BMM3643 Manufacturing Processes
Bulk Metal Forming Processes
(Extrusion & Drawing Operations)

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Chapter Synopsis

A continuity from pervious chapter on bulk deformation which consists of extended processes such as extrusion and drawing. Types metal forming defects occurs in these processes will be discussed briefly and method to avoid or eliminate these defects.

Chapter Information

Lesson Objectives:

Extrusion & Drawing Operations

Lesson Objective:

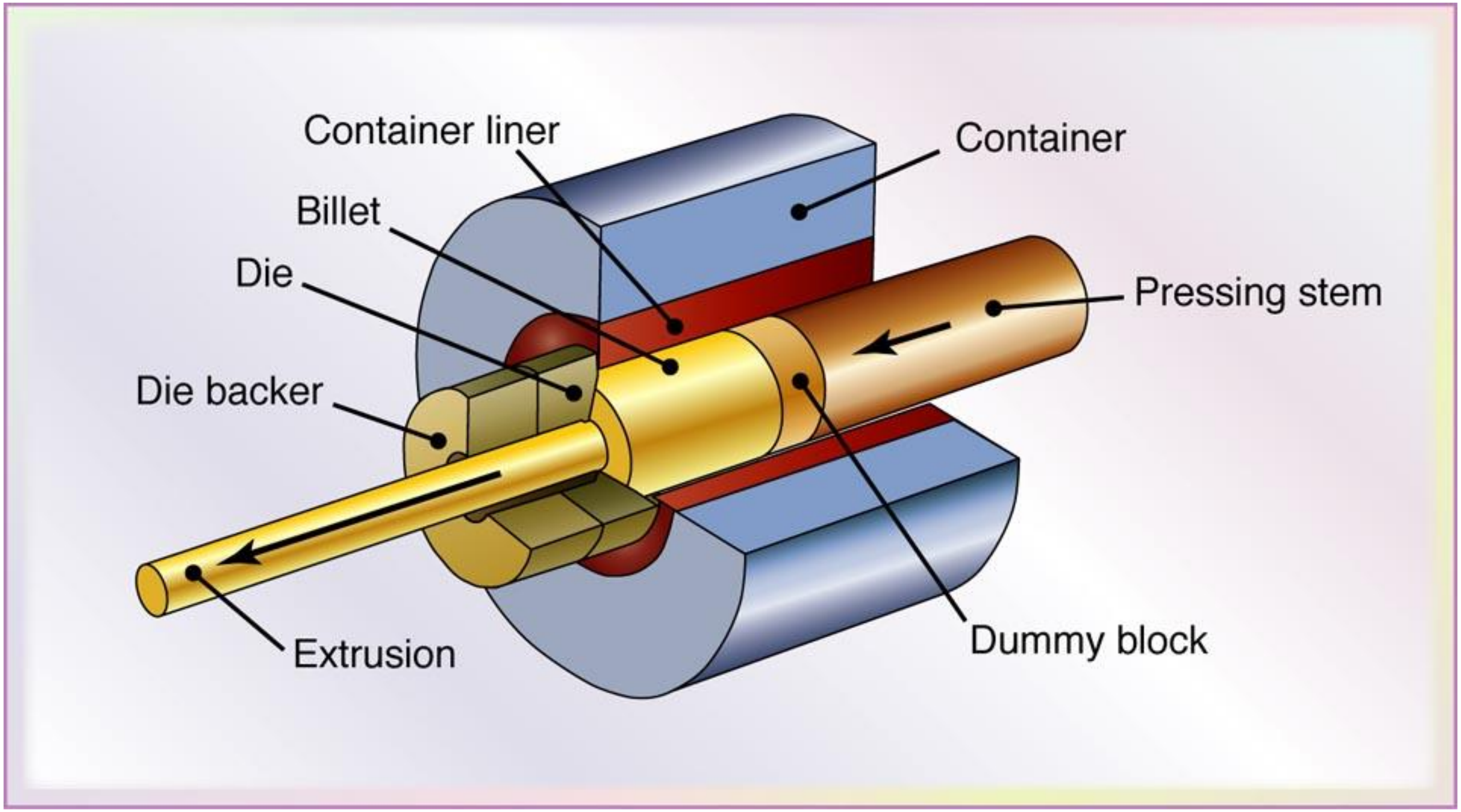
At the end of this lecture, students should be able to understand and explain the following:

- Understand the principles in various extrusion operations
- Understand the principles of drawing process
- Analyzed the proper practice and design to avoid defects in drawing

Extrusion Process

- Extrusion process - a billet (generally cylinder) is forced through a die, in a similar manner to squeezing toothpaste from a tube.
- Almost any solid or hollow cross-section may be produced by extrusion, which can create essentially <u>semi-finished parts</u>.
- Because the die geometry remains the same throughout the operations, extruded products have a <u>constant cross-section</u>.

