Wire Drawing

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- Theory and practice of wire drawing
- Wire drawing equipment
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Drawing of Rods, wires and Tubes

- Drawing operations involve pulling metal through a die by means of a tensile force applied to the exit side of the die.
- The plastic flow is caused by compression force, arising from the reaction of the metal with the die.
- Starting materials: hot rolled stock (ferrous) and extruded (nonferrous).
- Material should have high ductility and good tensile strength.
- Bar wire and tube drawing are usually carried out at room temperature, except for large deformation, which leads to considerable rise in temperature during drawing.
- The metal usually has a circular symmetry (but not always, depending on requirements).

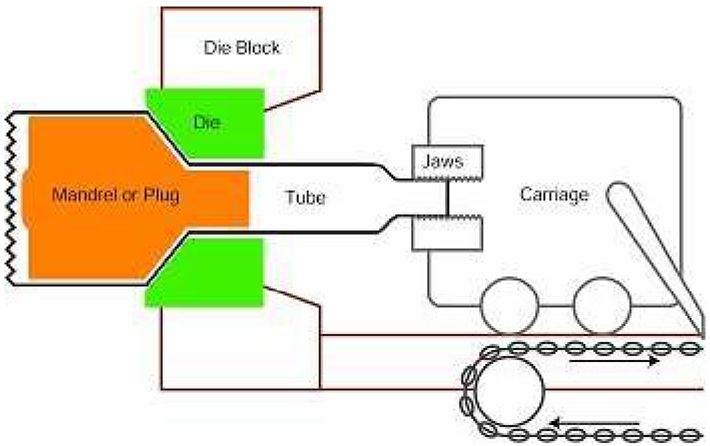
Rod and wire drawing

- Rods → relatively larger diameter products.
- Wires → small diameter products ~5 mm diameter
- Reducing the diameter through plastic deformation while volume remains the same.
- Sample principals for drawing bars, rods, and wire but equipment is different in sizes depending on products.

Metal rods

Rod Drawing

- Rods which can not be coiled are produced on draw benches



Machine capacity :

- 1 MN drawbench
- 30 m of runout
- 150-1500 $mm.s^{-1}$ draw speed Rod

Rod is swaged

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Insert though the die

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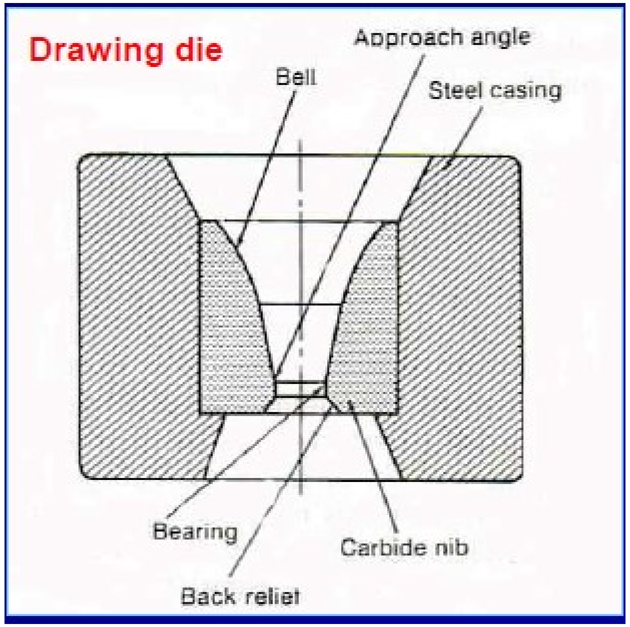
Clamped to the jaws of the draw head

↓

The draw head is moved by a hydraulic mechanism

Wire Drawing Die

- Shape of the bell causes hydrostatic pressure
  - Increase and promotes the flow of lubricant into the die.
- The approach angle
  - The actual reduction in diameter occurs
  - This half die angle α is important
- The bearing region produces
  - No reduction take place here
  - A frictional drag on the wire
  - It also removes surface damage due to die wear, without changing dimensions.
- The back relief
  - Allows the metal to expand slightly as the wire leaves the die
  - Also minimises abrasion if the drawing stops or the die is out of alignment.



