

*SME 2713  
Manufacturing Process*

# METAL FORMING – 5

(Rod, wire and tube drawing processes)

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## *Outline*

1. Introduction
2. Rod and wire drawing
3. Defects in rod and wire drawing
4. Tube drawing
  1. Sinking
  2. Plug drawing
  3. Mandrel drawing
5. Lubrication
6. Defects in cold drawn products

## Introduction

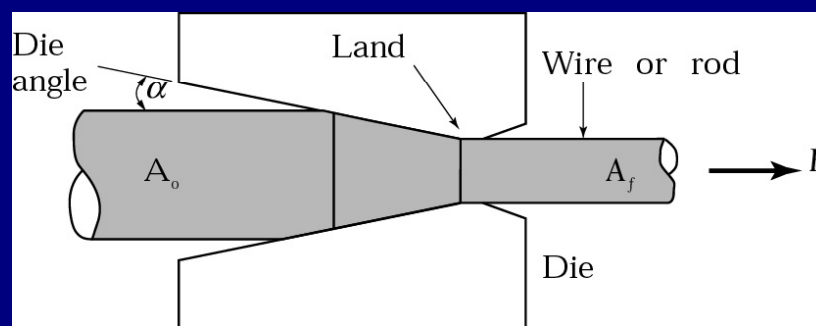
- **Drawing operations** involve pulling metal through a die by means of a tensile force applied to the exit side of the die
- The **plastic flow** is caused by compression force, arising from the reaction of the metal with the die
- **Starting materials** – hot rolled stocks (ferrous) and extruded (non-ferrous)
- Material should have **high ductility and good tensile strength**
- Bar, wire and tube drawings 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)

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## Process Variables in Wire Drawing



Process variables in wire drawing. The die angle, the reduction in cross-sectional area per pass, the speed of drawing, the temperature, and the lubrication all affect the drawing force,  $F$ .

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## Rod and wire drawing

- Reducing the diameter through plastic deformation while the volume remains the same
- Same principles for drawing bars, rods and wire but equipment is different in sizes depending on products



Metal rods



Metal wires

**Rods** → relatively larger diameter products.

**Wires** → small diameter products < 5 mm diameter.

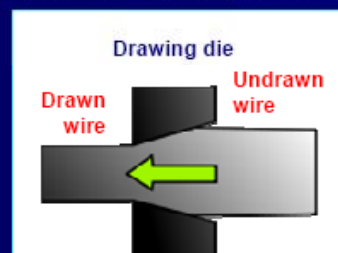
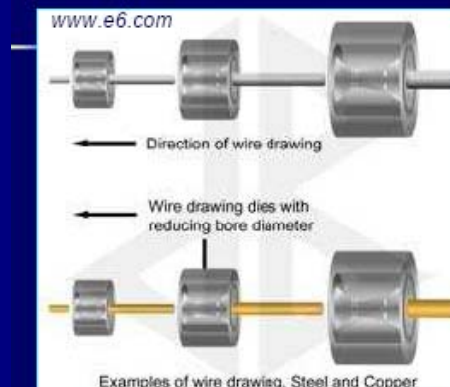
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## Wire drawing

- Wire drawing involves reducing the diameter of a rod or wire by passing through a series of drawing dies or plates



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## Wire drawing

- The subsequent drawing die must have smaller bore diameter than the previous drawing die



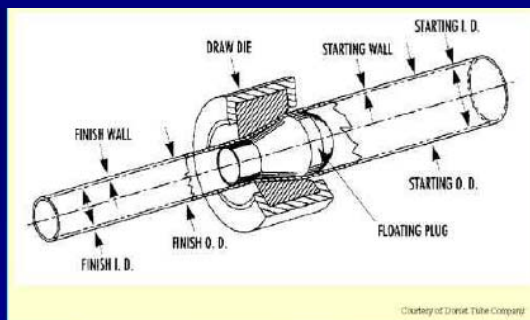
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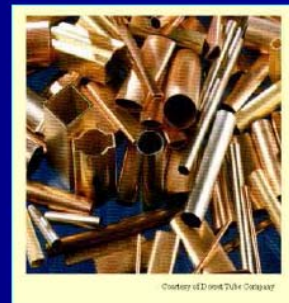
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## Tube drawing

- Tube drawing involves reducing the cross section and wall thickness through a draw die



Courtesy of Daniel Tube Company



Courtesy of Daniel Tube Company

- The **cross section** can be circular, square hexagonal or in any shapes.