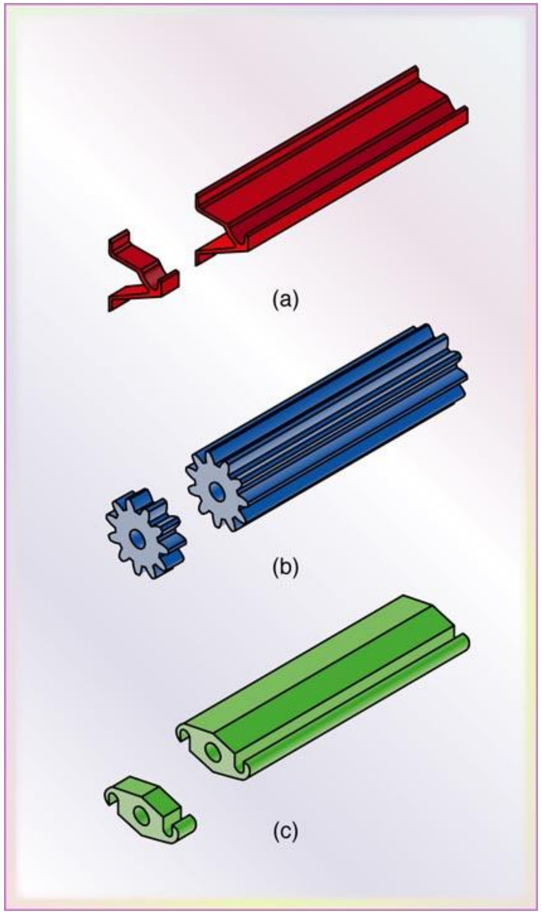
EXTRUSION PRINCIPLE

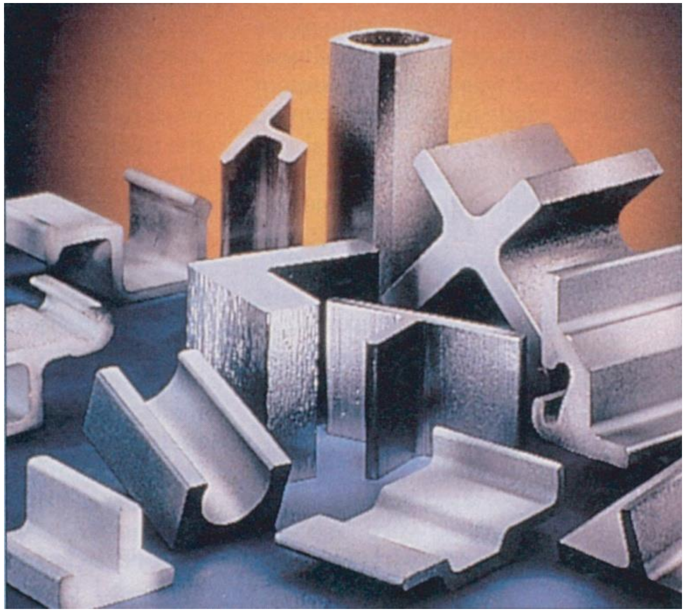


Schematic illustration of the extrusion process.

Source by Kalpakjian Book, 2014

Products Made from Extrusions Process





Extrusions and examples of products made by sectioning off extrusions. *Source:* Courtesy of Kaiser Aluminum.

Extrusion Process (continue)

- It has numerous important applications, including fasteners and components for automobile, bicycles, motorcycles, heavy machinery and etc.
- Typical products made by extrusion are railing for sliding doors, door and window frames, and etc.
- Commonly extruded materials are aluminium, copper, steel, magnesium and lead.

Extrusion Process (continue)

Types of Extrusion Processes.

1. The basic extrusion process is called direct or forward extrusion.
   - A round billet is placed in a chamber and forced through a die opening by a hydraulically-driven ram or pressing stem as shown in the figure.
   - The die opening may be round or it may have various shapes.

