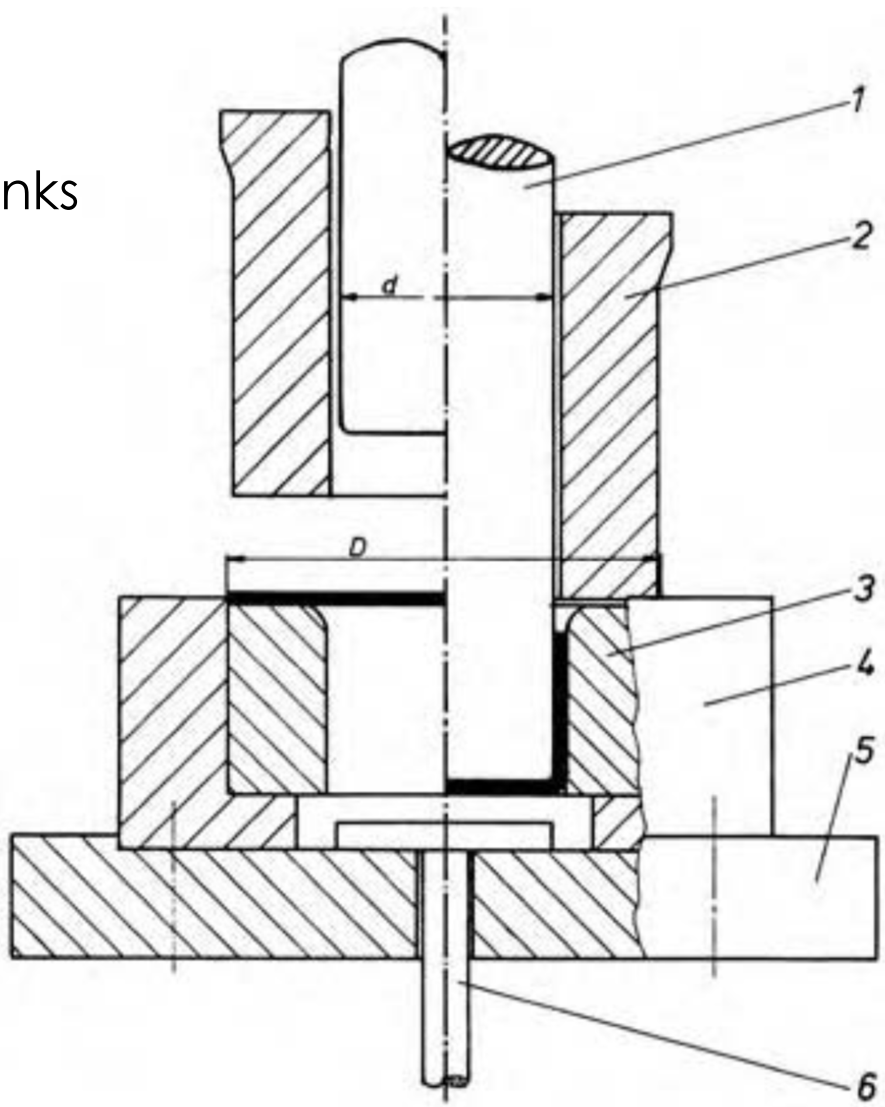
Sheet Metal Forming

Deep drawing

Introduction

Definition of sheet metal

Deep drawing is the forming of sheet blanks **into hollow parts**.