*Brass tubes for heat exchanger – cheap, strong, good corrosion resistant*

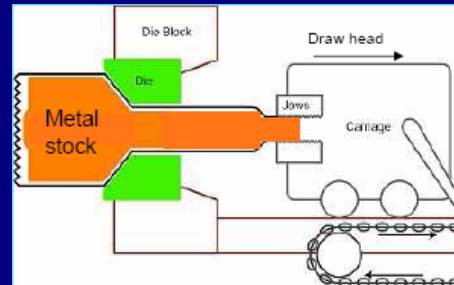
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## Rod drawing

- Rods which can not coiled, are produced on drawbenches
- Rod is swaged, inserted through the die and clamped to the jaws of the drawhead. The drawhead is moved by a hydraulic mechanism



### Machine capacity :

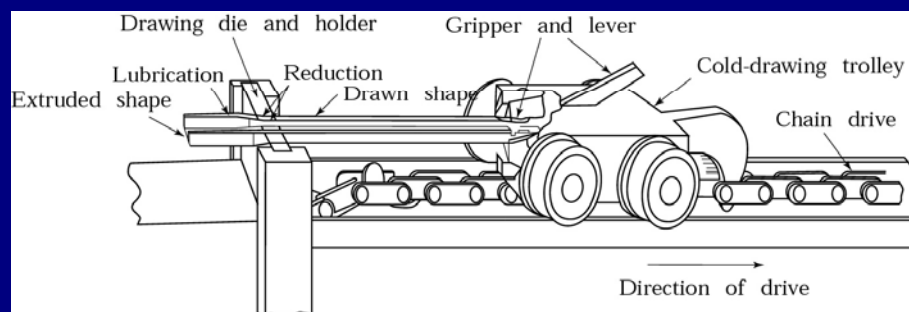
- 1 MN drawbench
- 30 m of runout
- 150-1500 mm.s<sup>-1</sup> draw speed

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## Cold Drawing



Cold drawing of an extruded channel on a draw bench, to reduce its cross-section. Individual lengths of straight rod or of cross-sections are drawn by this method. *Source:* Courtesy of The Babcock and Wilcox Company, Tubular Products Division.

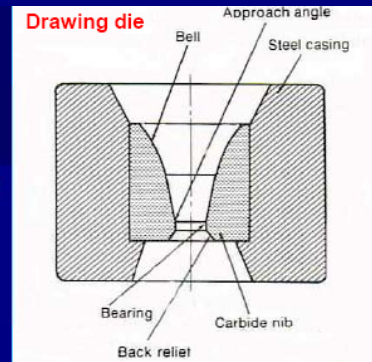
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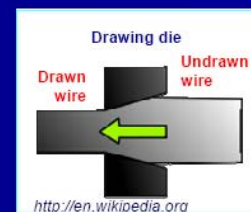
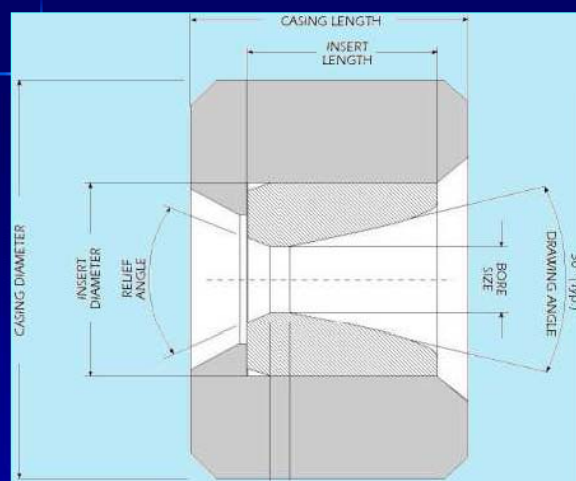
- Shape of the bell causes hydrostatic pressure to increase and promotes the flow of lubricant into the die
- The approach angle – where the actual reduction in diameter occurs, giving the half die angle,  $\alpha$
- The bearing region produces a frictional drag on the wire and also remove surface damage due to die wear, without changing dimensions
- The back relief allows the metal to expand slightly as the wire leaves the die and also minimises abrasion if the drawing stops or the die is out of alignment

## Wire drawing die

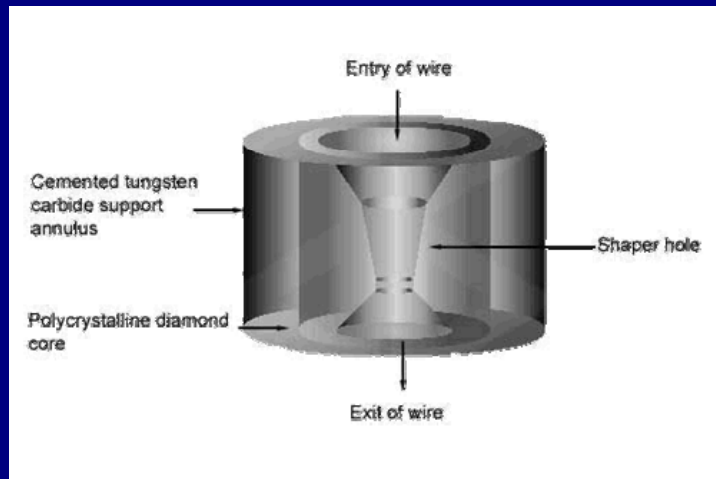


- The **die nib** made from **cemented carbide** or **diamond** is encased for protection in a thick steel casing.

