Manufacturing Engineering Technology in SI Units, 6th Edition

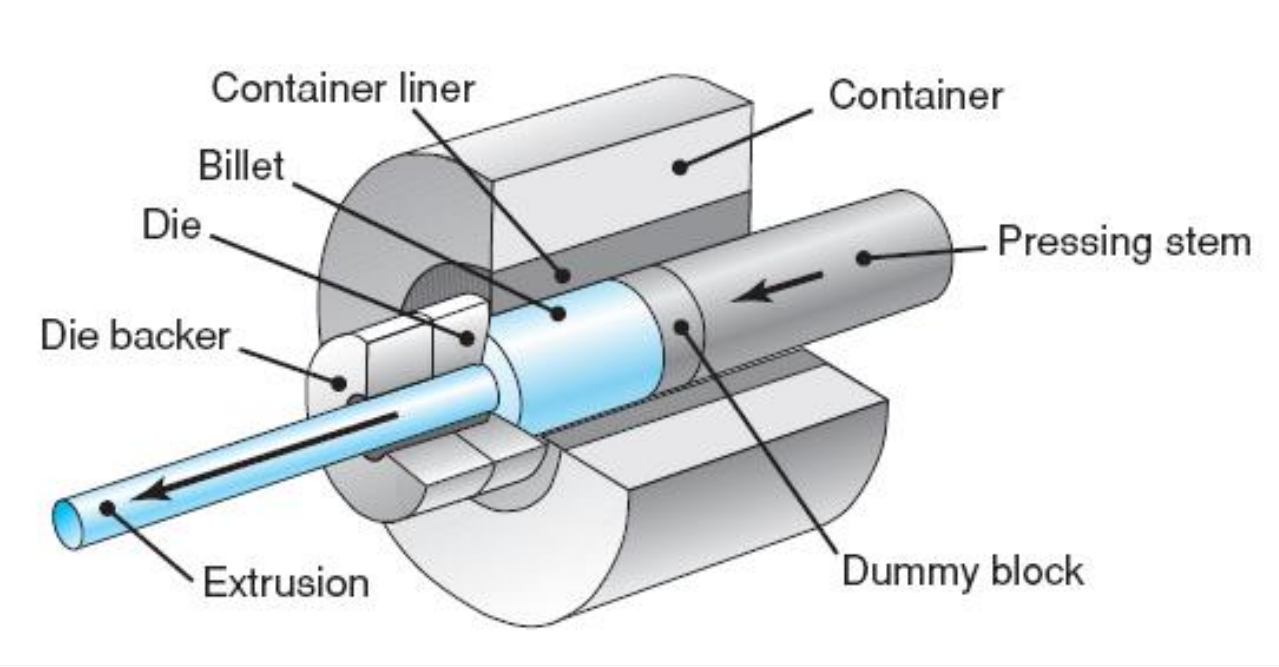
Chapter 15: Metal Extrusion and Drawing Processes and Equipment

Chapter Outline

1. Introduction
2. The Extrusion Process
3. Hot Extrusion
4. Cold Extrusion
5. Extrusion Defects
6. Extrusion Equipment
7. The Drawing Process
8. Drawing Practice
9. Drawing Defects and Residual Stresses
10. Drawing Equipment

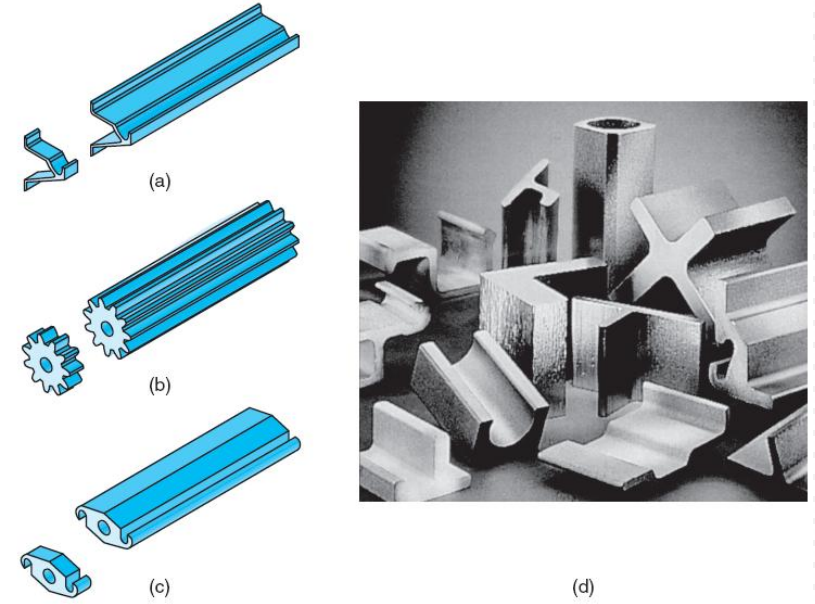
Introduction

- Extrusion and drawing is used for continuous manufacture of discrete products from metals and alloys