1 drawing punch
2 blank holder
3 drawing ring
4 container
5 base plate
6 ejector

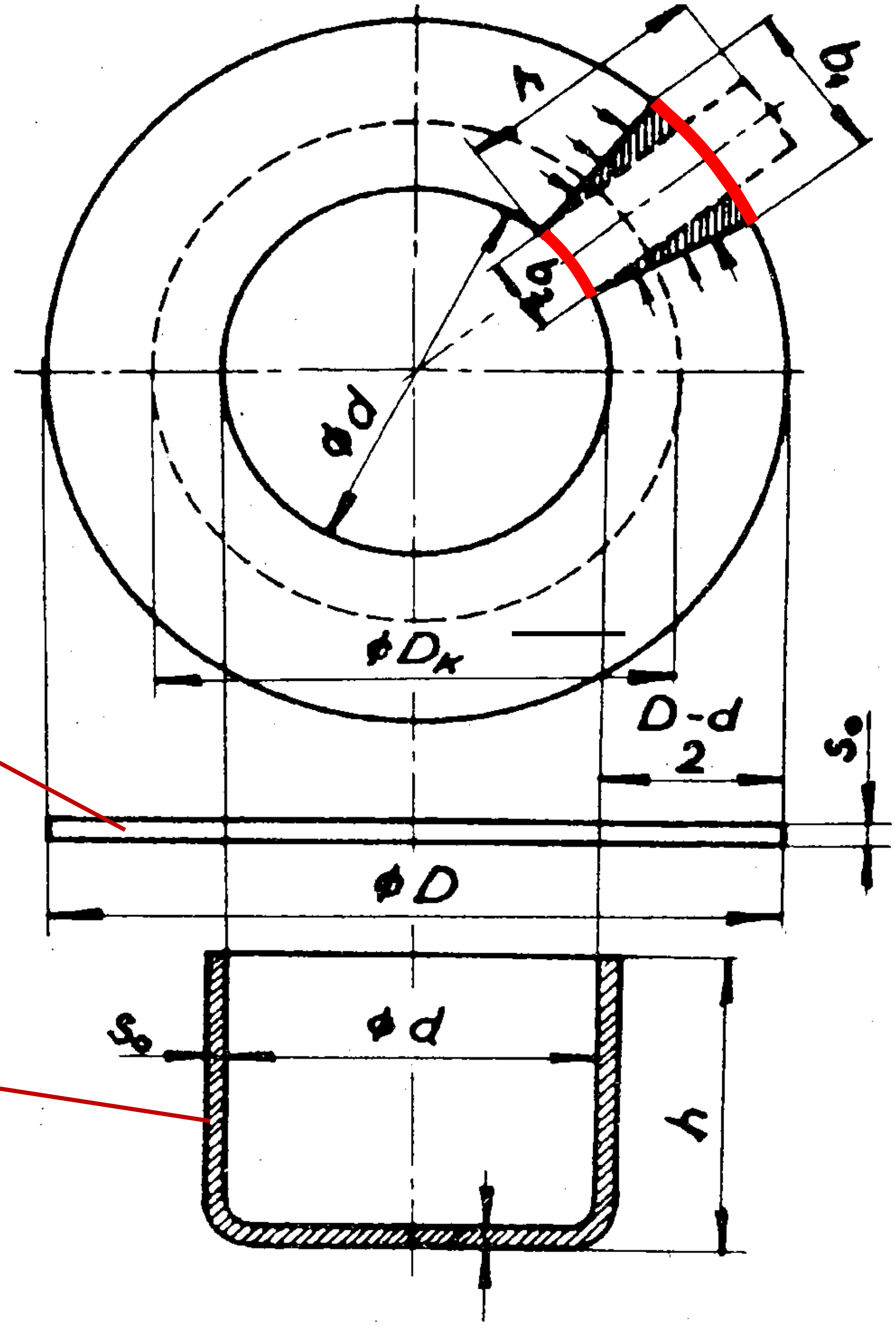
Products

Deformation - stress

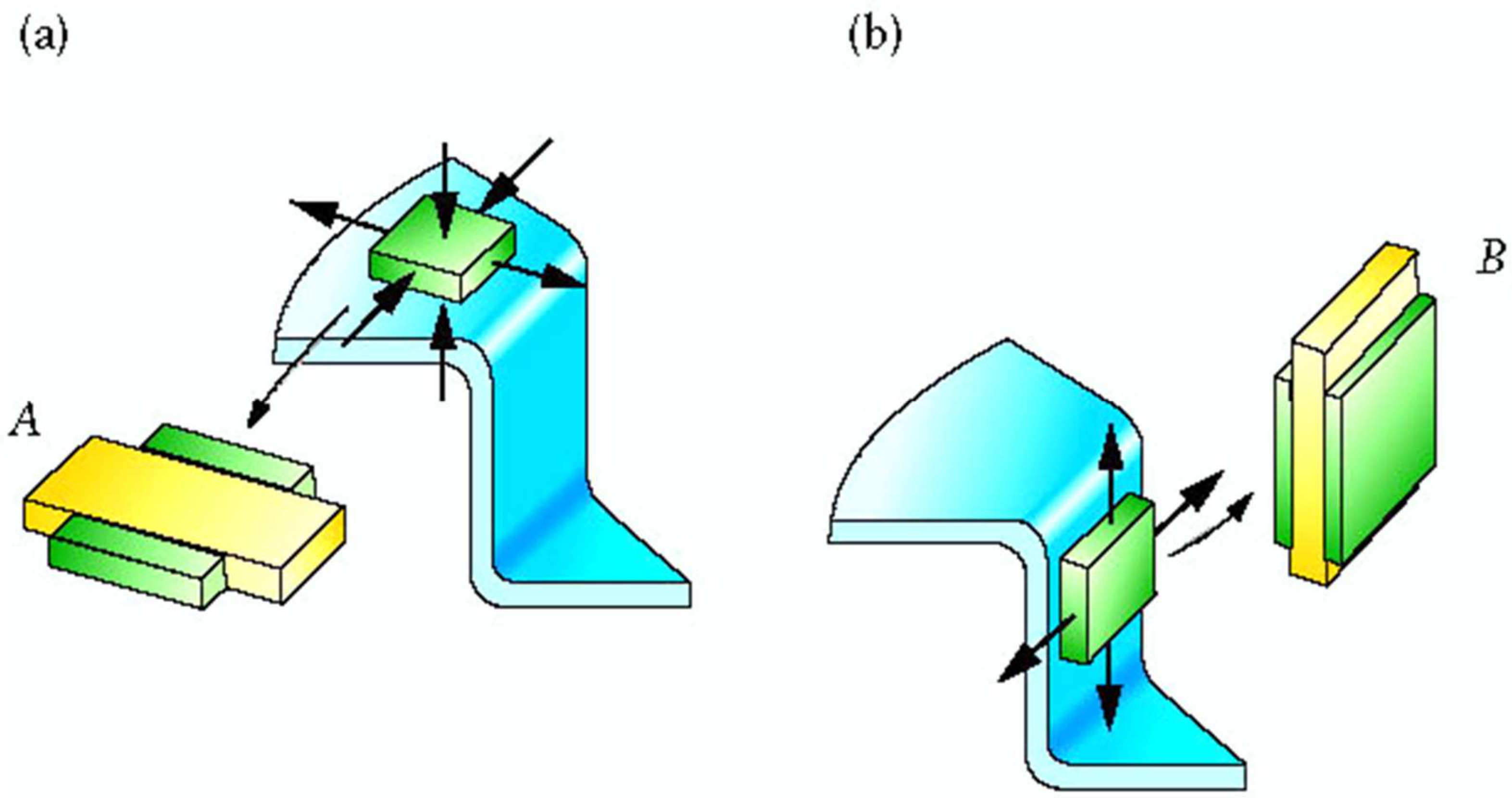
Role of tangential stress in wrinkling

stock

product

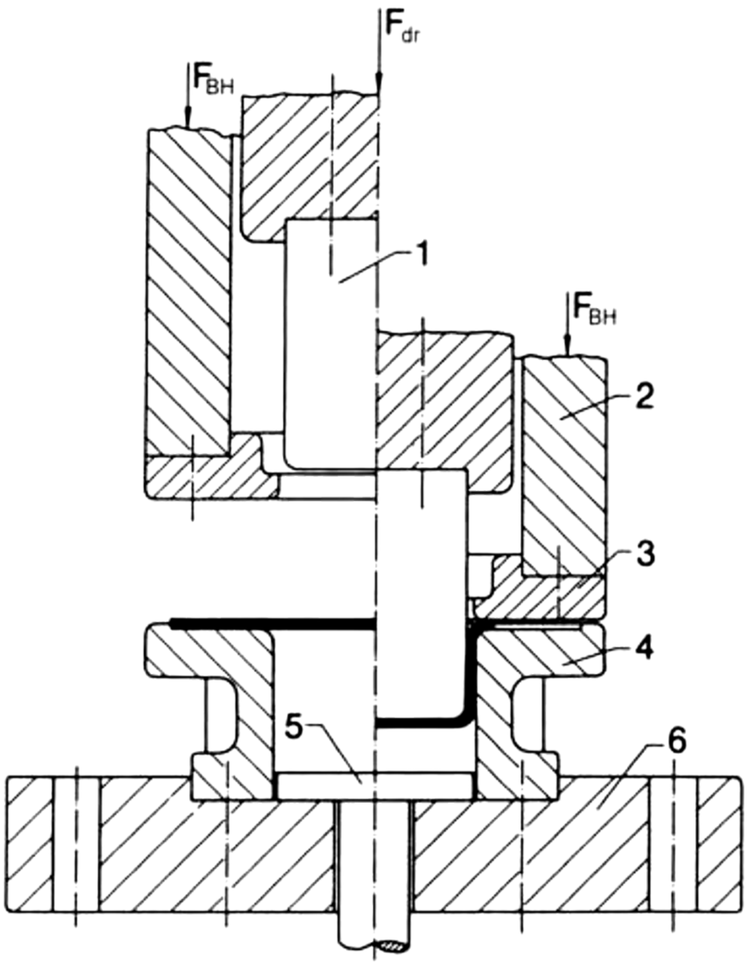


Deformation - stress



Complex inhomogeneous stress and strain state exists.

Role of blank holder

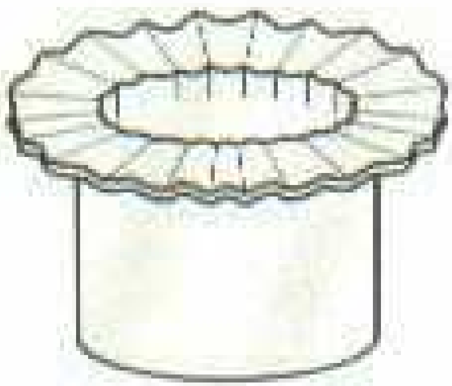


If D/s < 20 (thick sheet), no blank holder is needed.