## Example of wire drawing dies



## Example of wire drawing dies



*Wire drawing die made from cemented tungsten carbide with polycrystalline diamond core.*

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## Drawing die materials

- Most drawing dies are cemented carbide or industrial diamond (for fine wires)
- Cemented carbide is composed of carbides of Ti, W, Ni, Mo, Ta, Hf



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## Drawing die materials

- Cemented carbides are the most widely used for drawing dies due to their superior strength, toughness, and wear resistance
- Polycrystalline diamond (PCD) used for wire drawing dies – for fine wires. Longer die life, high resistance to wear, cracking or bearing



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## Wire drawing equipment

- The wire is first passed through the overhead loop and pulley, brought down and then inserted through the die of the second drum and drawn through this die for further reduction



**Bull block drawing machines**

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## Wire drawing equipment



*Multiple bull block machines - common*

- Thus, the wire is drawn through all the wire drawing drums of the set in a continuous manner to get the required finished diameter of the wire. Speed of each draw block has to be synchronised to avoid slippage between the wire and the block.
- The drawing speed – up to 10 m/sec for ferrous and up to 30 m/sec for nonferrous drawing

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## Wire drawing process



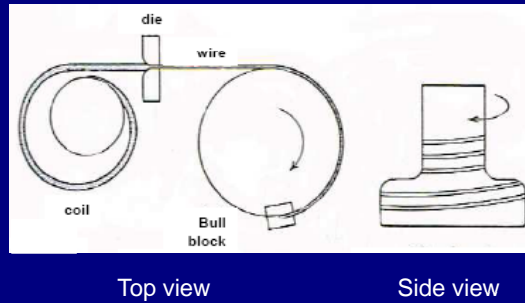
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## Wire drawing process

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



$$\%RA = \left[ 1 - \left( \frac{D_{Outlet}}{D_{Inlet}} \right)^2 \right] \times 100$$

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### Example: Drawing of stainless wire



- **Stainless steels:** 304, 304L, 316, 316L
- **Applications:** redrawing, mesh weaving, soft pipe, steel rope, filter elements, making of spring.



Stainless steel rope

- Larger diameter stainless wire is first **surface examined**, tensile and hardness tested, diameter size measured.
- Surface preparation by **pickling** in acid (ferritic 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°C or plus skin pass**).



Stainless steel meshes

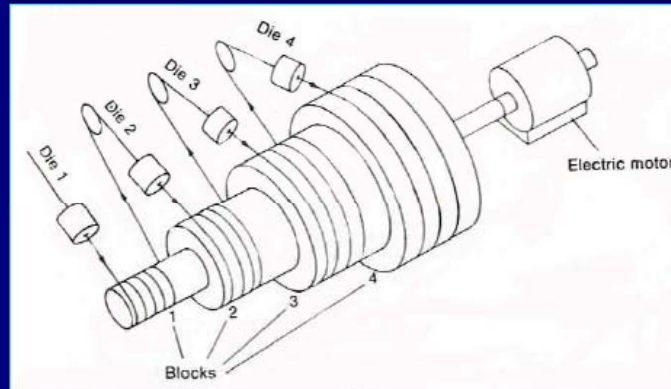
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## Stepped-cone multi-pass wire drawing

- 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

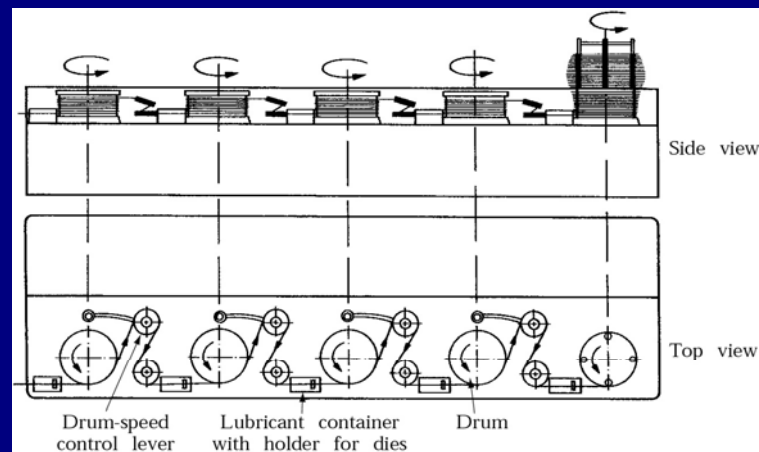


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## Multistage Wire-Drawing



Two views of a multistage wire-drawing machine that is typically used in the making of copper wire for electrical wiring. *Source: H. Auerswald.*