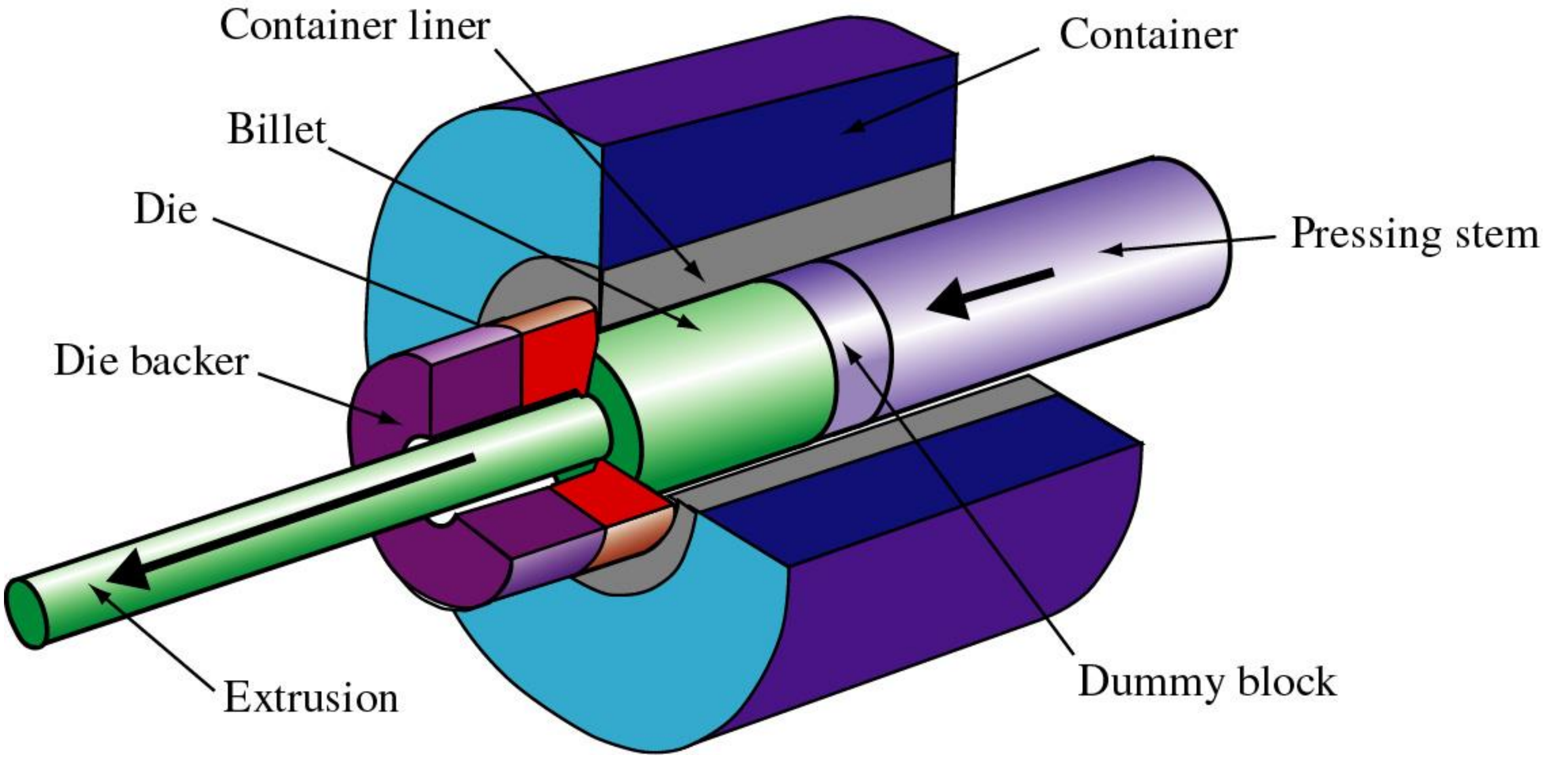
2. Another type is Indirect Extrusion.
   - It is also known as reverse, inverted or backward extrusion.
   - The die moves toward the billet.

Extrusion Process (continue)

3. Another type is Hydrostatic Extrusion
   - The chamber which is filled with a fluid.
   - The pressure is transmitted to the billet by a ram.
   - Unlike in direct extrusion, there is no friction to overcome along the container walls.

4. Another type is lateral, or side extrusion.
   - Billet is prepared vertically and pressed.
   - The extruded parts will come out horizontally through the dies.

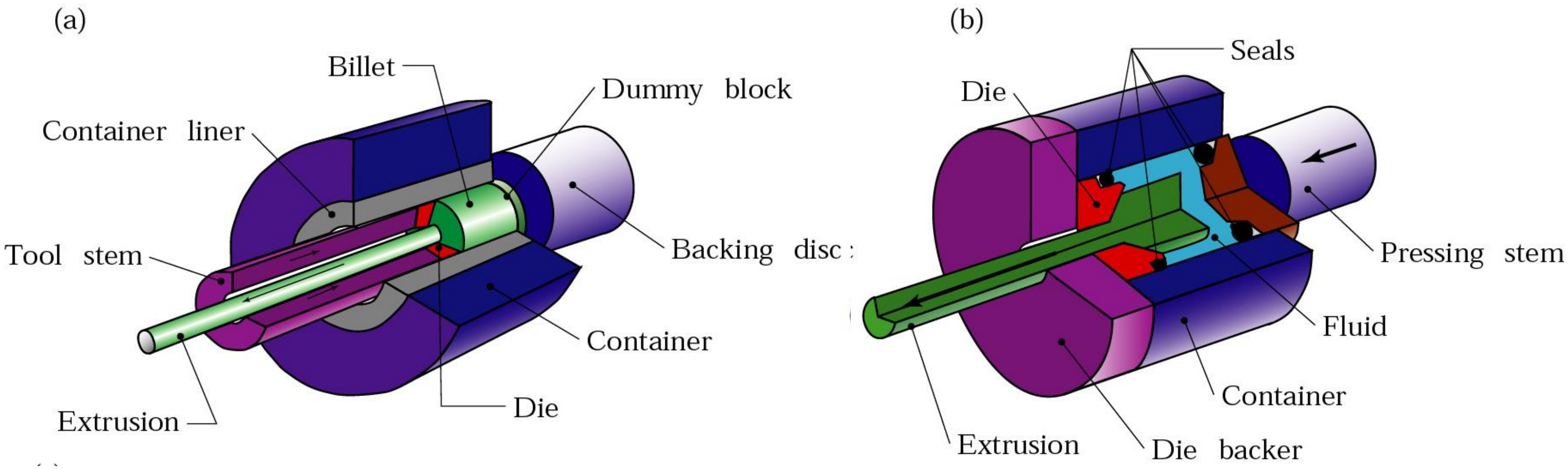
DIRECT EXTRUSION



Schematic illustration of the direct extrusion process.