Too low blank holder pressure
→ wrinkling

Too high blank holder pressure
→ crack

Defects



Wrinkling

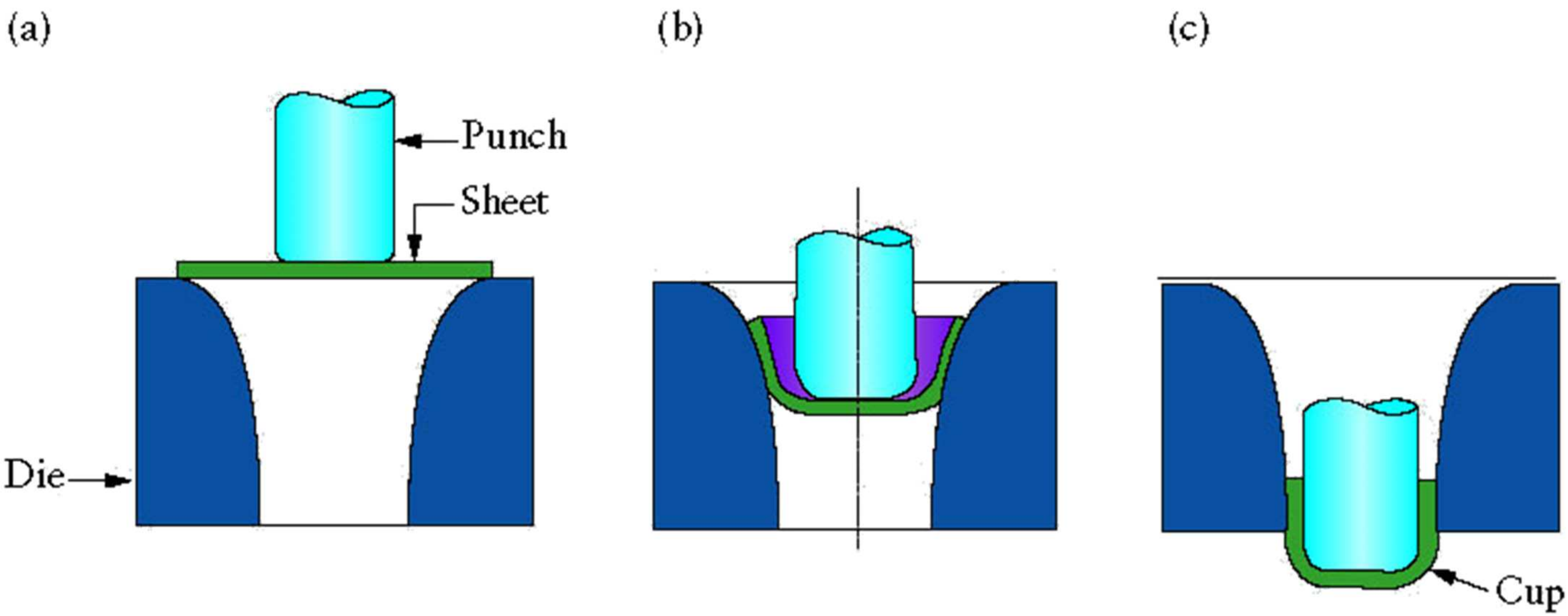
Wall wrinkling

Crack

Earing

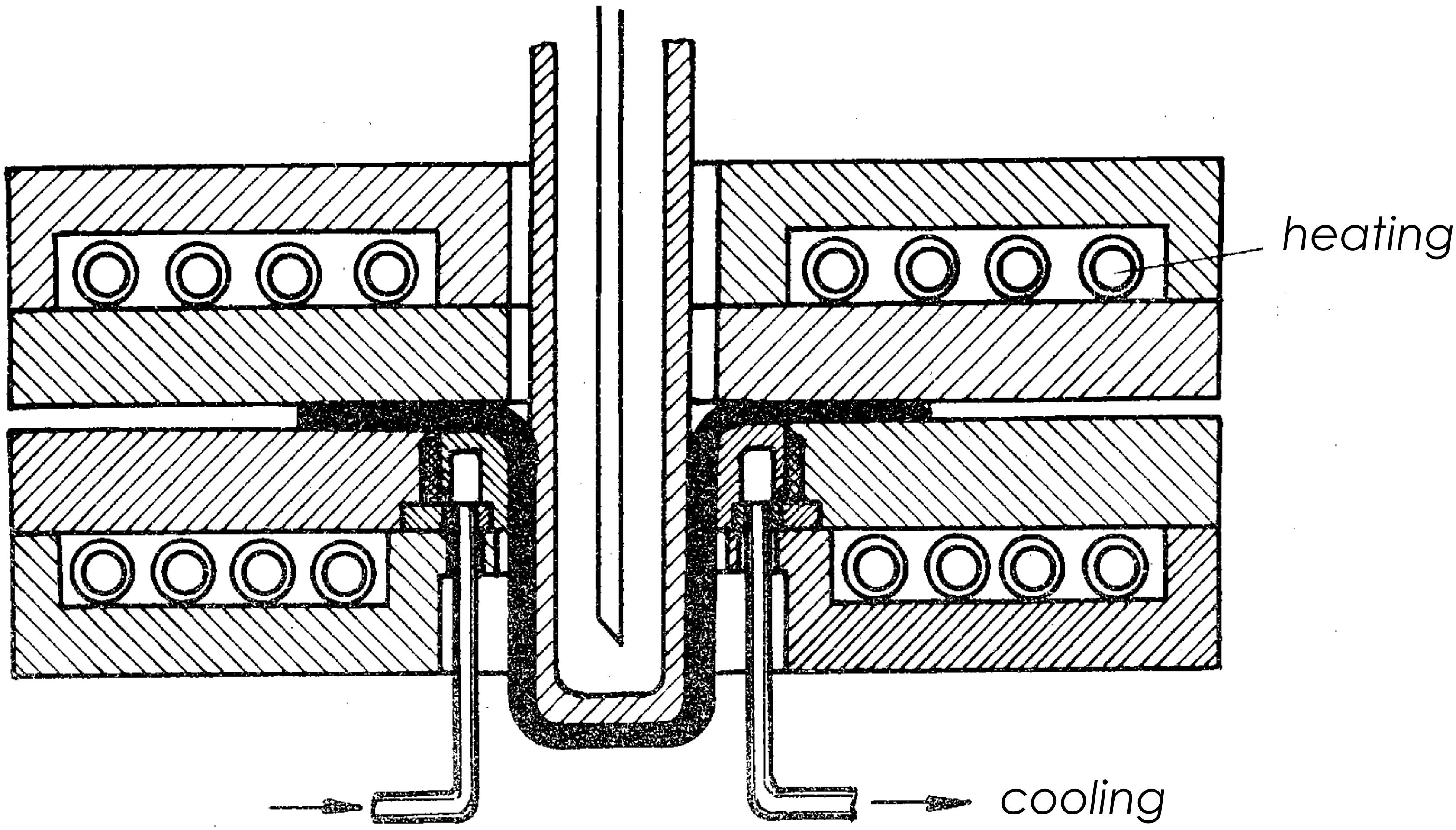
Deep drawing without blank holder

Deep drawing with **tractrix** curved die without blank holder:



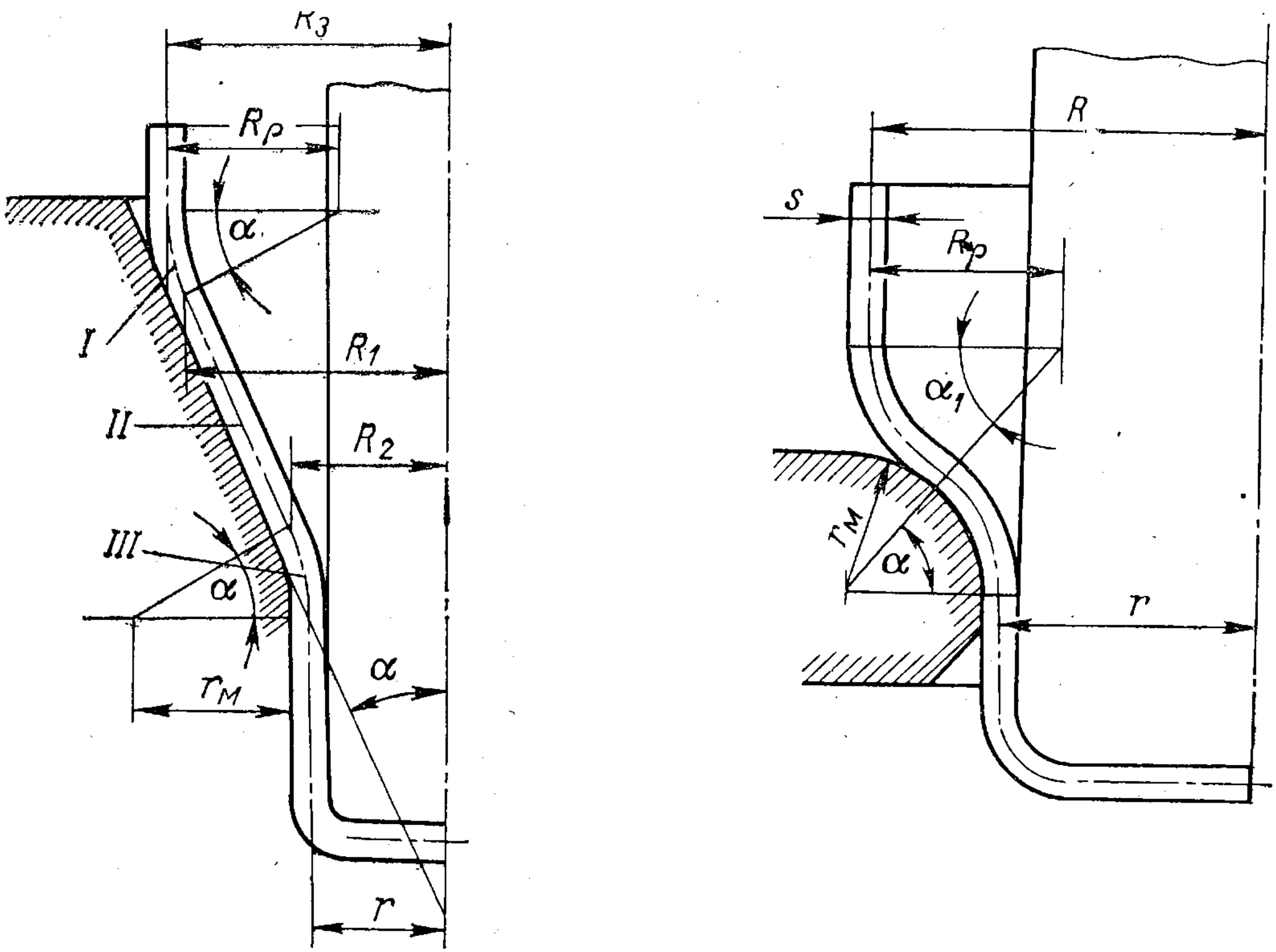
A tractrix is a curve for which the section of the tangent between the point of contact and the y-axis is constant.