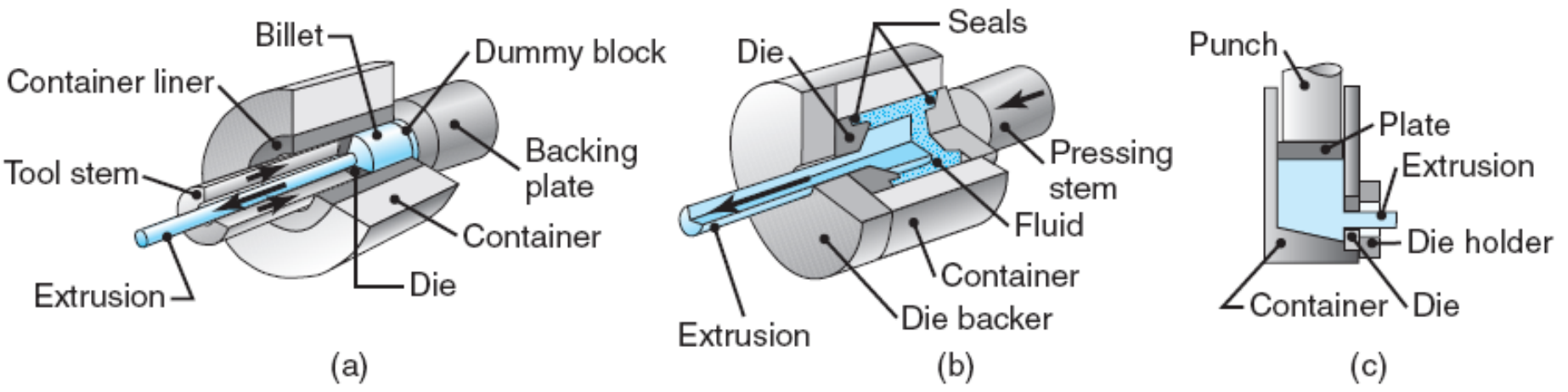
Introduction

- In extrusion, large deformations can take place without fracture as the material is under high triaxial compression
- Products made by extrusion are railings for sliding doors and window frames



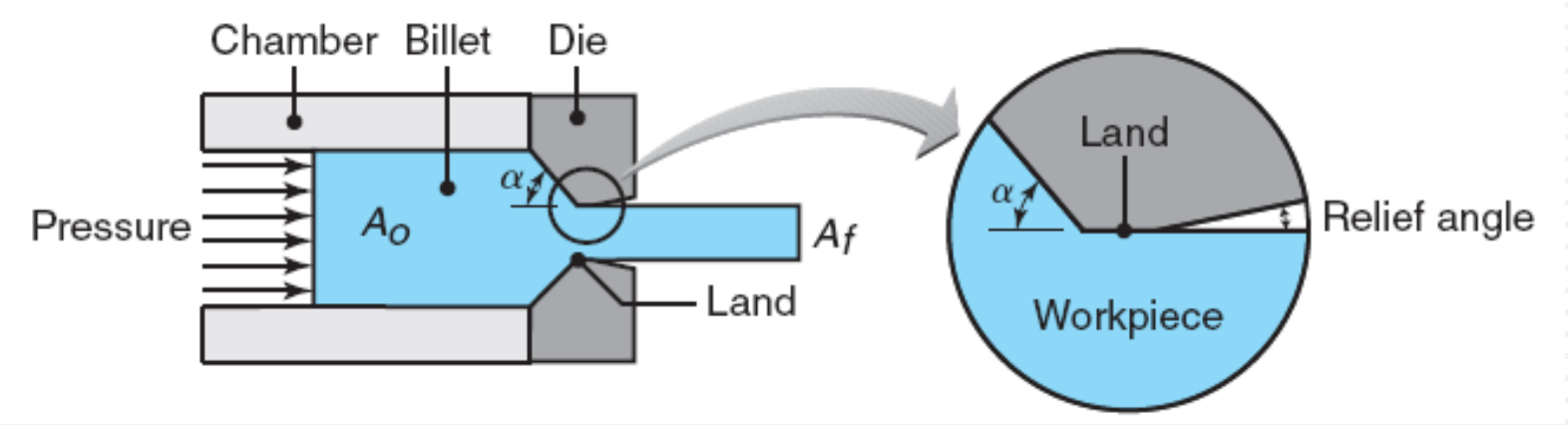
The Extrusion Process

- 3 basic types of extrusion:(a) indirect, (b) hydrostatic and (c) lateral



The Extrusion Process

- Geometric variables in extrusion are the die angle and **extrusion ratio**



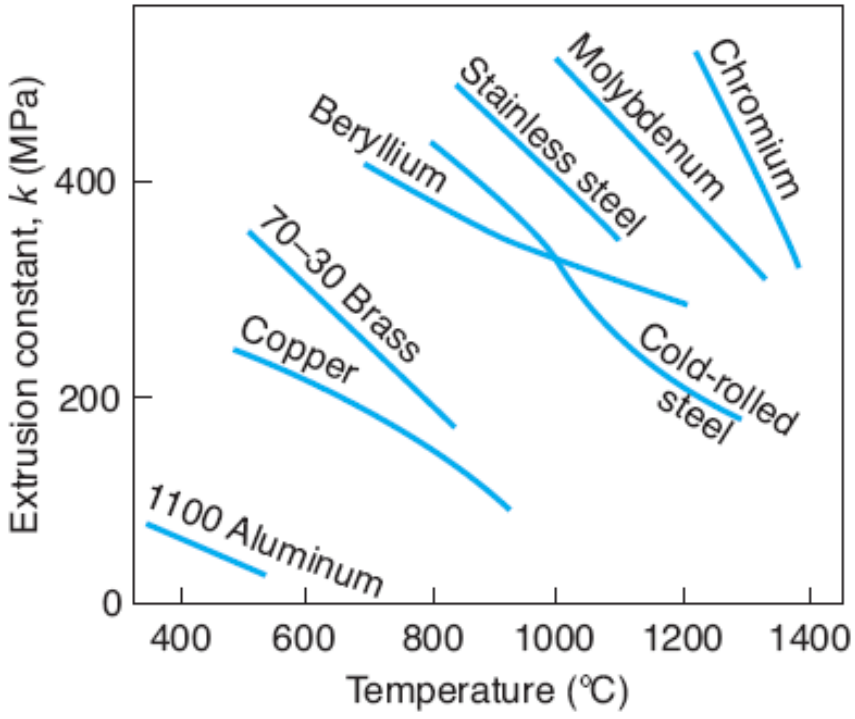
The Extrusion Process

Extrusion Force

- The *extrusion force, F*, can be estimated from

$$F = A_0 k \ln\left(\frac{A_0}{A_f}\right)$$

k = **extrusion constant**
A_o, A_f = billet and extruded product areas



The Extrusion Process

EXAMPLE 15.1

Calculation of Force in Hot Extrusion

A round billet made of 70–30 brass is extruded at a temperature of 675°C. The billet diameter is 125 mm, and the diameter of the extrusion is 50 mm. Calculate the extrusion force required.