Source by Kalpakjian Book, 2014

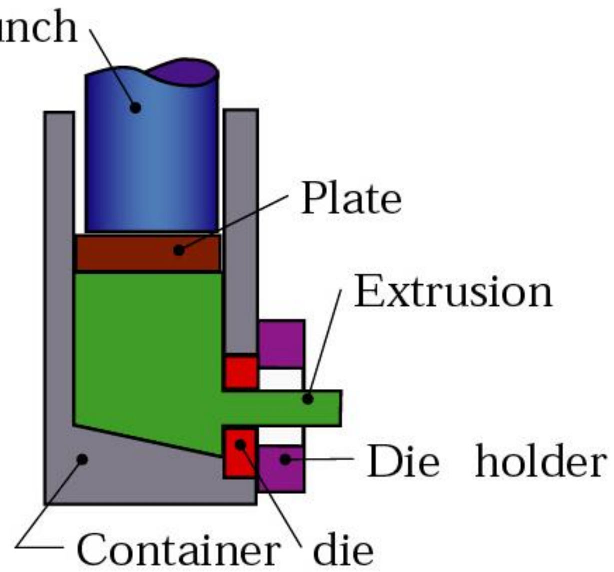
INDIRECT EXTRUSION



Types of extrusion: (a) indirect; (b) hydrostatic

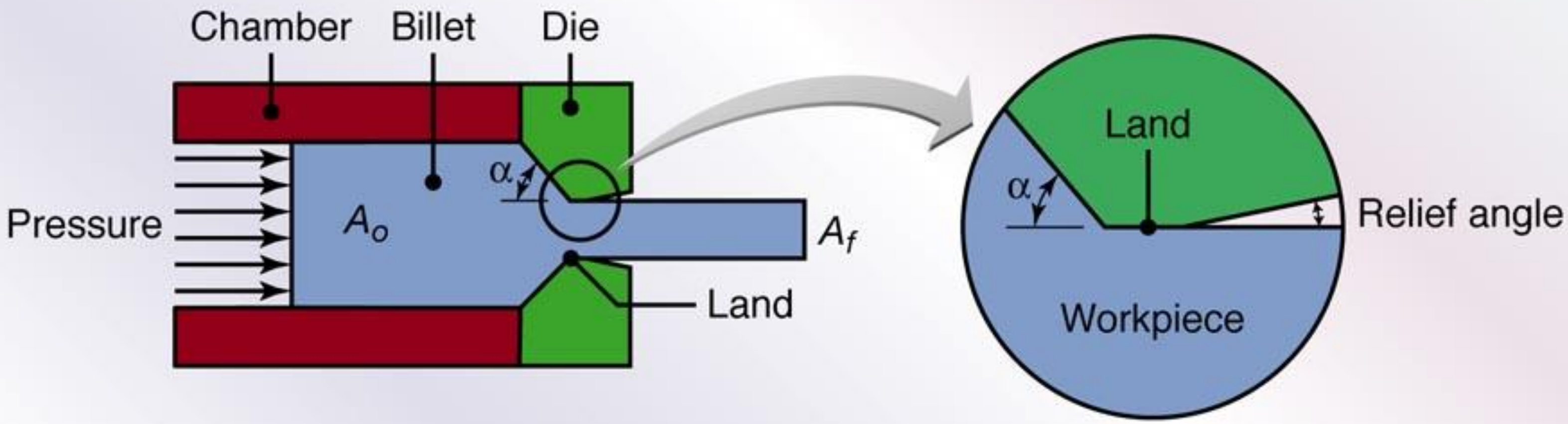
LATERAL EXTRUSION

(c)



Types of extrusion: (c) lateral.

Process Variables in Direct Extrusion



Process variables in direct extrusion. The die angle, reduction in cross-section, extrusion speed, billet temperature, and lubrication all affect the extrusion pressure.