Conical drawing die

Drawing Die Materials

- Cemented carbides are the most widely used for drawing dies due to their superior strength, toughness, and wear resistance.
  - Cemented carbide is composed of carbides of Ti, W, Ni, Mo, Ta, Hf.

- Polycrystalline Diamond (PCD) used for wire drawing dies – for fine wires. Longer die life, high resistance to wear, cracking or bearing.

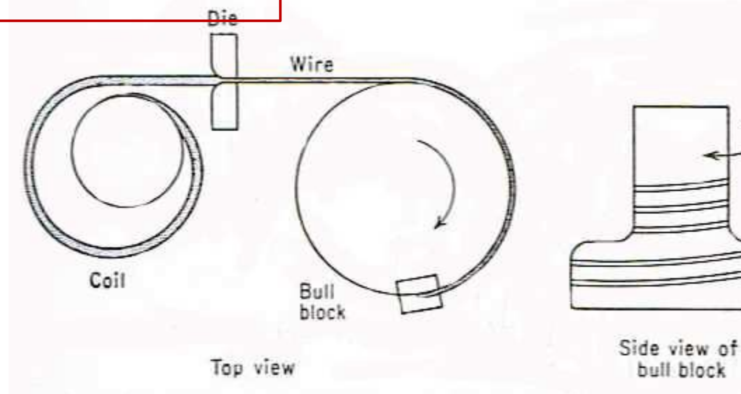
Wire Drawing

Remove Scale – causing surface defects

Lubrication:
- High strength materials
  - Cu or Sn surface coating
  - Sulfates or oxalates
- Wet drawing
  - (immersed in) oil or grease
  - Mulsifiable oils
- Dry Drawing
  - Soap

Bull block drawing allows the generation of long lengths
Area reduction per drawing pass is rarely greater than 30-35%

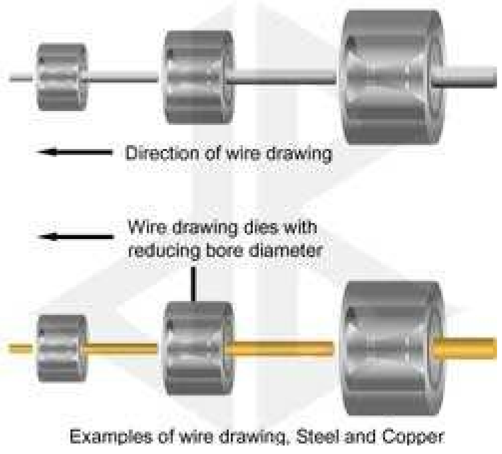
Hot rolled rod → Pickling, descaling → Lubricating → drawing