Solution

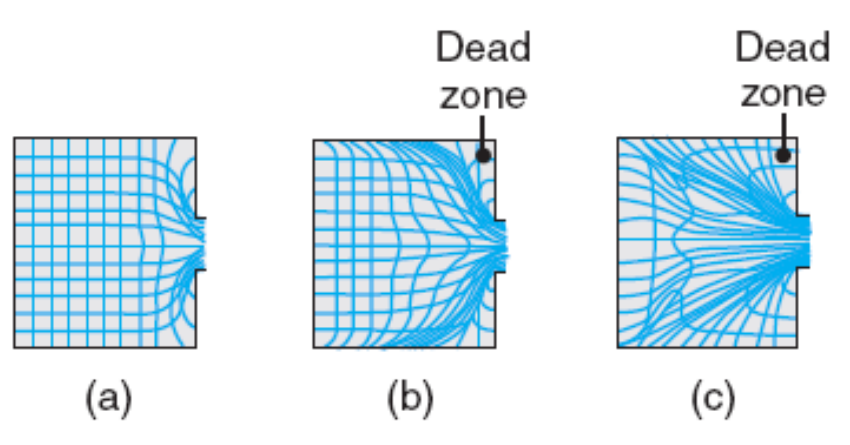
For brass, k is 250 MPa, thus

$$F = \frac{\pi(125)^2}{4}(250)\ln\left[\frac{\pi(125)^2}{\pi(50)^2}\right] = 5.6\,\text{MN}$$

The Extrusion Process

Metal Flow in Extrusion

- Metal flow pattern in extrusion is important as it influence the quality and mechanical properties of the extruded product
- Types of metal flow in extruding with square dies:



The Extrusion Process

Process Parameters

- Extrusion ratios, *R*, usually range from about 10 to 100
- Lower speeds are preferred
- Dimensional tolerances in extrusion are in the range from 0.25 to 2.5 mm
- In **coaxial extrusion**, or **cladding**, coaxial billets are extruded together

Hot Extrusion

- Metals and alloys do not have ductility at room temperature
- To reduce the forces required, extrusion is carried out at elevated temperatures

Typical Extrusion Temperature Ranges for Various Metals and Alloys

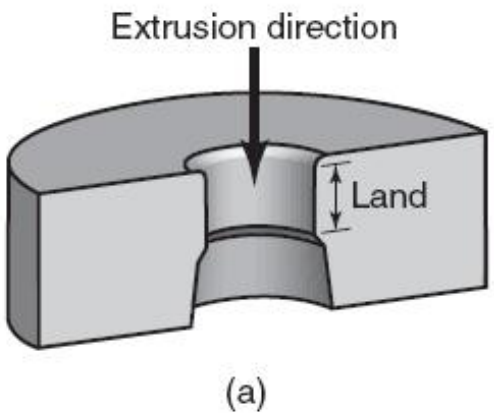
	°C
Lead	200–250
Aluminum and its alloys	375–475
Copper and its alloys	650–975
Steels	875–1300
Refractory alloys	975–2200

Hot Extrusion

- As the billet is hot, it develops an oxide film, unless it is heated in an inert-atmosphere furnace

Die Design

- Die design requires considerable experience



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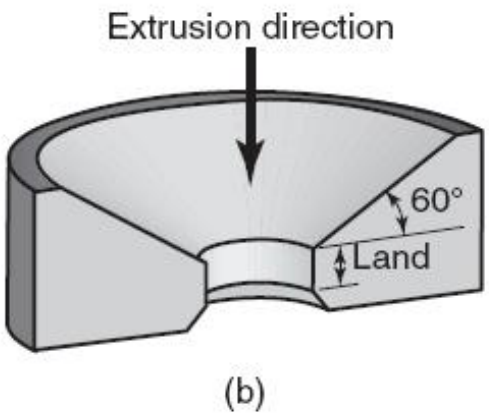

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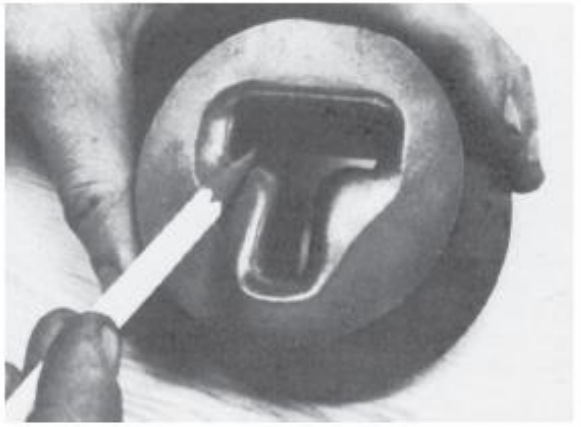

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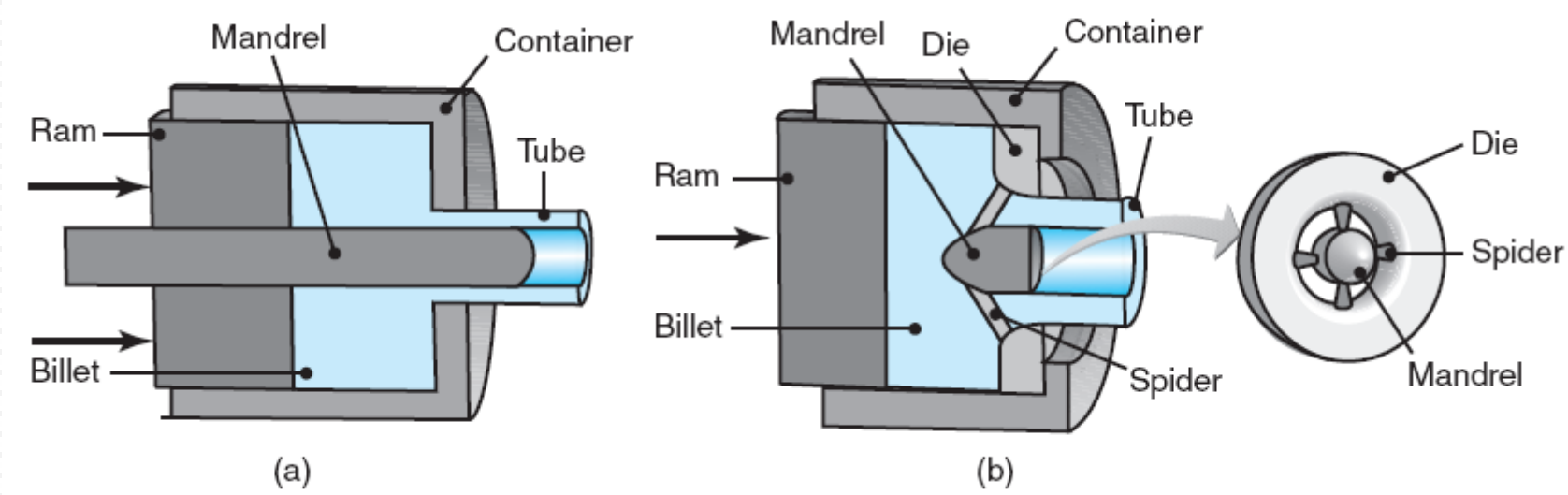
Hot Extrusion