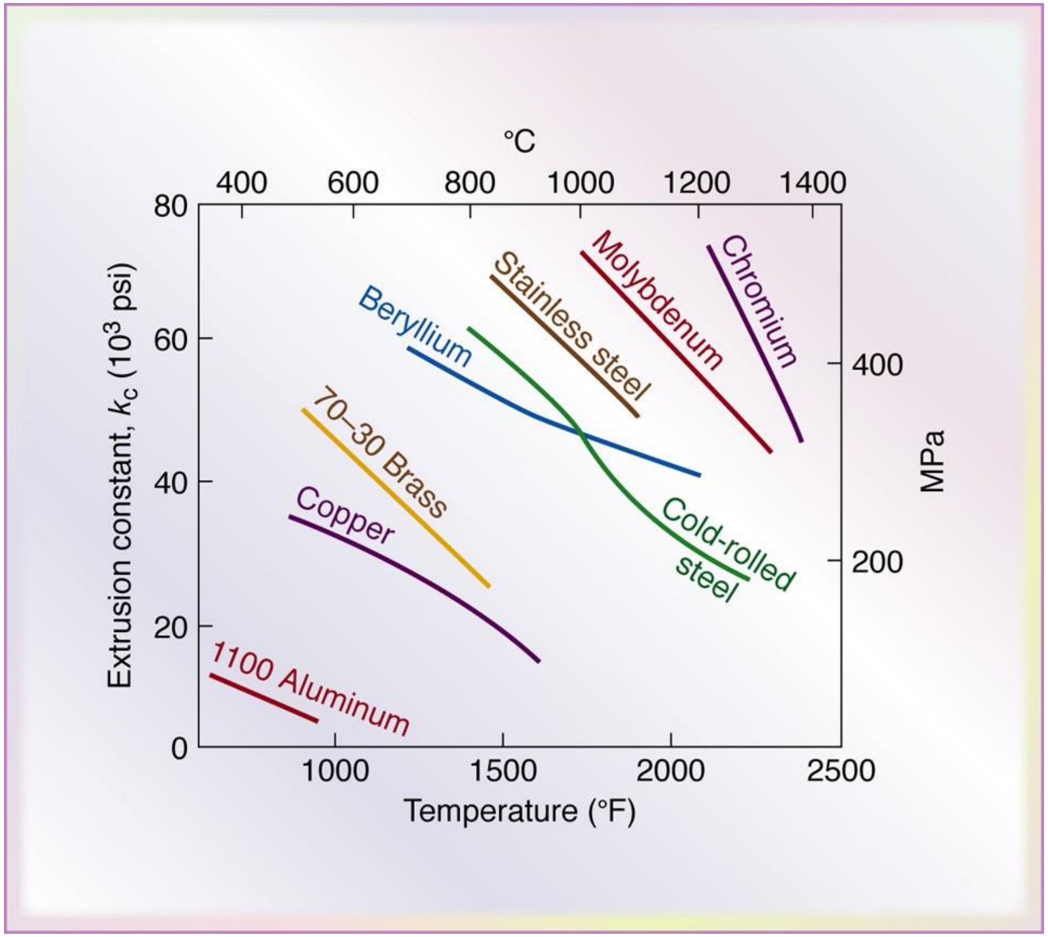
Extrusion Force

- Extrusion force, F, can be calculated as,

$$F = A_o k \ln (A_o/A_f)$$

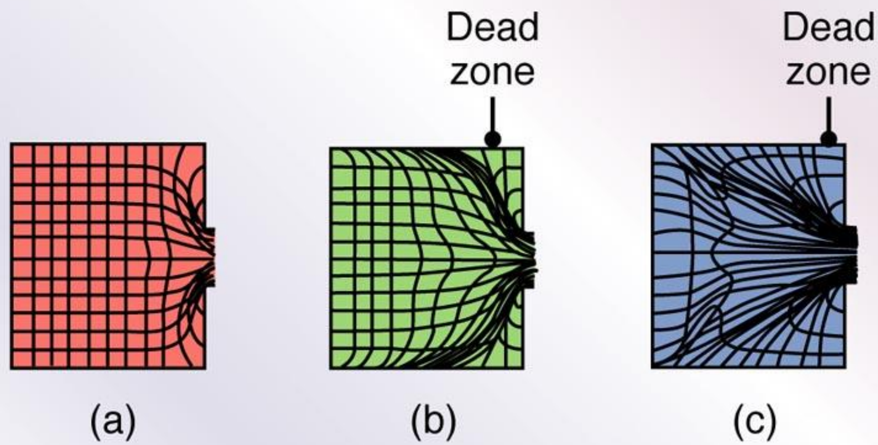
  - k = extrusion constant
  - A_o = billet area
  - A_f = extruded product area
  - (A_o/A_f) = also known as extrusion ratio, R

Extrusion Force



Extrusion constant *k* for various metals at different temperatures. *Source*: After P. Loewenstein

Metal Flow Pattern in Extrusion with Square Dies



Types of metal flow in extruding with square dies. (a) Flow pattern obtained at low friction or in indirect extrusion. (b) Pattern obtained with high friction at the billet-chamber interfaces. (c) Pattern obtained at high friction or with coiling of the outer regions of the billet in the chamber. This type of pattern, observed in metals whose strength increases rapidly with decreasing temperature, leads to a defect known as pipe (or extrusion) defect.

Source by Kalpakjian Book, 2014

Hot Extrusion

- Hot extrusion is carried out at elevated temperature to reduce the forces required.
- For metals or alloys that do not have sufficient ductility at room temperature.
- At elevated temperature, material's ductility is increased but it carries some drawbacks.

TABLE 15.1

Typical Extrusion Temperature Ranges for Various Metals and Alloys. (See also Table 14.3.)