Deep drawing with heated die

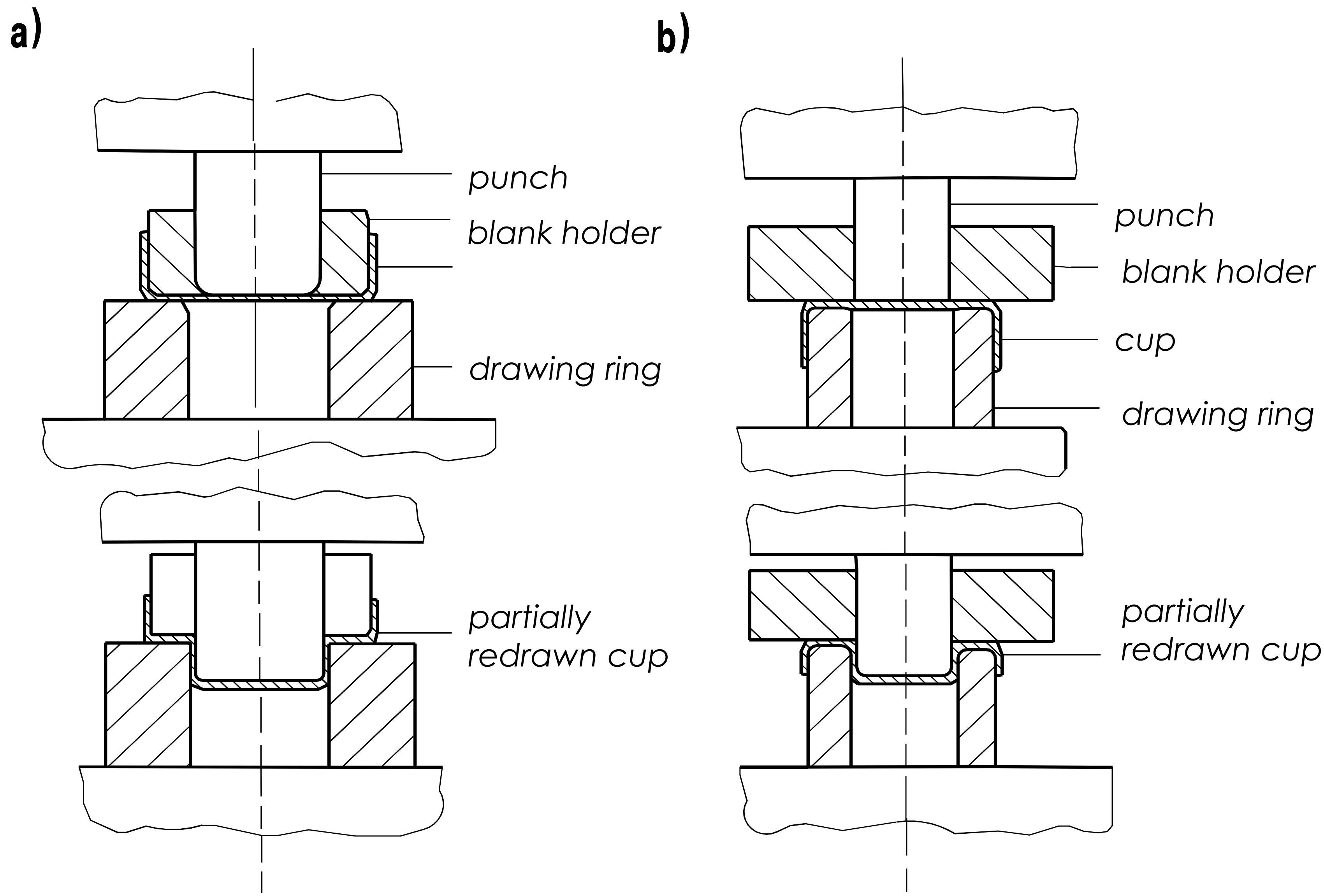


For **high strength** and for materials with **low deep drawability**

Multistep deep drawing – second step



Multistep deep drawing – reverse redrawing

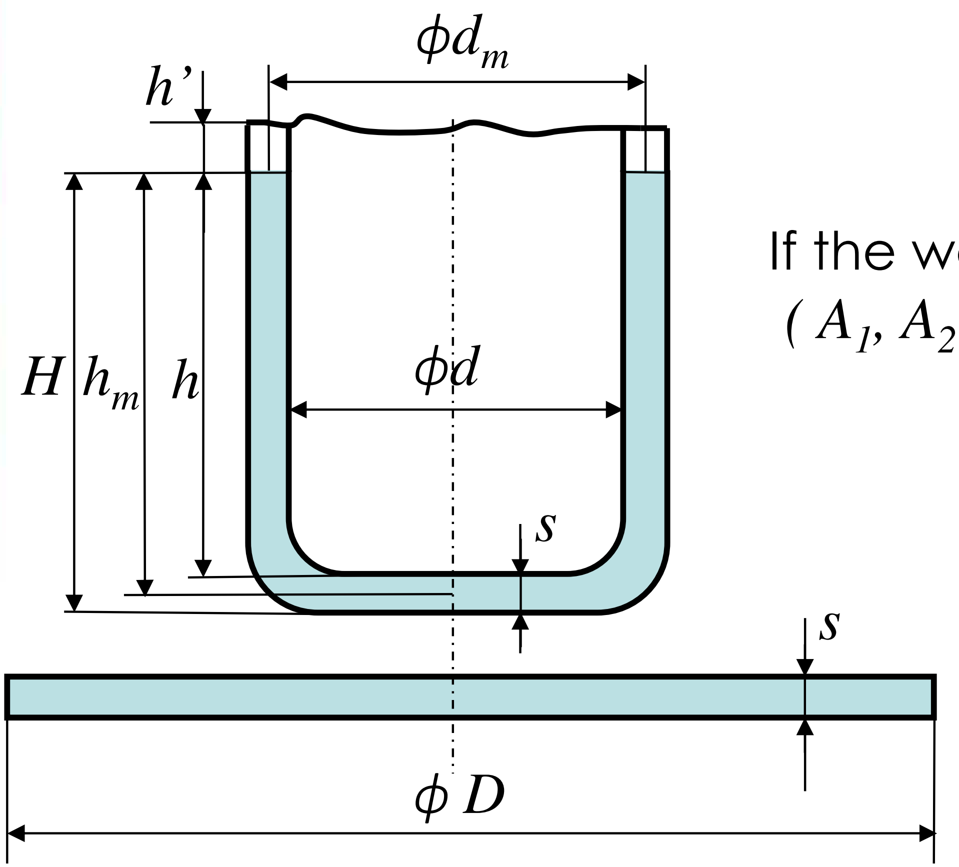


Blank geometry – axisymmetric part

Assuming constant surface area:

$$A = \frac{D^2\pi}{4} = \frac{d_m^2\pi}{4} + d_m\pi\left(h_m + h'\right)$$

$$D = \sqrt{d_m^2 + 4d_m\left(h_m + h'\right)}$$



If the workpiece consist of simple shapes (A_1, A_2 ..... A_n)

$$A = \frac{D^2\pi}{4} = \sum_{i=1}^{n} A_i, \quad D = \sqrt{\frac{4}{\pi}\sum_{i=1}^{n} A_i}$$

h/d=0,5..4 mm, h=20..300 mm, h'=2-12 mm

Technology planning

Due to the material and geometric limit, not any geometry can be done in one step; The drawn cup can be formed further in other deep drawing steps. For each steps a draw ratio $m_t = d_n / d_{n-1}$ can be defined: the ratio of the diameters in the nth and n-1th step.