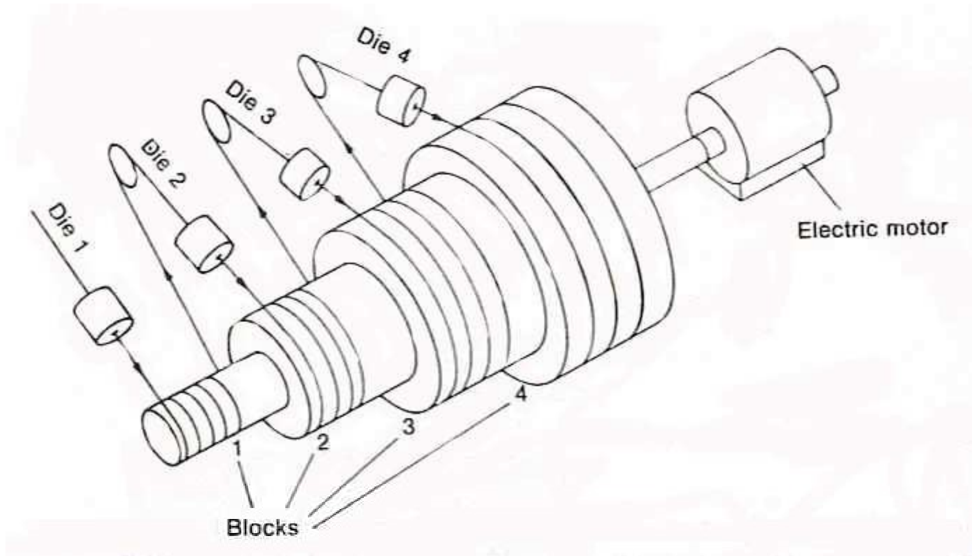


Drawing of Stainless Steel

- Stainless steels: 304, 304L, 316, 316L
- Applications: redrawing, mesh weaving, soft pipe, steel rope, filter elements, making of spring.
- Larger diameter stainless wire is first surface examined, tensile and hardness tested, diameter size measured.
- Surface preparation by pickling in acid (ferrictic and martensitic steels) and basic solutions (austenitic steels). The prepared skin is then coated with lubricant.
- Cold drawing is carried out through diamond dies or tungsten carbide dies till the desired diameter is obtained.
- Cleaning off oil/lubricant is then carried out and the wire is heat-treated (annealing at about 1100^{o}C or plus skin pass)

Multiple-pass wiredrawing





- Reduction take place in multiple steps require multiple block machines
  - Wire diameter ↓ in each pass
  - Velocity and length ↑

Stepped-cone multiple-pass wiredrawing

- More economical design.
- Use a single electrical motor to drive a series of stepped cones.
- The diameter of each cone is designed to produce a peripheral speed equivalent to a certain size reduction

Heat Treatment

- Nonferrous wire / low carbon steel wire undergoes tempering (ranging from dead soft to full hard). This also depends on the metal and the reduction involved.
- Steels (C content > 0.25%) normally 0.3-0.5% require Patenting heat treatment before being drawn.
- Patented wire have improved reduction of area up to 90% due to the formation of very fine pearlite.

Heating above the upper critical temperature T~ 970^{o}C → Change into austentite structure

↓

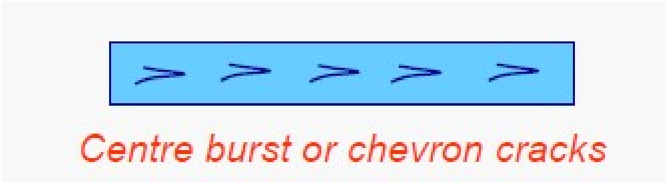
Cooling in controlled rate to a lead bath at T~315^{o}C → Controlled cooling to 315^{o}C give fine pearlite

↓

Good combination of strength and ductility

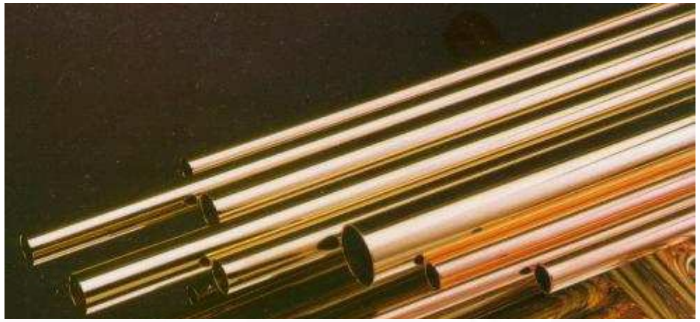
Defects in rod and wire drawing

- Defects in the starting rod (seams, slivers and pipe).
- Defects from the deformation process, i.e., centre burst or chevron cracking (cupping).