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

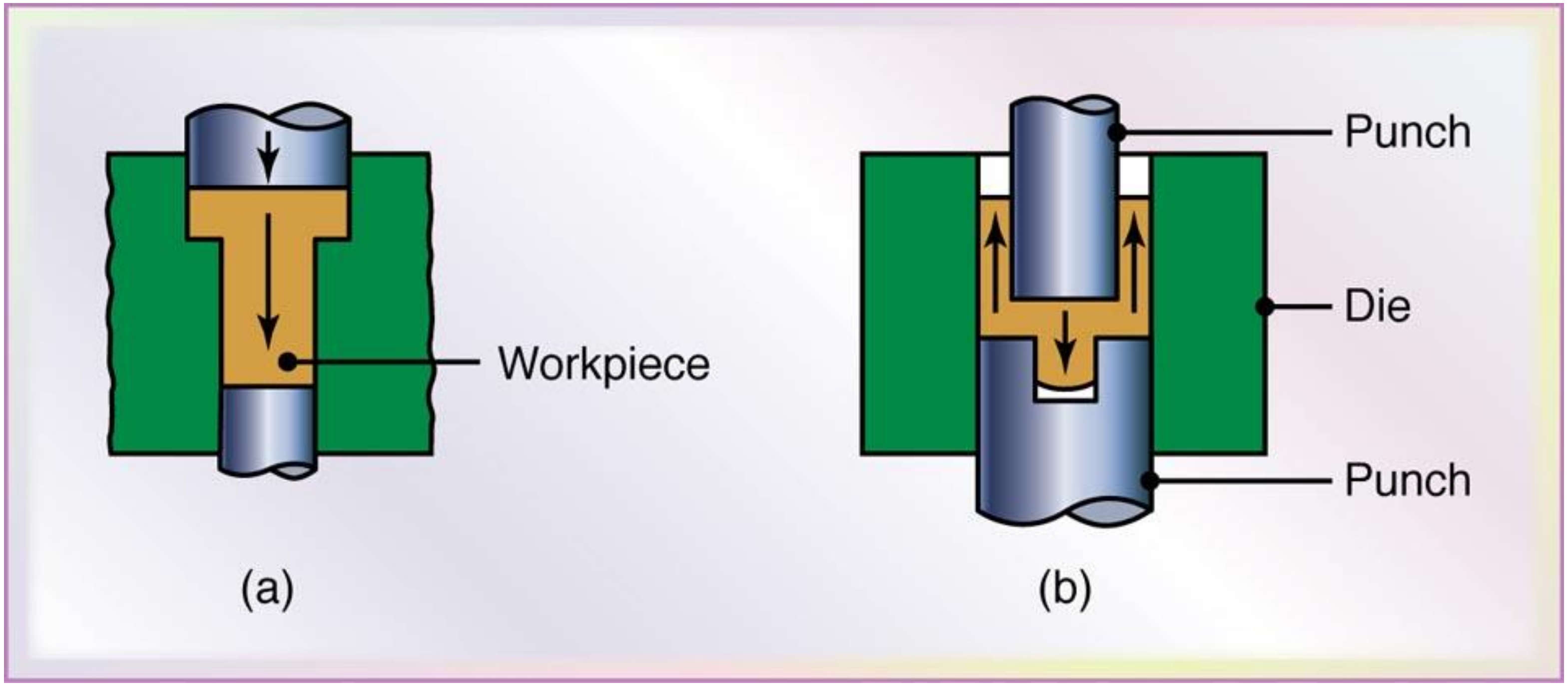
Cold Extrusion

- It denotes a combination of operations such as direct and indirect extrusion and forging.
- Widely used for automobile components.
- The force, F, in cold extrusion is calculated as:

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

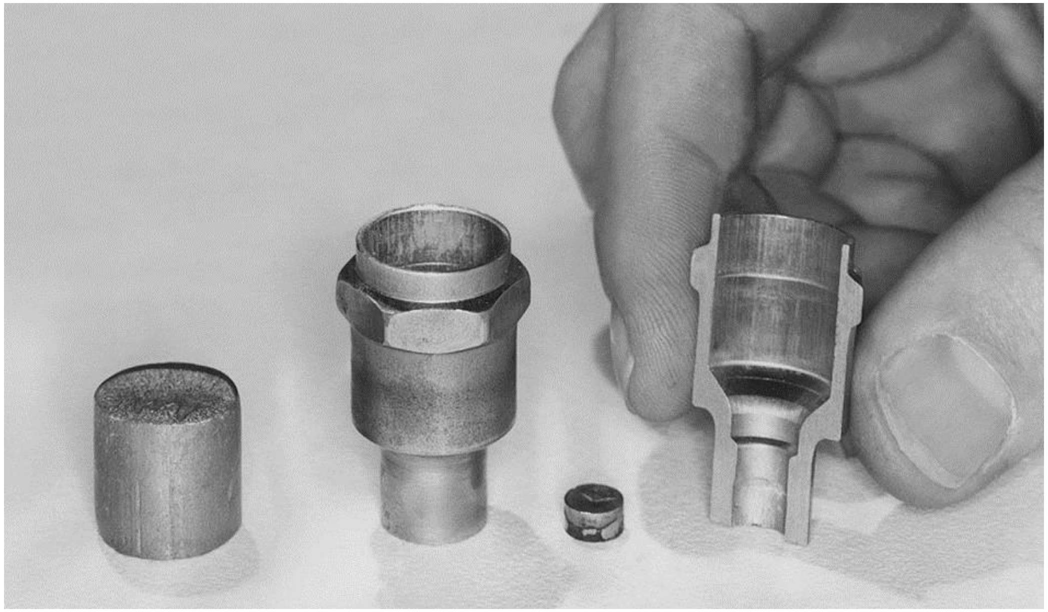
  - A_o = original area, Y_{avg} = flow stress, ε = true strain