Its maximal values is material dependent, but $m = 0.55\text{-}0.6$ for the first step (forming a cup from planar blank) and $m_t = 0.75\text{-}0.85$ for the further drawing steps.

The material is characterized by a maximum total draw ratio of q_{max} .

(If q_{max} is smaller, the drawability is better!)

Blank for cylindrical pieces

1) Assuming that the **surface area is constant**;
   the surface area of the final geometry is calculated.

2) If the material is **anisotropic**, the **cup height is increased with 5-15%** depending on the anisotropy value of the material

3) The blank diameter D is calculated.

Technology planning

Knowing the maximal drawing ratio, the first diameter is $d_1 = mD$, the further drawing diameters are: $d_2 = m_t d_1 = m_t mD$, $d_3 = m_t d_2 = m_t^2 mD$ ...

Diameter after ***n*** drawing: $d_n = m_t^{n-1} mD$

If D and d_n are known, then the **number of** necessary drawing **steps**:

$$\boxed{n = \frac{\ln d_n - \ln(mD)}{\ln m_t} + 1}$$

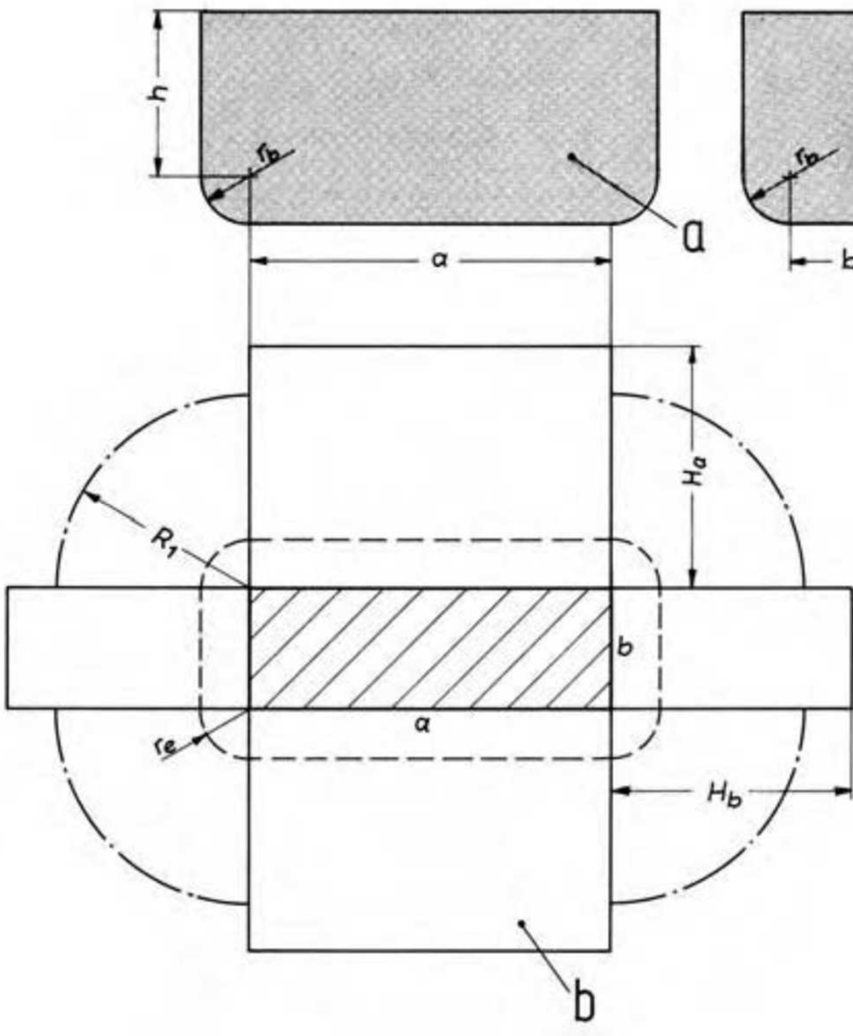
The resulted value must be **rounded up.** Therefore, it is useful to continuously increase a bit the ratios from the first step to distribute the difference.

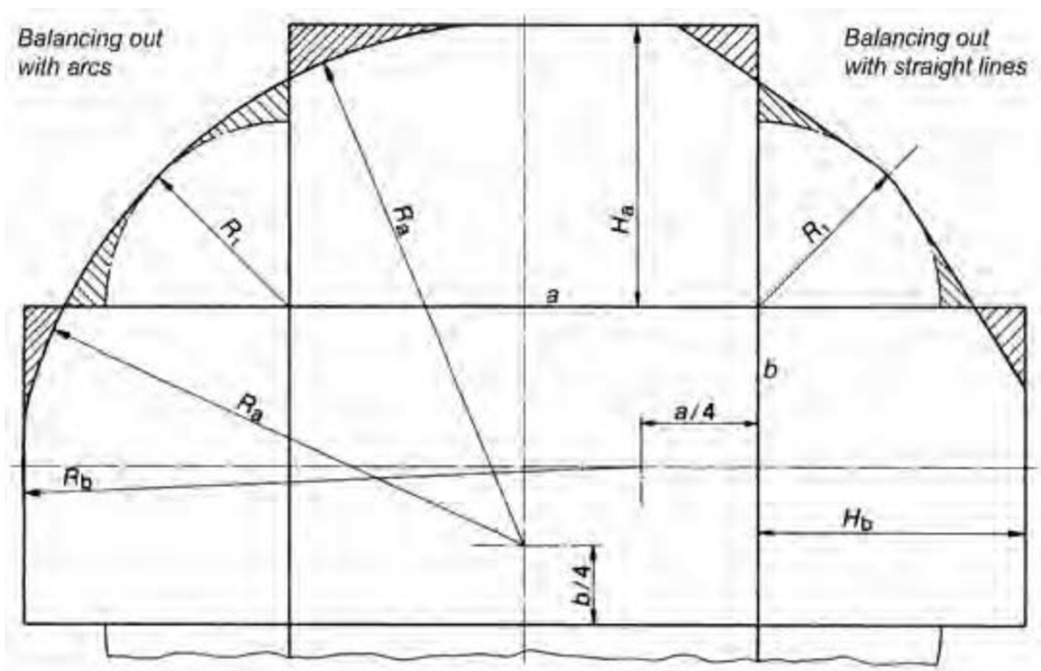
The number of drawing steps to the first annealing:

$$k = \frac{\ln(1 - q_{max}) - \ln m}{\ln m_t} + 1$$

The resulted value must be **rounded down.**

Blank for complex geometries

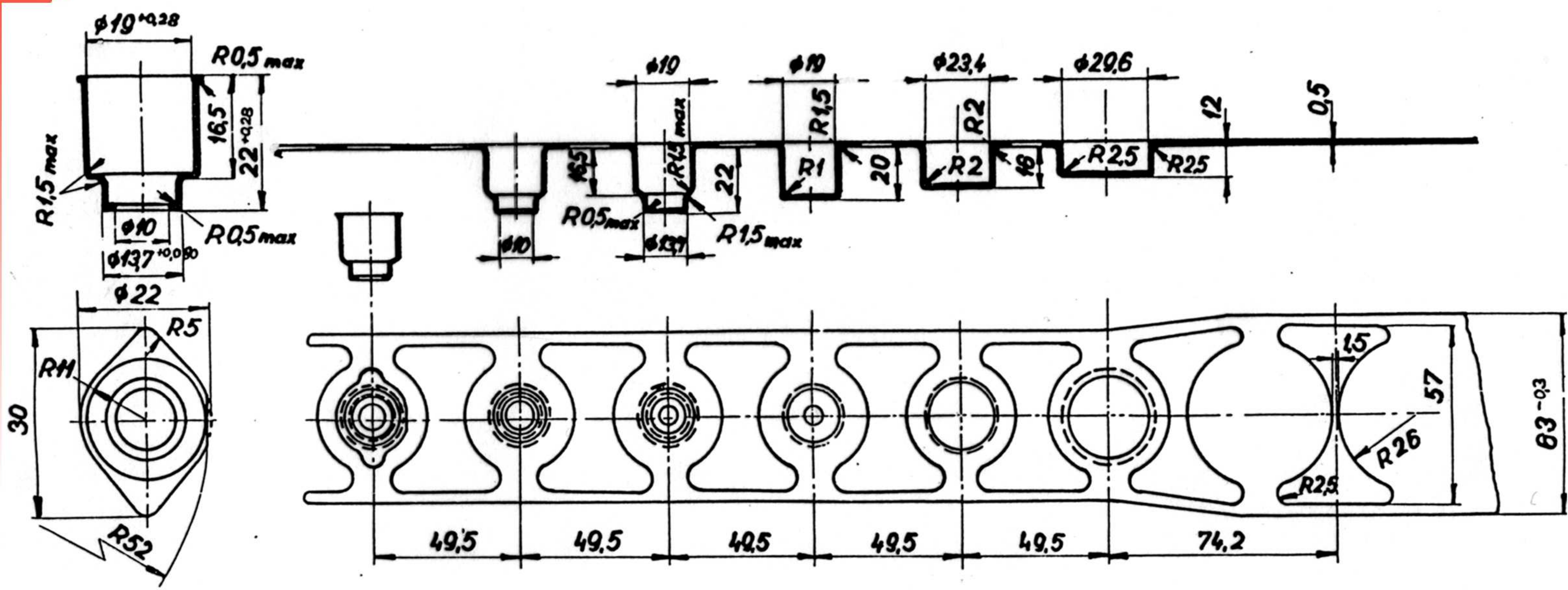




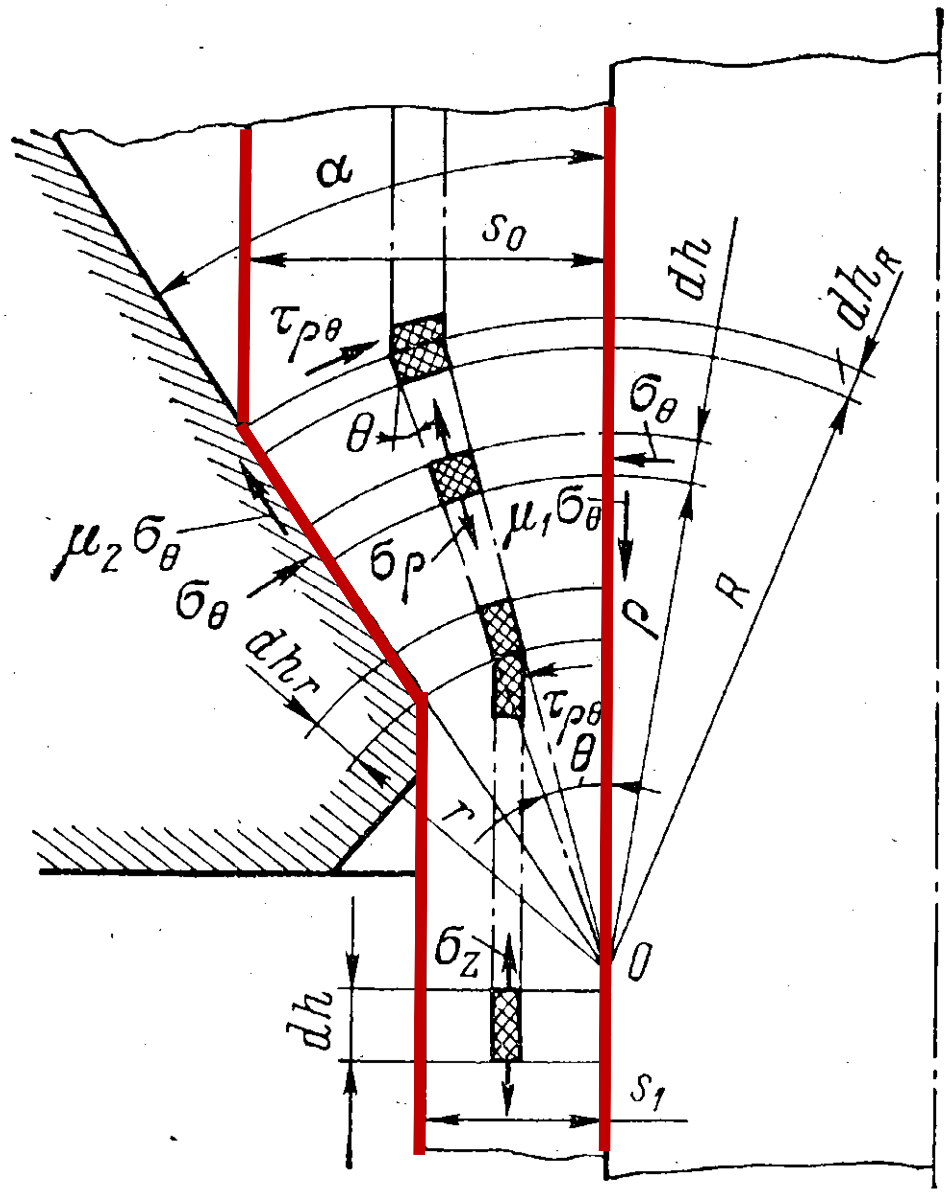
Breakdown of a rectangular hollow part into elements of equal area