Die Design

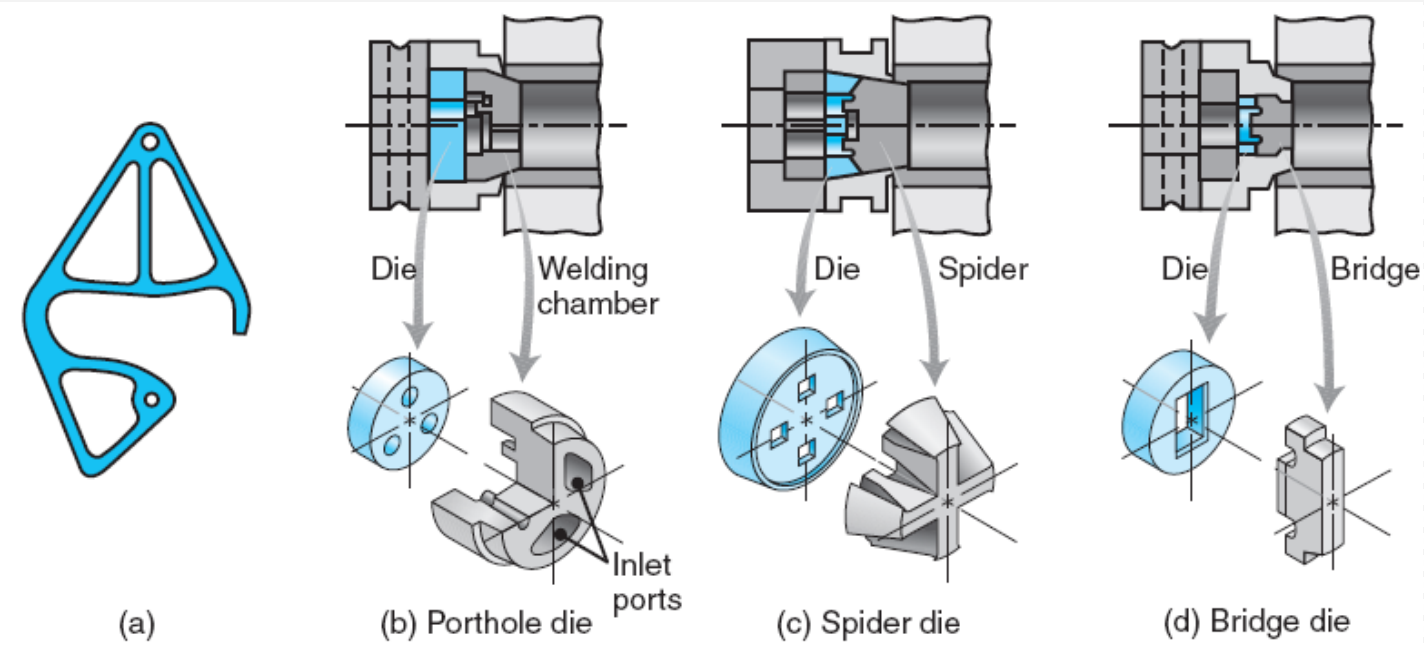
- *Square dies* (*shear dies*) are used in extruding nonferrous metals
- *Tubing* is extruded from a solid or hollow billet



Hot Extrusion

Die Design

- *Hollow cross sections* can be extruded by welding-chamber and using various dies known as a **porthole die, spider die**, and **bridge die**

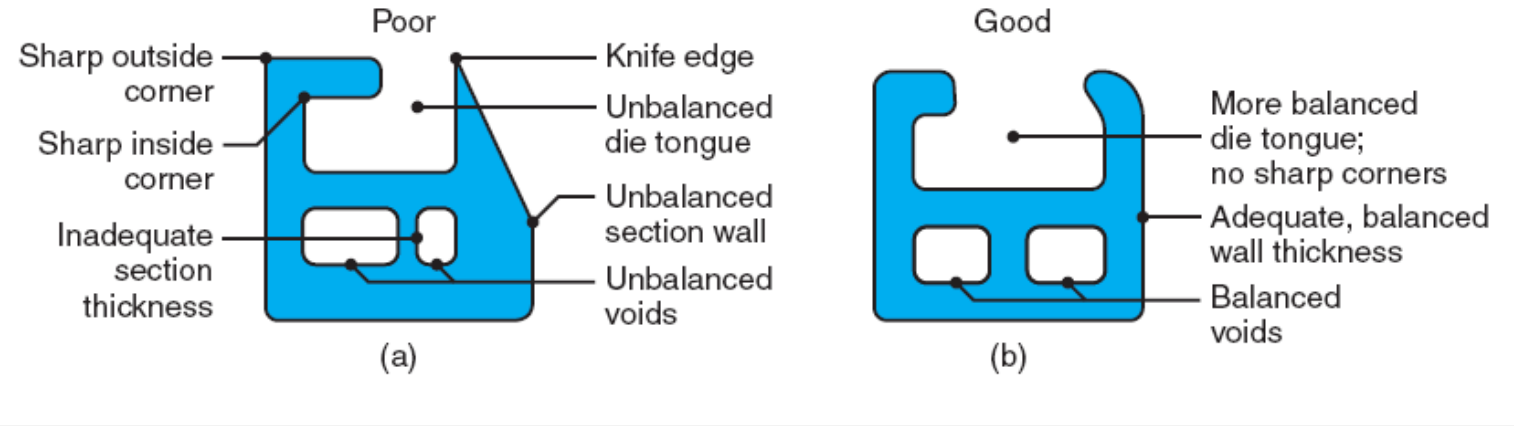


Hot Extrusion

Die Design

- Guidelines for proper die design in extrusion:

1. Symmetry of cross section
2. Avoidance of sharp corners
3. Avoidance of changes in die dimensions



Hot Extrusion

Lubrication

- Lubrication is important as it has effects on

1. Material flow during extrusion
2. Surface finish and product quality
3. Extrusion forces

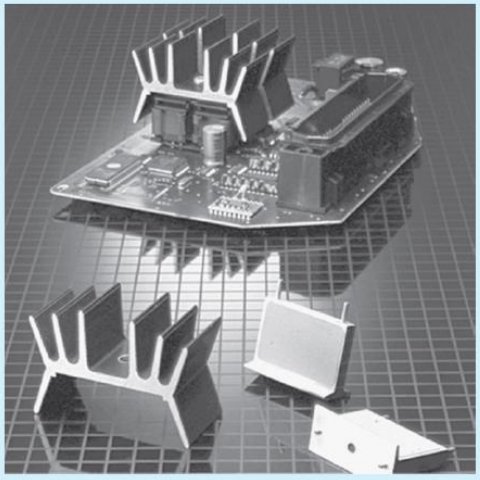
- *Glass* is an excellent lubricant for steels, stainless steels and high-temperature metals and alloys

Hot Extrusion

EXAMPLE 15.2

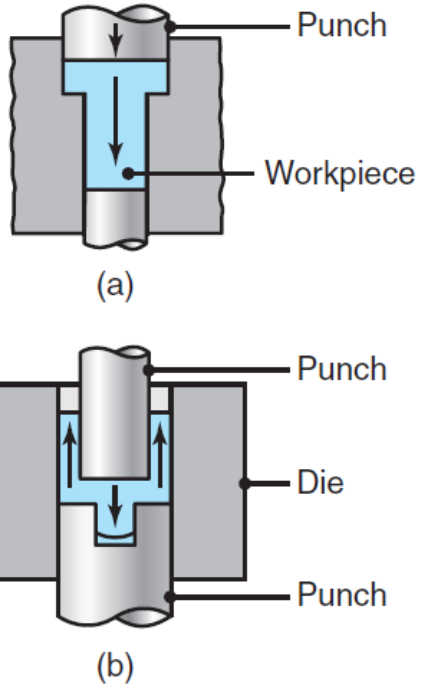
Manufacture of Aluminum Heat Sinks

- Hot extrusion of aluminum is preferred for heat sink applications
- Tooling for hot extrusion can be produced through electrical-discharge machining



Cold Extrusion

- *Cold extrusion* is a general term for a *combination* of operations, such as direct and indirect *extrusion and forging*
- Used widely for components in automobiles



- The *force, F*, is estimated from

$$F = 1100 A_0 Y_{avg} \varepsilon$$

A_0 = cross-sectional area of the blank
Y_{avg} = average flow stress of the metal
ε = true strain

Cold Extrusion

- Advantages over cold extrusion:

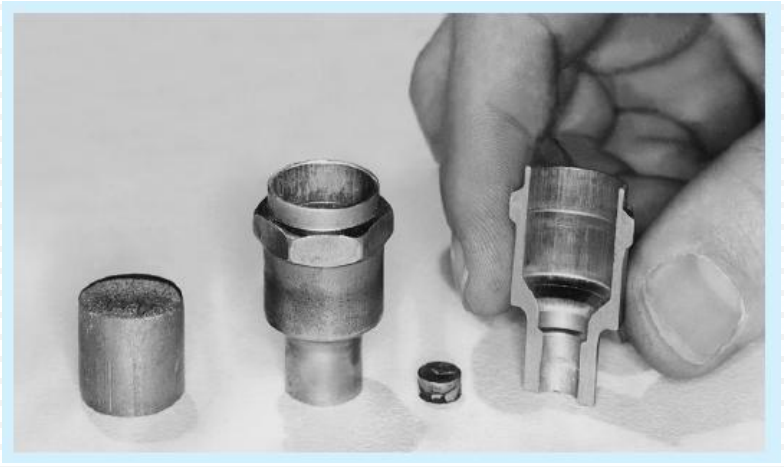
1. Improved mechanical properties
2. Good control of dimensional tolerances
3. Improved surface finish
4. Production rates and costs that are competitive