Examples of Cold Extrusion

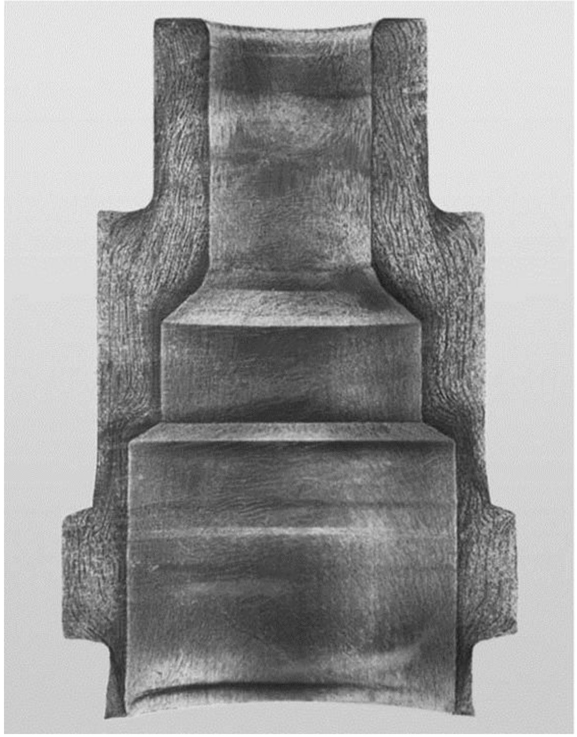


Examples of cold extrusion. Thin arrows indicate the direction of metal flow during extrusion process.

Products Made from Cold Extrusion

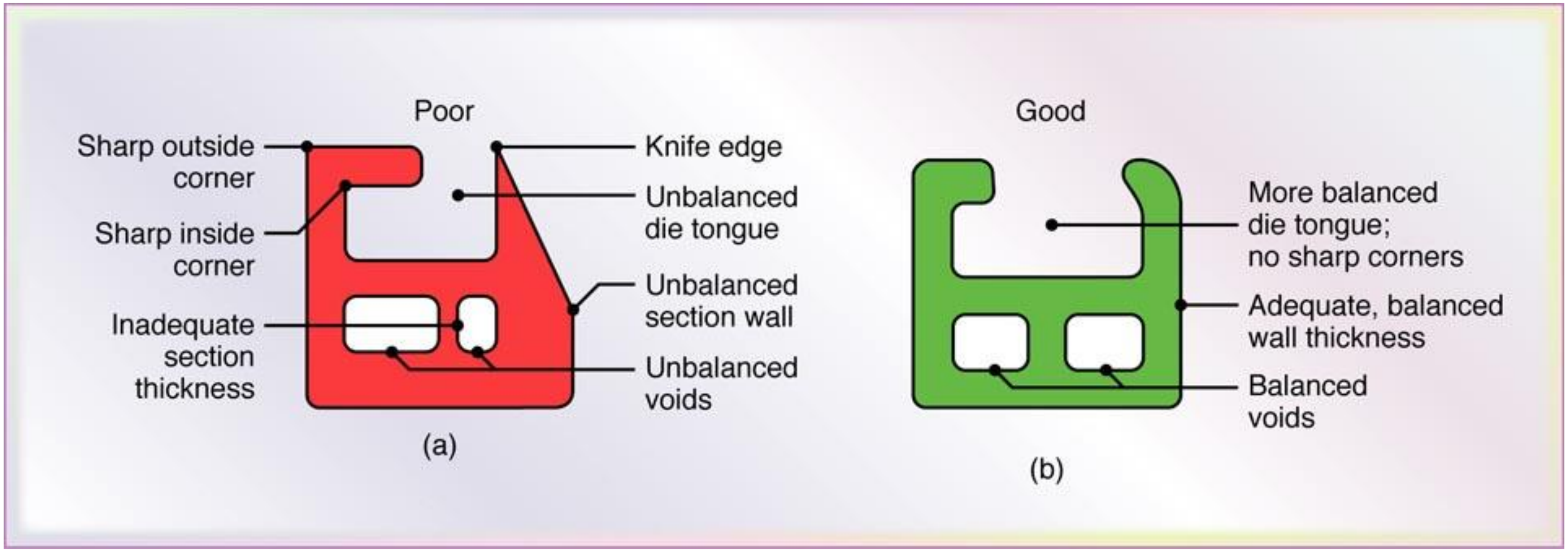


Production steps for a cold-extruded spark plug.
Source: Courtesy of National Machinery Company.



A cross-section of the metal part in figure above showing the grain-flow pattern.
Source: Courtesy of National Machinery Company.

