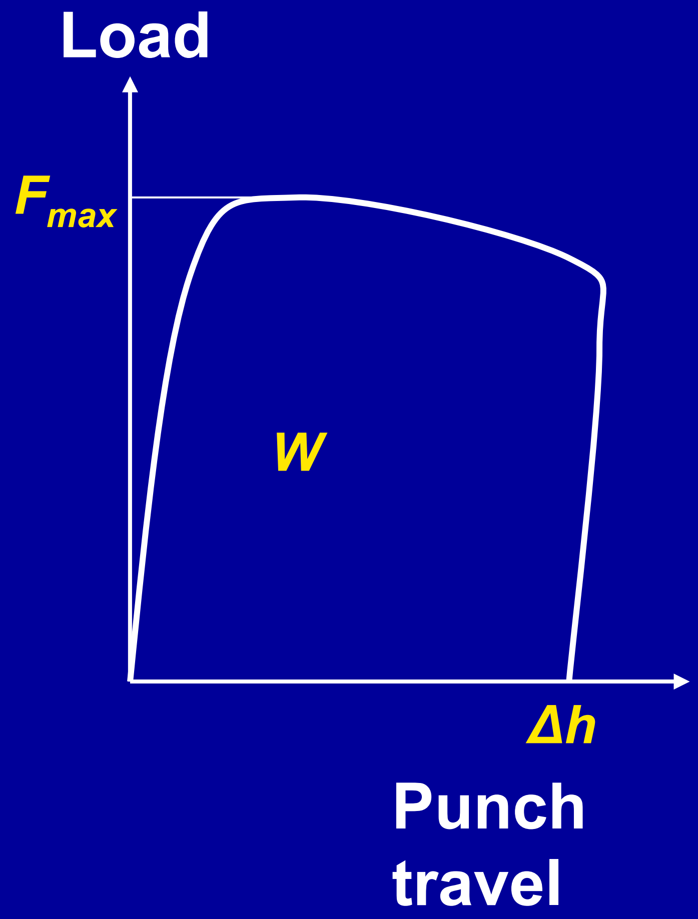
  $$F = p\,A$$

- Work (energy)

  $$W = c\,F\,\Delta h$$

  $(c=0{,}6\ldots0{,}8)$

- where:
  - A	cross sectional area
  - Δh	punch travel



Materials and lubrication

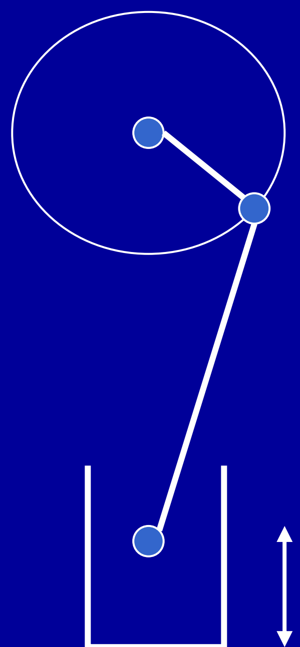
- Good formability:
  mild steel, copper, aluminium
- Medium formability:
  low alloy steels, Zn
- Preparation for cold forging:
  - Surface treatment
  - Lubrication
  - Forging

Equipment

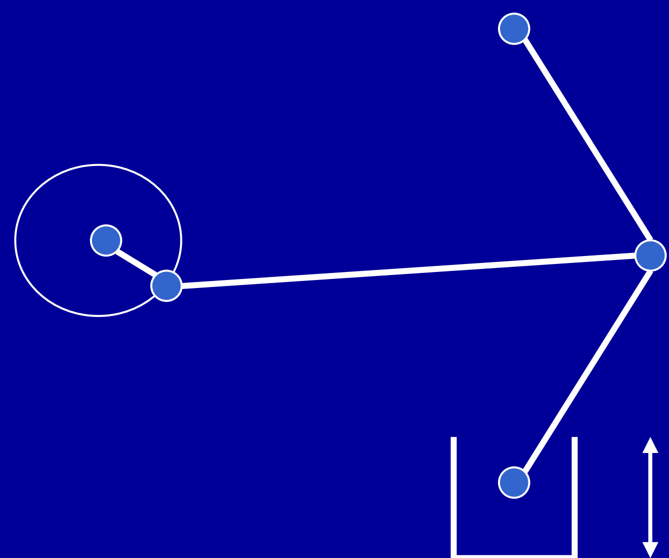
- **Machines:**
  - Crank presses
  - Knuckle-joint presses
  - Hydraulic presses
  - Special purpose cold forging and heading machines
- **Requirements:**
  - Sufficient flywheel energy and load capacity
  - Rigid frame