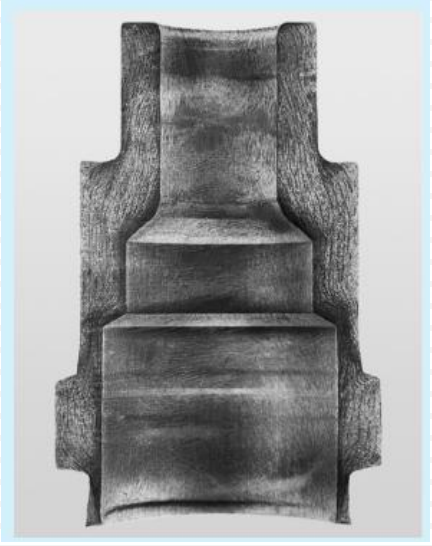
Cold Extrusion

EXAMPLE 15.3

Cold-extruded Part

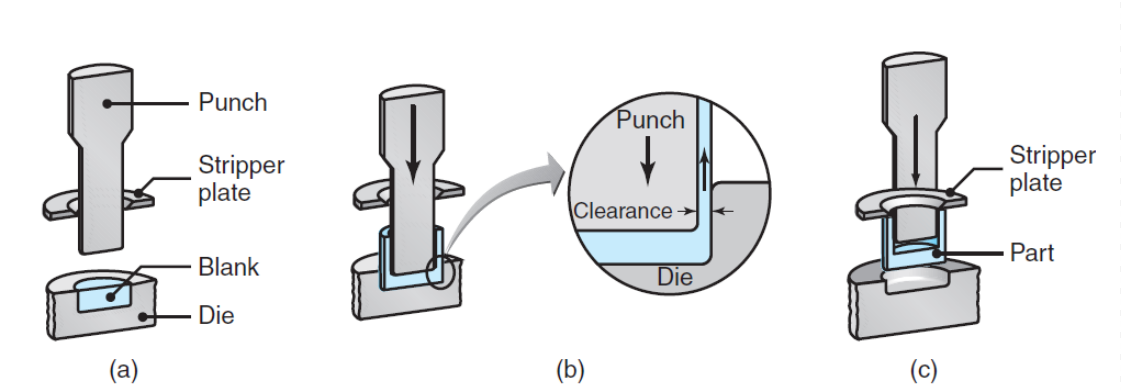
- Investigating material flow during the deformation of the slug helps avoid defects
- Part is sectioned in the mid-plane, polished and etched to display the grain flow

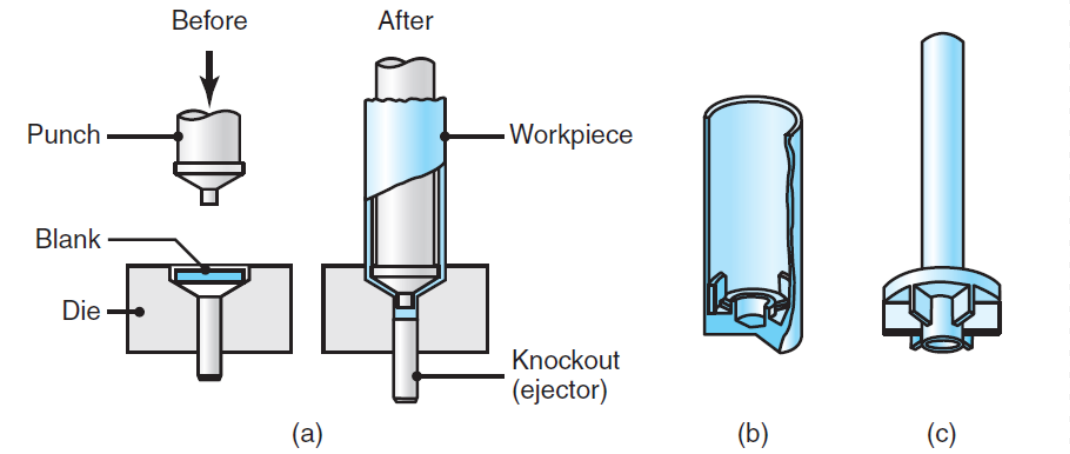




Cold Extrusion: Impact Extrusion

- Similar to indirect extrusion





Cold Extrusion: Hydrostatic Extrusion

- Pressure required in the chamber is supplied through an incompressible fluid medium
- Brittle materials can be extruded successfully as the hydrostatic pressure increases the ductility of the material

Extrusion Defects

- Extruded products can develop defects that affect their strength and product quality
- Some defects are visible to the naked eye while others can be detected only by some techniques

Surface Cracking

- High surface temperatures can cause surface cracking and tearing
- Cracks are intergranular caused by **hot shortness**
- Can be avoided by lowering the billet temperature and the extrusion speed

Extrusion Defects

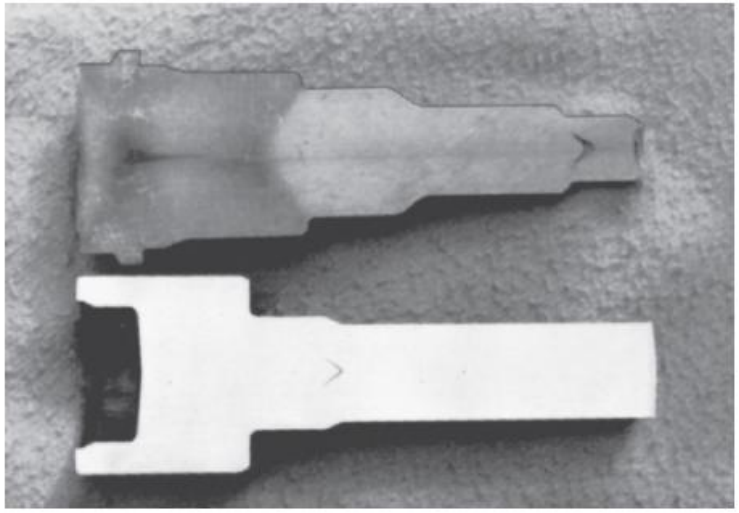
Pipe

- Type of metal-flow pattern in extrusion will draw surface oxides and impurities toward the center of the billet
- Defect is known as *pipe defect*, *tailpipe*, or *fishtailing*
- Reduced by having more uniform flow pattern

Extrusion Defects

Internal Cracking

- Center of the extruded product can develop cracks, called *center cracking, center-burst, arrowhead fracture,* or *chevron cracking*



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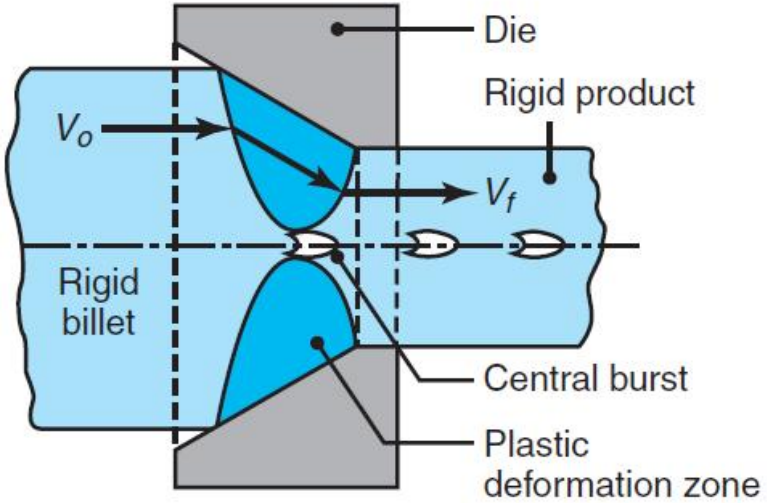