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## 4. Tube drawing processes

- Following the hot forming process, tubes are cold drawn using dies, plugs or mandrels to the required shape, size, tolerances and mechanical strength
- Provide good surface finishes
- Increase 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



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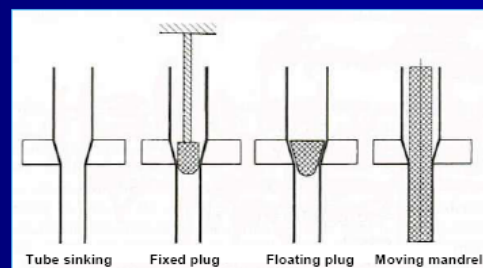
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## Classification of tube drawing processes



There are **three** basic types of **tube-drawing** processes

- **Sinking**
- **Plug drawing**
  - Fixed plug
  - Floating plug
- **Mandrel drawing.**

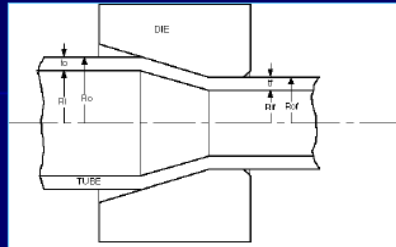


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## Tube sinking



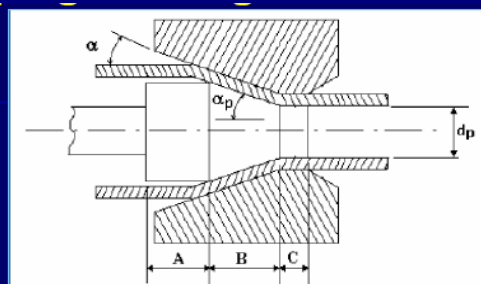
- The tube, while passing through the die, **shrinks** in outer radius from the **original radius  $R_o$**  to a **final radius  $R_{of}$** .
- No internal tooling (internal wall is not supported), the wall then thicken slightly.
- **Uneven** internal surface.
- The final thickness of the tube depends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

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## Fixed plug drawing



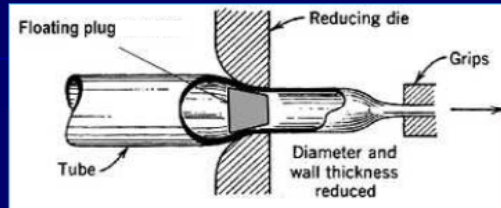
- Use cylindrical / conical plug to control size/shape of inside diameter.
- Use **higher drawing loads** than floating plug drawing.
- Greater dimensional accuracy than tube sinking.
- **Increased friction** from the plug limit the reduction in area (seldom > 30%).
- can draw and coil long lengths of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

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## Floating plug drawing



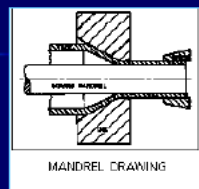
- A **tapered plug** is placed inside the tube.
- As the tube is drawn the plug and the die act together to reduce both the outside/inside diameters of the tube.
- Improved reduction in area than tube sinking (~ 45%).
- Lower **drawing load** than fixed plug drawing.
- Long lengths of tubing is possible.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

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## Moving mandrel drawing



- **Draw force** is transmitted to the metal by the pull on the exit section and by the friction forces acting along the tube -mandrel interface.
- **minimised friction.**
- $V_{mandrel} = V_{tube}$
- The mandrel also imparts a **smooth inside finish surface** of the tube.
- mandrel removal disturbs dimensional tolerance.

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## 5. Lubrication

Proper lubrication is essential in drawing, in order to improve die life, reduce drawing forces and temperature, and improve surface finish.

### Types of Lubrication

- a) Wet drawing : Dies and Rods are completely immersed in lubricant
- b) Dry drawing : Surface of the rod to be drawn is coated with a lubricant
- c) Coating : Rod or Wire is coated with a soft metal that acts as a solid lubricant
- d) Ultrasonic Vibration of the dies and mandrels.

## 6. Defects in cold drawn products

- Longitudinal scratches - scored die, poor lubrication, or abrasive particles
- Slivers - swarf drawn into the surface
- Long fissures – originating from ingot
- Internal cracks – pre-existing defects in starting material or ruptures in the centre due to overdrawing
- Corrosion induced cracking – due to internal residual stresses