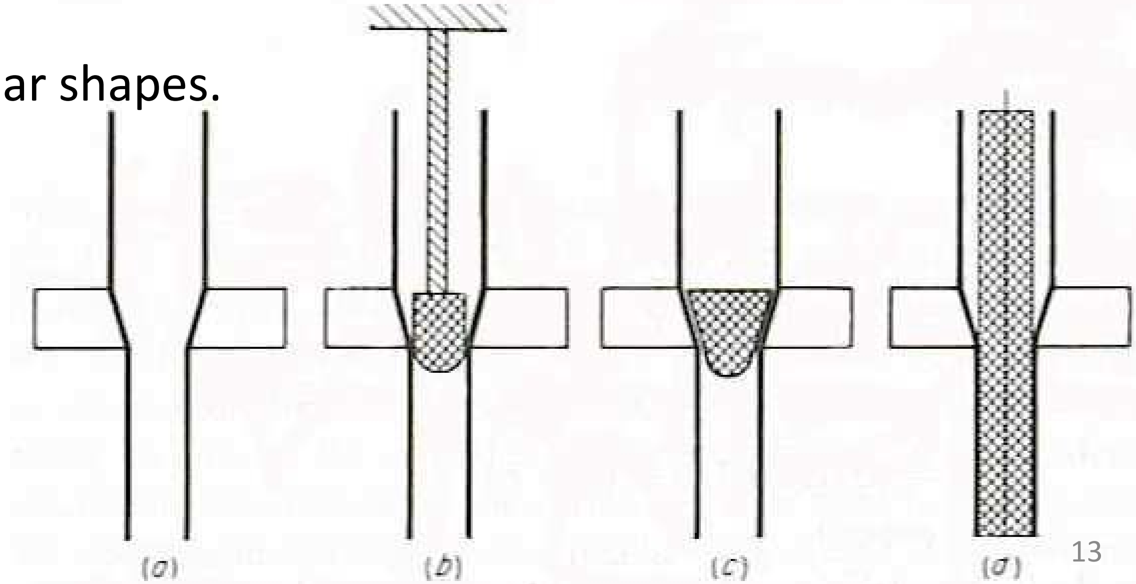


  - This defect will occur for low die angles at low reductions.
  - For a given reduction and die angle, the critical reduction to prevent fracture increases with the friction.

Tube Drawing

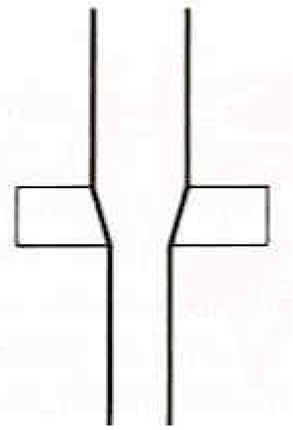


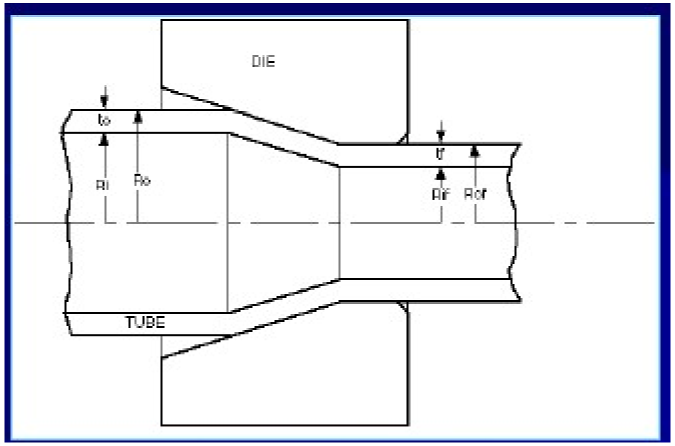
- Following the hot forming process, tubes are cold drawn using dies, plugs or mandrels to the required shape, size, tolerances and mechanical strength.
- Provides good surface finishes.
- Increase of mechanical properties by strain hardening.
- Can produce tubes with thinner walls or smaller diameters than can be obtained from other hot forming methods.
- Can produce more irregular shapes.
- Classification
  - Sinking (a)
  - Plug drawing
    - Fixed plug (b)
    - Floating plug (c)
  - Mandrel drawing (d)