Evening out the design of the blank using arcs or straight lines

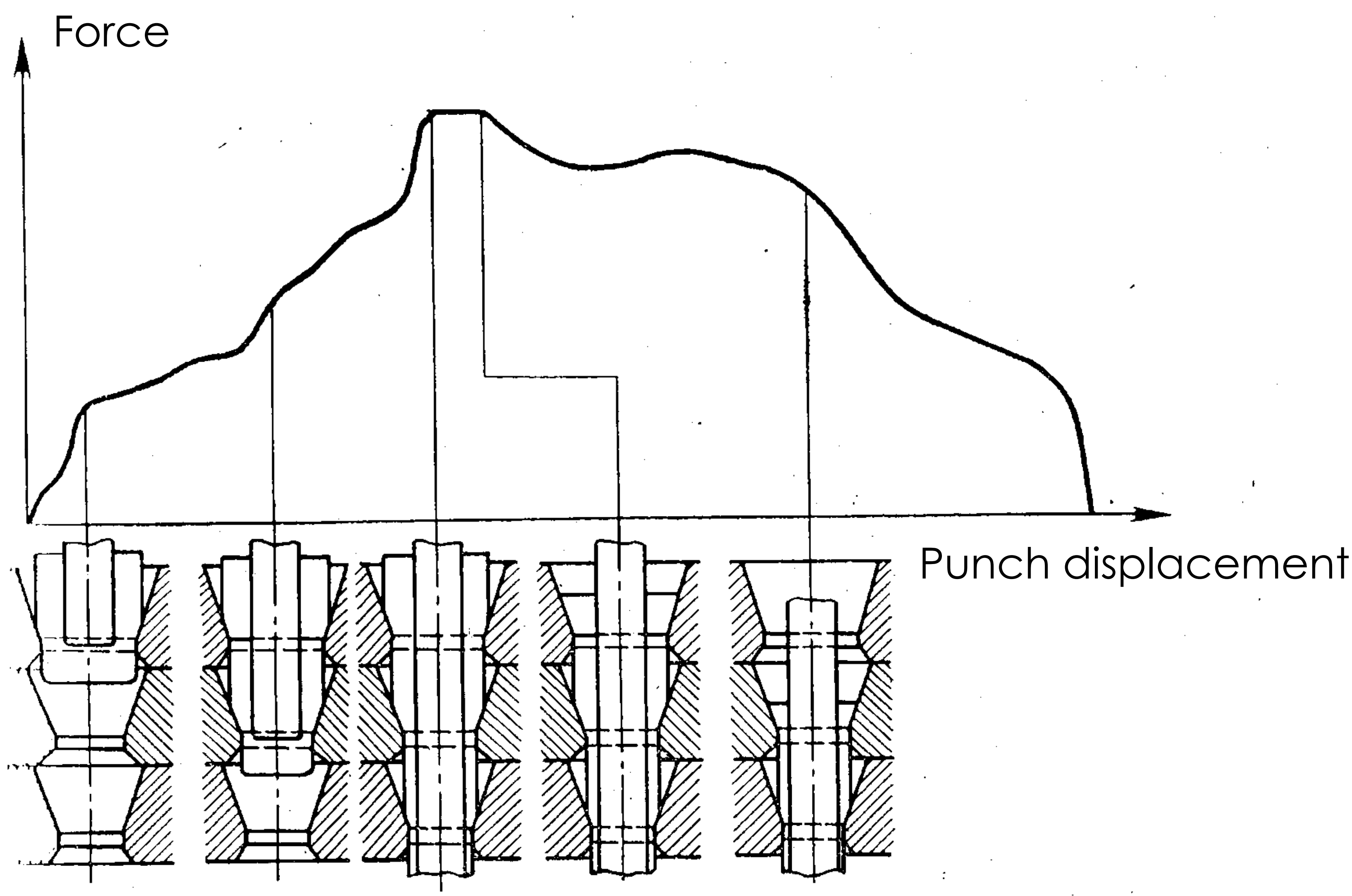
Technology planning



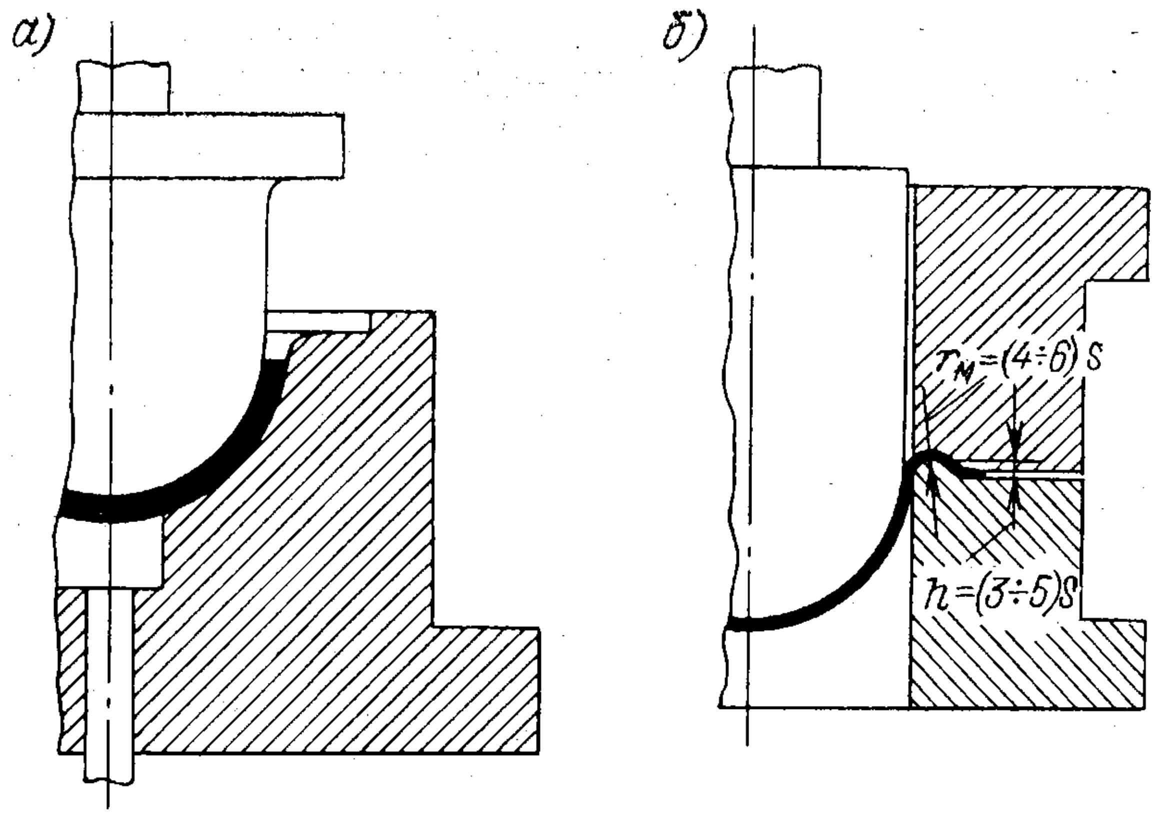
Related technique - ironing



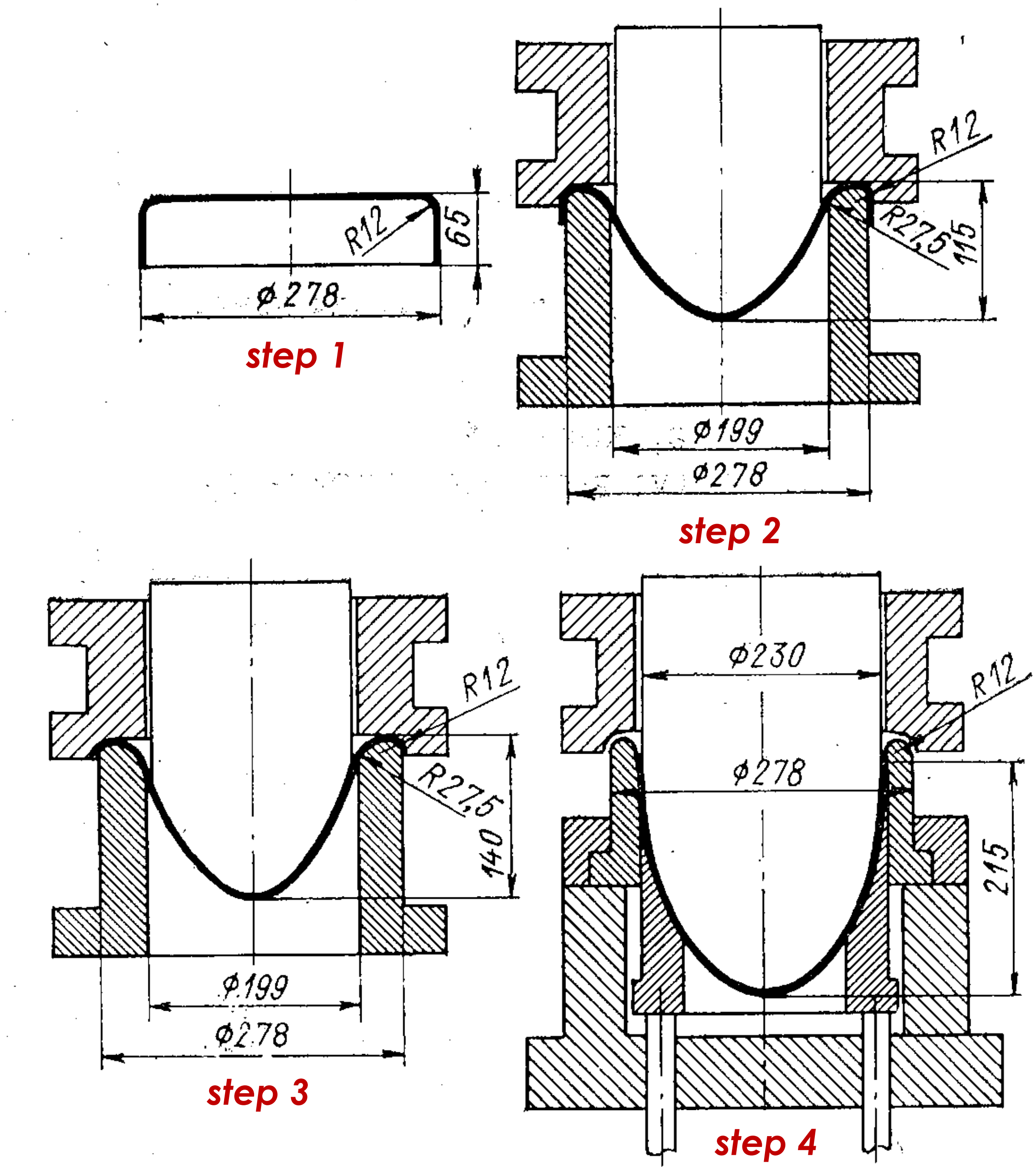
Multistep redraw with ironing



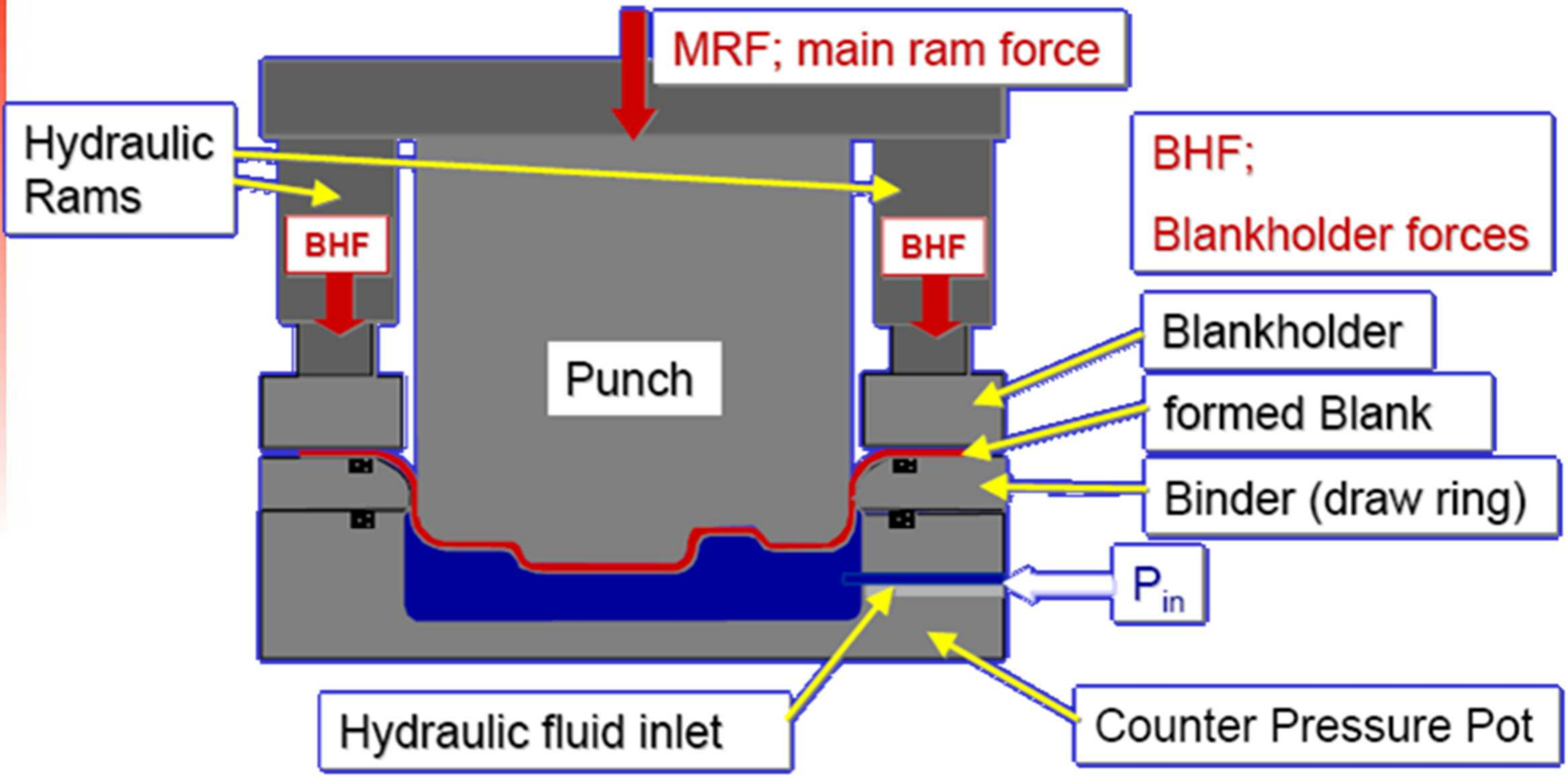
Die design examples



Die design examples