Presses

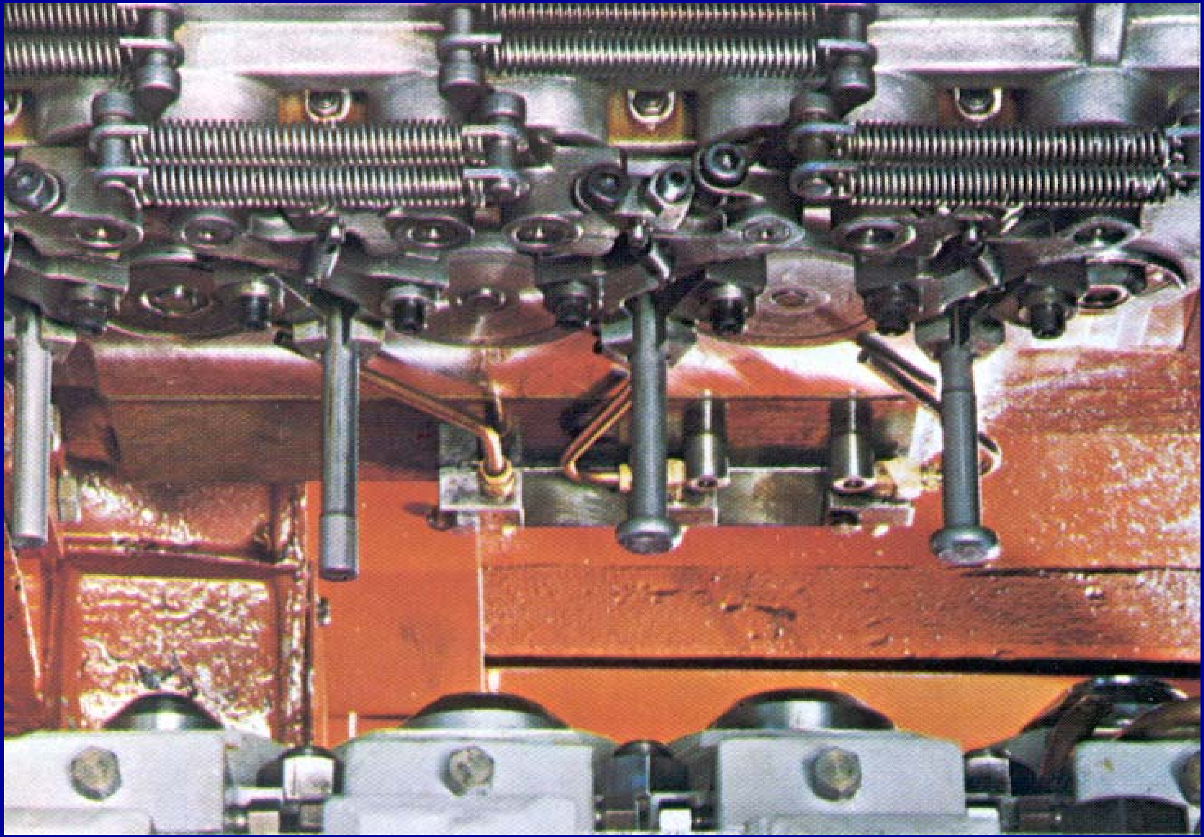
crank press



knuckle-joint press



Automated press

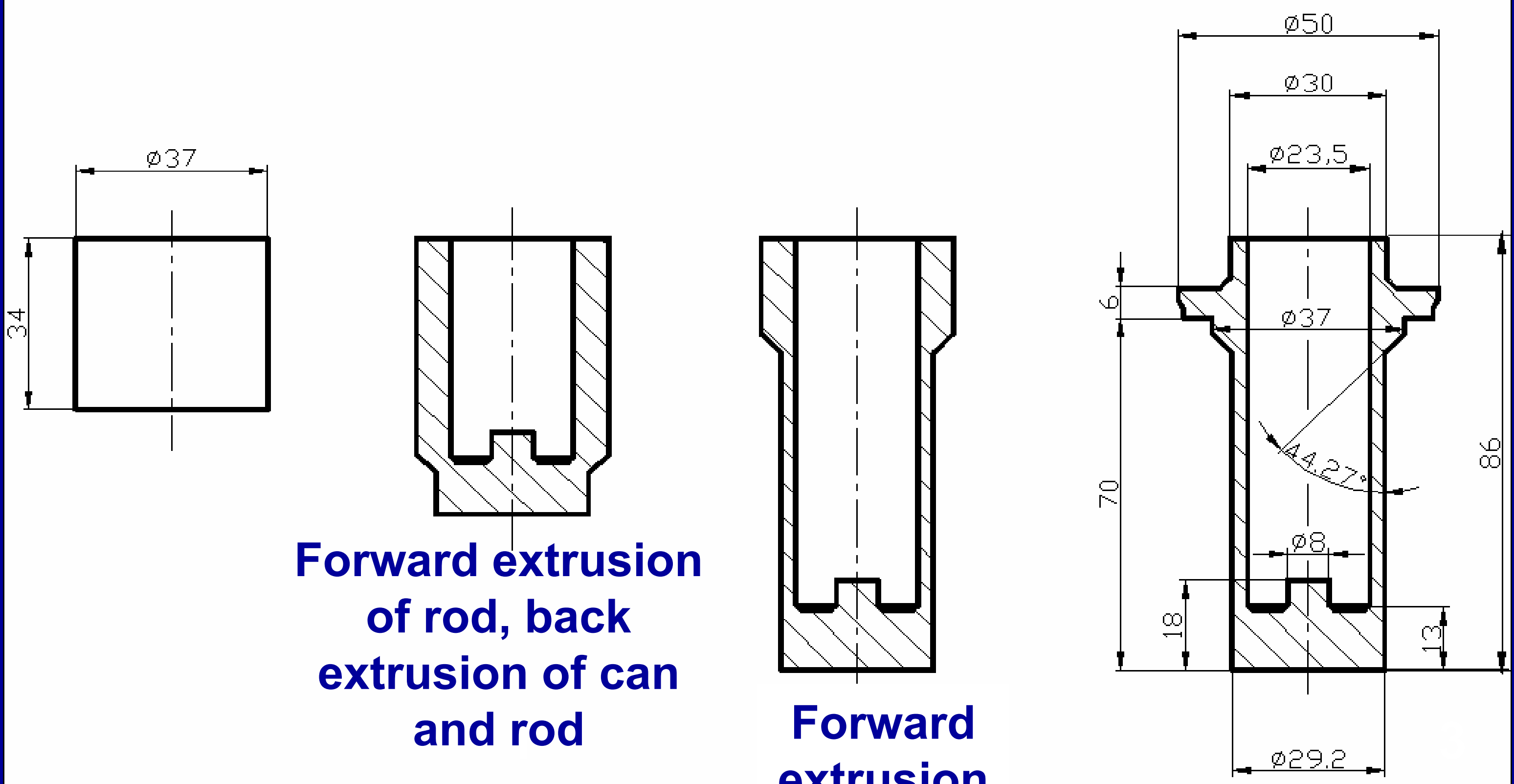


Feeding, shearing	Preforming of head	Cold heading	Coining and sizing

Cold Forging Machines

Cold forged parts

Example: multiple-step forging

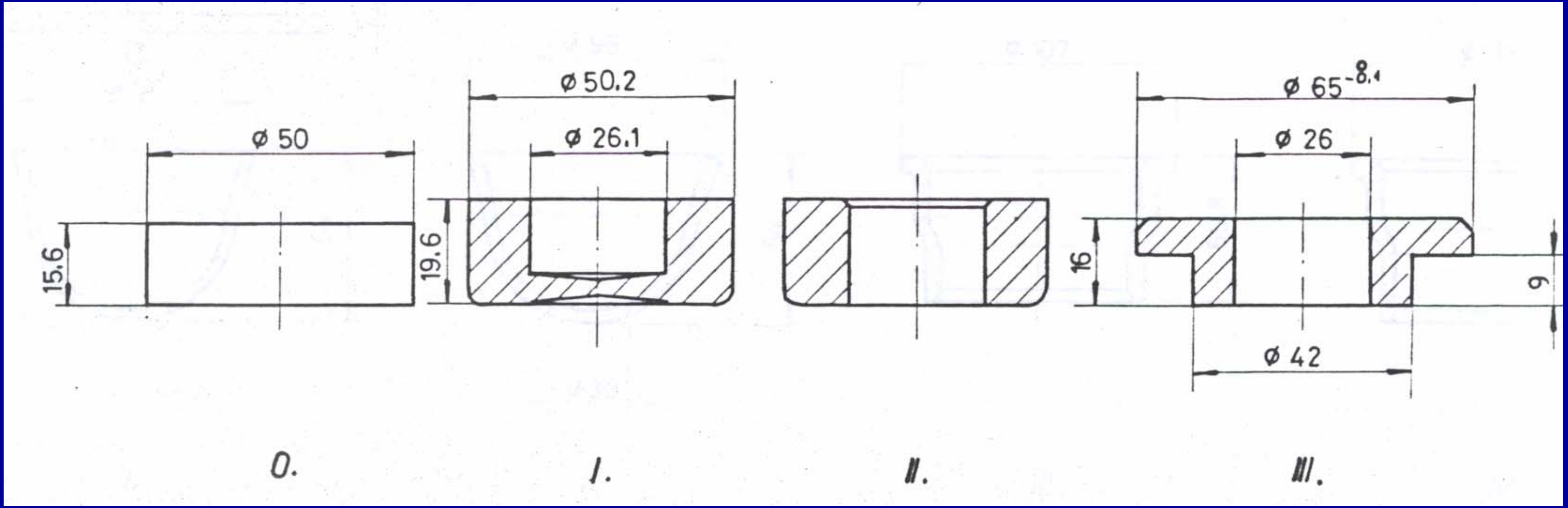


Forward extrusion of rod, back extrusion of can and rod

Forward extrusion of hollow part

radial extrusion

Example: multiple-step forging



Billet	Back extrusion of can	Piercing	Radial extrusion

Example: production of nut

Comparison of material yield and energy consumation

Process	Material yield, %	Energy, 10^6 J/kg
Cold forging	85	41
Warm forging	85	41
Hot forging	75…80	46…49
Cutting	40…50	66…82