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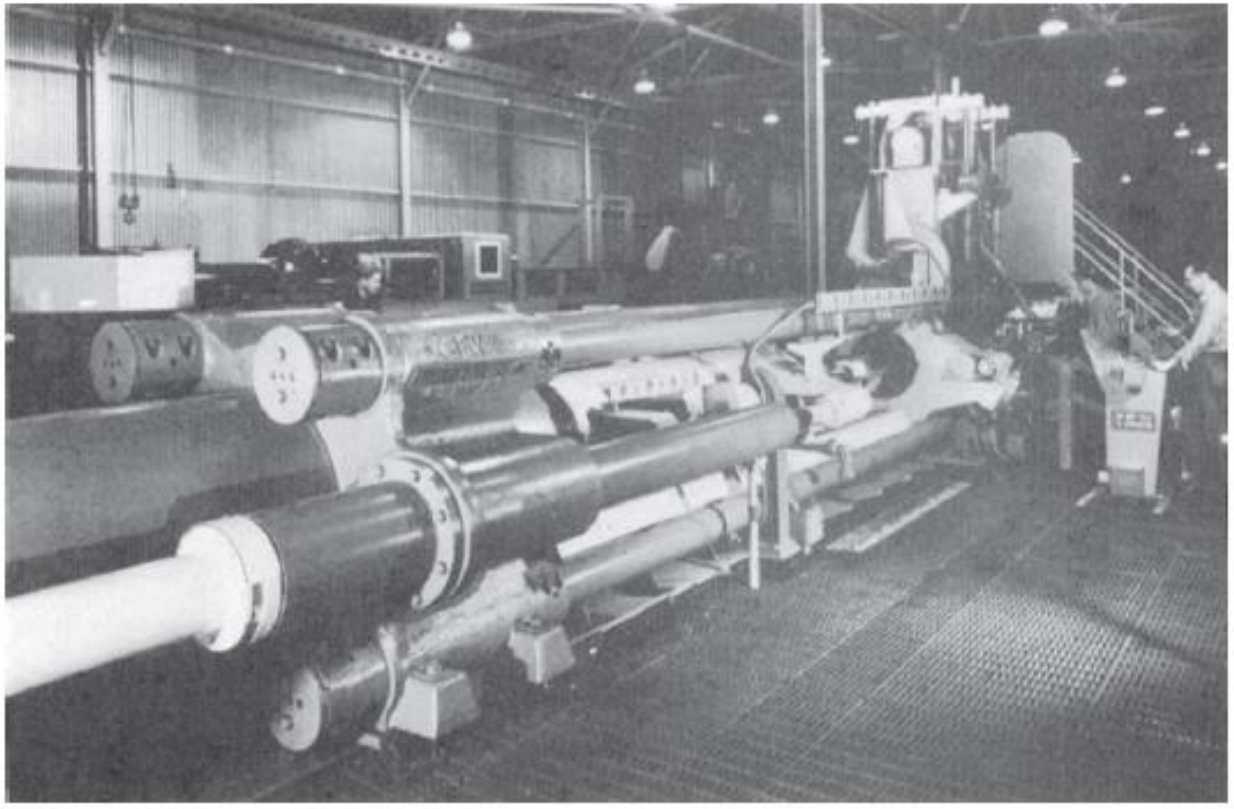
Extrusion Equipment

- Basic equipment for extrusion is a *horizontal hydraulic press*

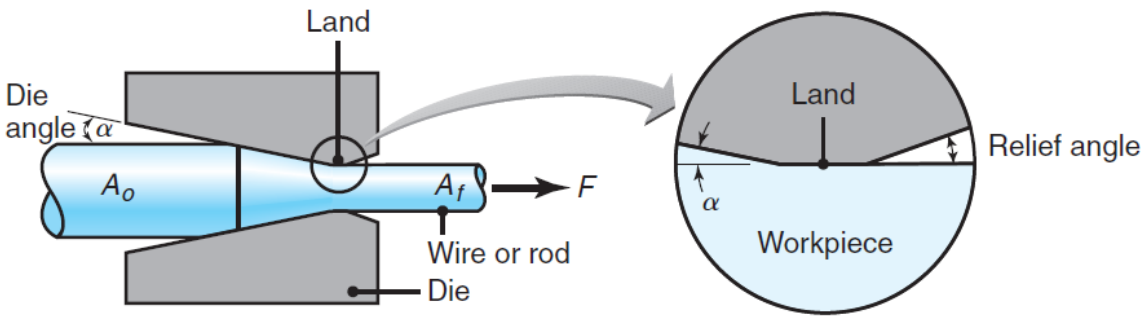


Extrusion Equipment

- The stroke and speed of the operation can be controlled
- Capable of applying a constant force over a long stroke
- *Vertical hydraulic presses* are used for cold extrusion
- Have less capacity than hot extrusion but take up less floor space
- *Crank-joint* and *knuckle-joint* mechanical presses are used for impact extrusion to mass-produce small components

The Drawing Process

- Cross section of a long rod or wire is reduced by pulling it through a *draw die*