Tube Sinking

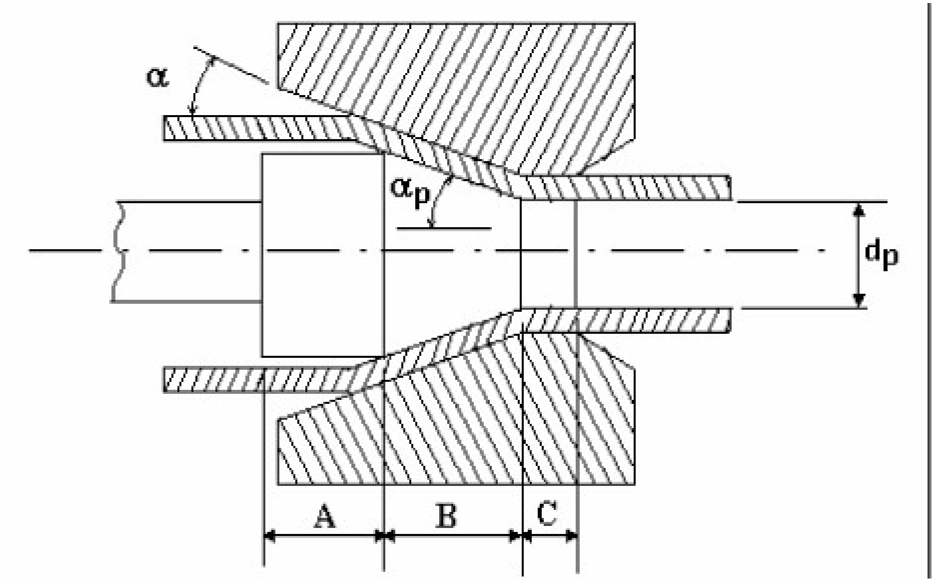
- The tube, while passing through the die, shrinks in outer radius from the original radius R_o to a final radius R_f.
- No internal tooling (internal wall is not supported), the wall then thicken slightly.
- Uneven internal surface.
- The final thickness of the tube depends on
  - original diameter of the tube,
  - the die diameter and
  - friction between tube and die.
- Lower limiting deformation.

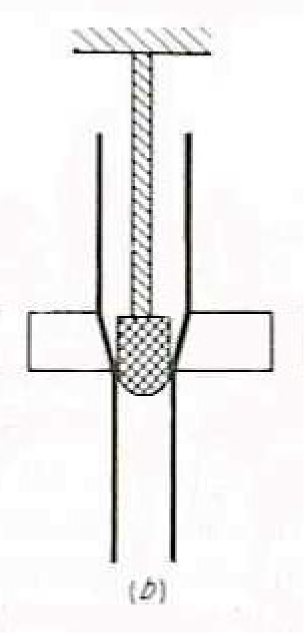




Fixed Plug Drawing

- Use cylindrical / conical plug to control size/shape of inside diameter.
- Use higher drawing loads than floating plug drawing.
- Greater dimensional accuracy than tube sinking.
- Increased friction from the plug limit the reduction in area (seldom > 30%).
- can draw and coil long lengths of tubing.

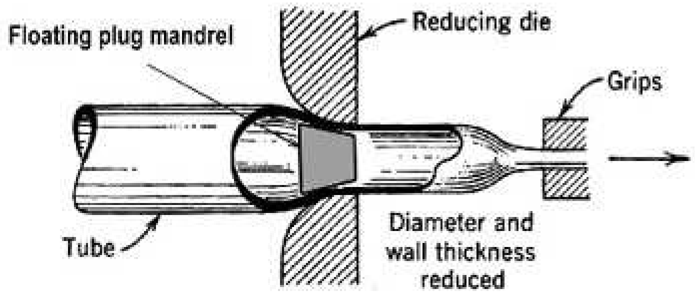


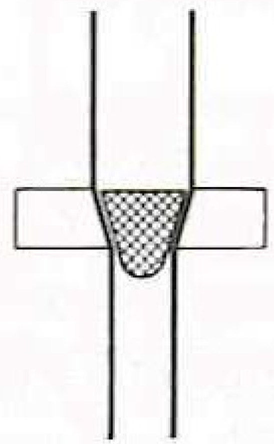


Floating Plug Drawing

A tapered plug is placed inside the tube.

- As the tube is drawn the plug and the die act together to reduce both the outside/inside diameters of the tube.
- Improved reduction in area than tube sinking (~ 45%).
- Lower drawing load than fixed plug drawing.
- Long lengths of tubing is possible.
- Tool design and lubrication can be very critical.





(c)

Moving Mandrel Drawing

- In addition to die and tube, the friction forces acting along the tube – mandrel interface.
- Minimised friction is important.
- $V_{mandrel} = V_{tube}$
- The mandrel also imparts a smooth inside finish surface of the tube.
- mandrel removal disturbs dimensional tolerance.