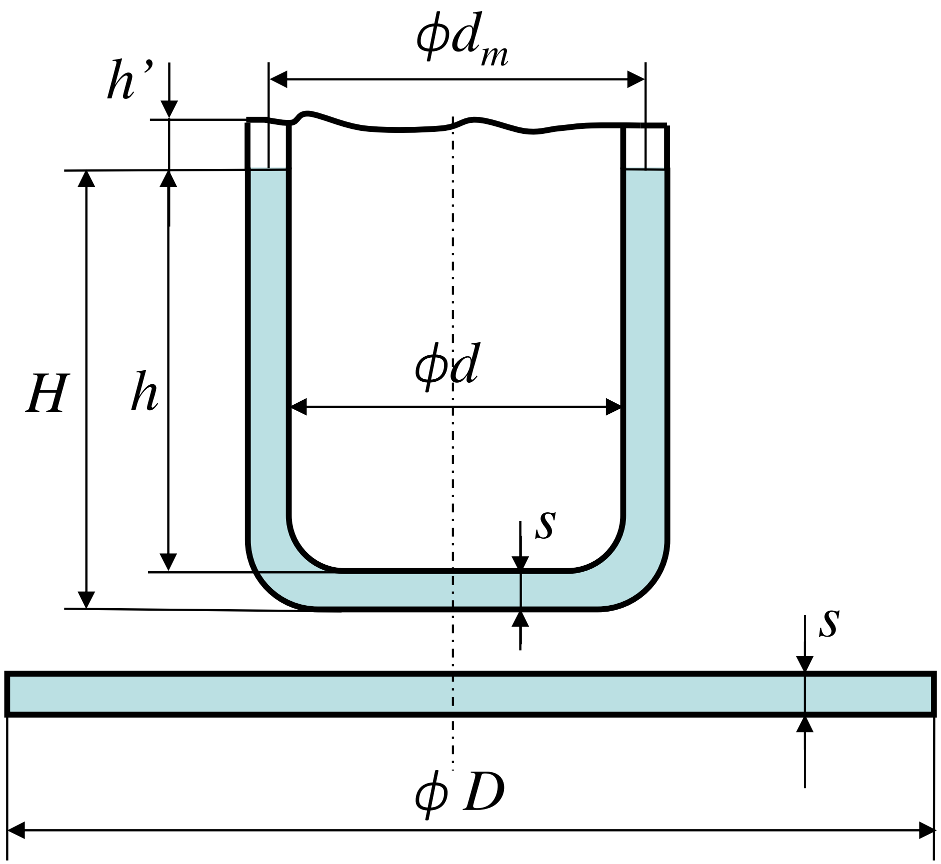


Hydro-mechanical deep drawing



Example

Calculate the total number of drawing steps and the number of steps to the first annealing:



$$d_m = 30\,mm$$

$$h = 70\,mm$$

$$s = 2\,mm$$

$$D = ???$$

$$n = ???$$

$annealing$??? (q_{max} = 0.5)

(m = 0.6)

(m_t = 0.85)

Thank you for your attention!