Drawing Force

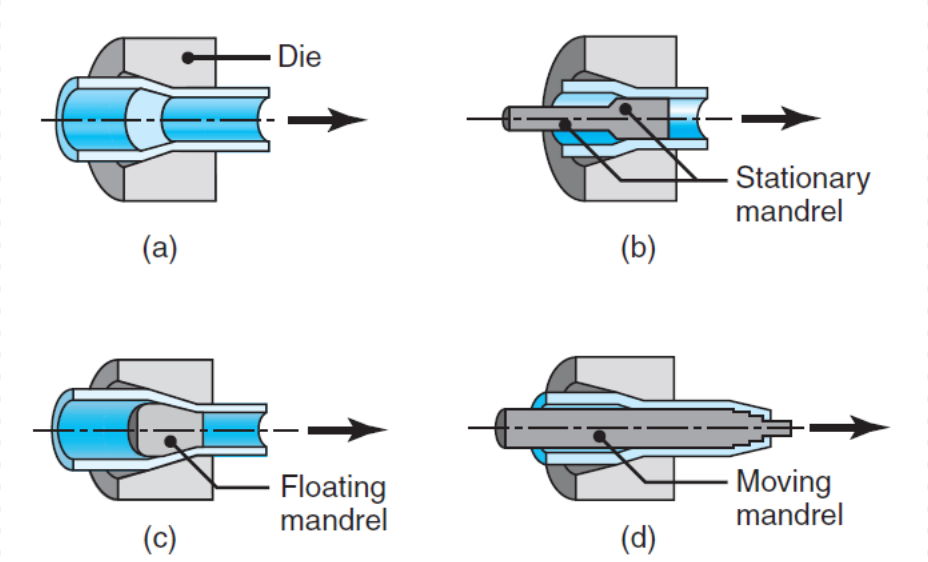
- Under *ideal and frictionless* conditions, is $F = Y_{avg} A_f \varepsilon \left(\frac{A_o}{A_f} \right)$
- With friction and the redundant work is

$$F = Y_{avg} A_f \left[\left(1 + \frac{\mu}{\alpha} \right) \ln \left(\frac{A_o}{A_f} \right) + \frac{2}{3} \alpha \right]$$

The Drawing Process

Drawing of Other Shapes

- Selection of reduction sequence is required to reduce internal / external defects and improve surface quality
- Wall thickness, diameter or shape of tubes can be reduced further by *tube-drawing* processes



Drawing Practice

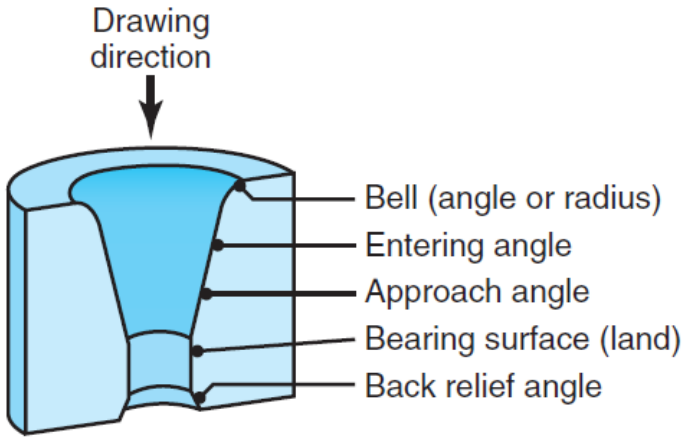
Bundle Drawing

- Increase productivity by drawing many wires simultaneously as a *bundle*
- Wires are separated by a metallic material with similar properties but lower chemical resistance
- Wires are used in electrically conductive plastics, heat-resistant and electrically conductive textiles

Drawing Practice

Die Design

- There are 2 angles (entering and approach) in a typical die
- Purpose of the bearing surface (*land*) is to set the final diameter of the product (*sizing*)
- **Profile drawing** involves stages of deformation to produce the final profile



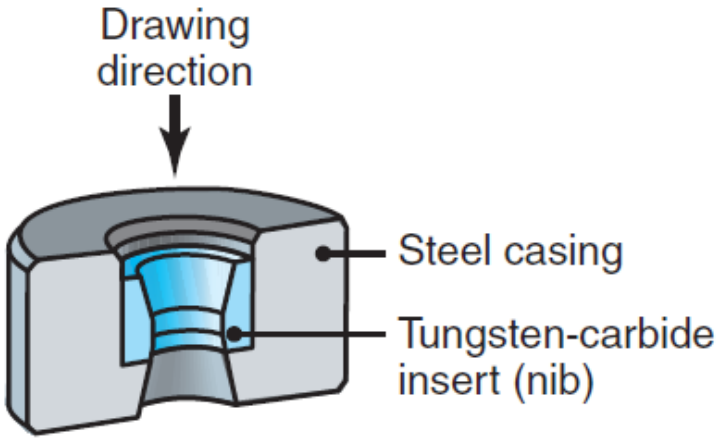
Drawing Practice

Die Materials

- For hot drawing, cast-steel dies are used because of their high resistance to wear at elevated temperatures
- Diamond dies have very low tensile strength and toughness, thus used as **inserts** or **nibs**

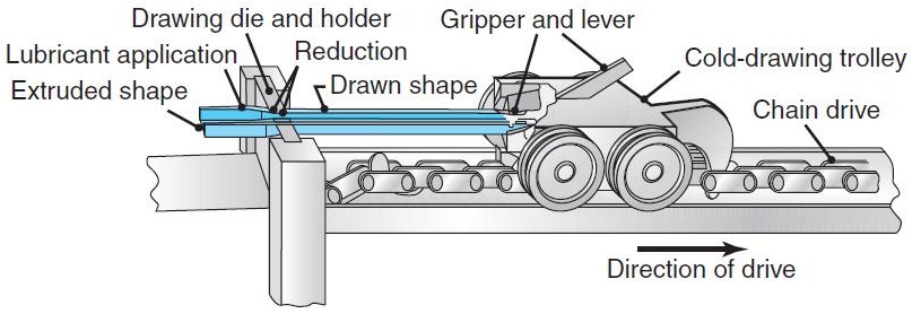
Lubrication

- To improve die life and product surface finish
- To reduce drawing forces and temperature



Drawing Defects and Residual Stresses

- Typical defects in a drawn rod or wire are *center cracking*
- Another major defect in **seams** are longitudinal scratches in the material
- Surface defects include scratches and die marks
- Due to nonuniform deformation during drawing, cold-drawn products have *residual stresses*



Drawing Equipment

- A **draw bench** contains a single die, similar to horizontal tension-testing machine
- Long rods and wire are drawn by a rotating **drum**