Design Considerations for Extruded Process

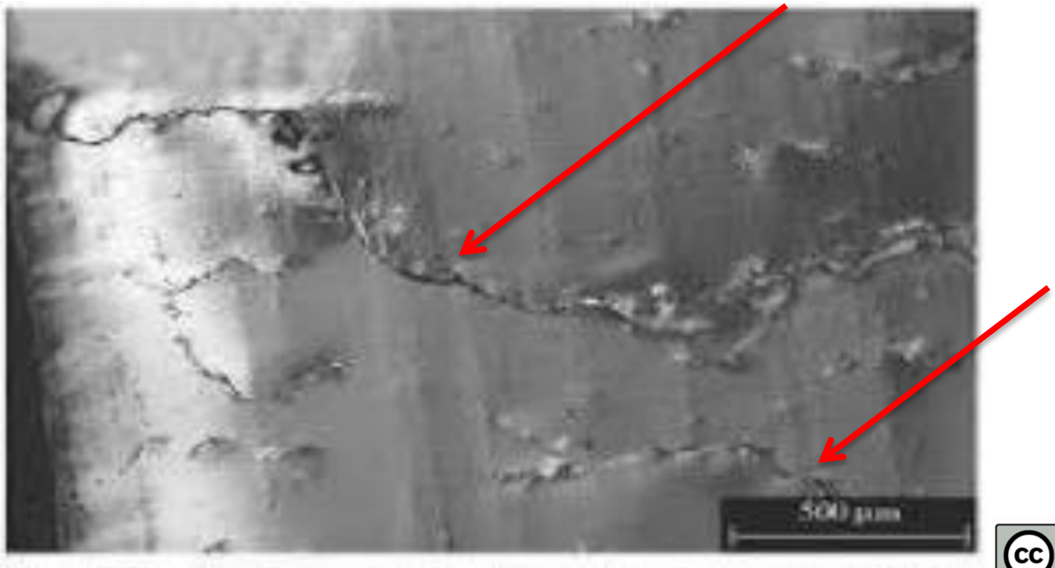


Poor and good examples of cross-sections to be extruded. Note the importance of eliminating sharp corners and of keeping section thicknesses uniform. *Source:* J.G. Bralla (ed.); *Handbook of Product Design for Manufacturing.* New York: McGraw-Hill Publishing Company, 1986.

Examples of Extrusion Defects

Examples of defects happened in extrusion process:

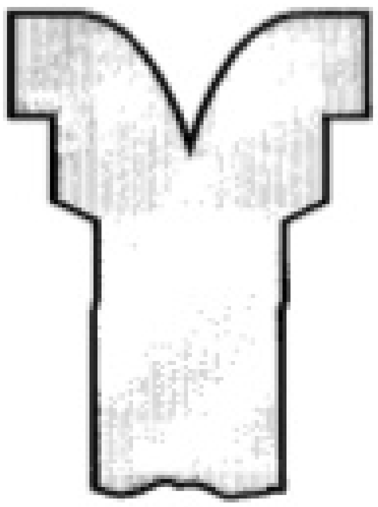
1. Surface cracking
   - Cracking or tearing at the surface
   - Due to high extrusion temperature, friction or speed of extrusion
   - May occur at lower temperature when the extruded product temporarily sticks to the die land



Examples of Extrusion Defects (continue)

2. Pipe:

- Sink hole at the end of billet under direct extrusion.
- During metal-flow pattern products tend to draw surface oxides or impurities toward the center of the billet.
- Occur as much as one third of the extruded product length.

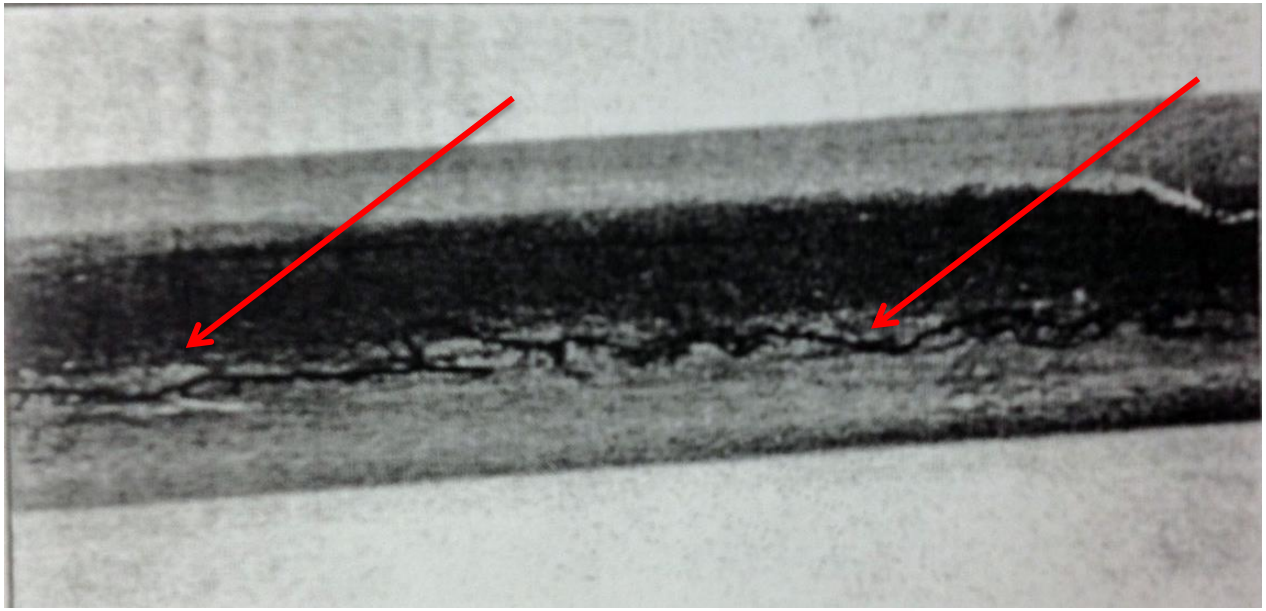


Examples of Extrusion Defects (continue)

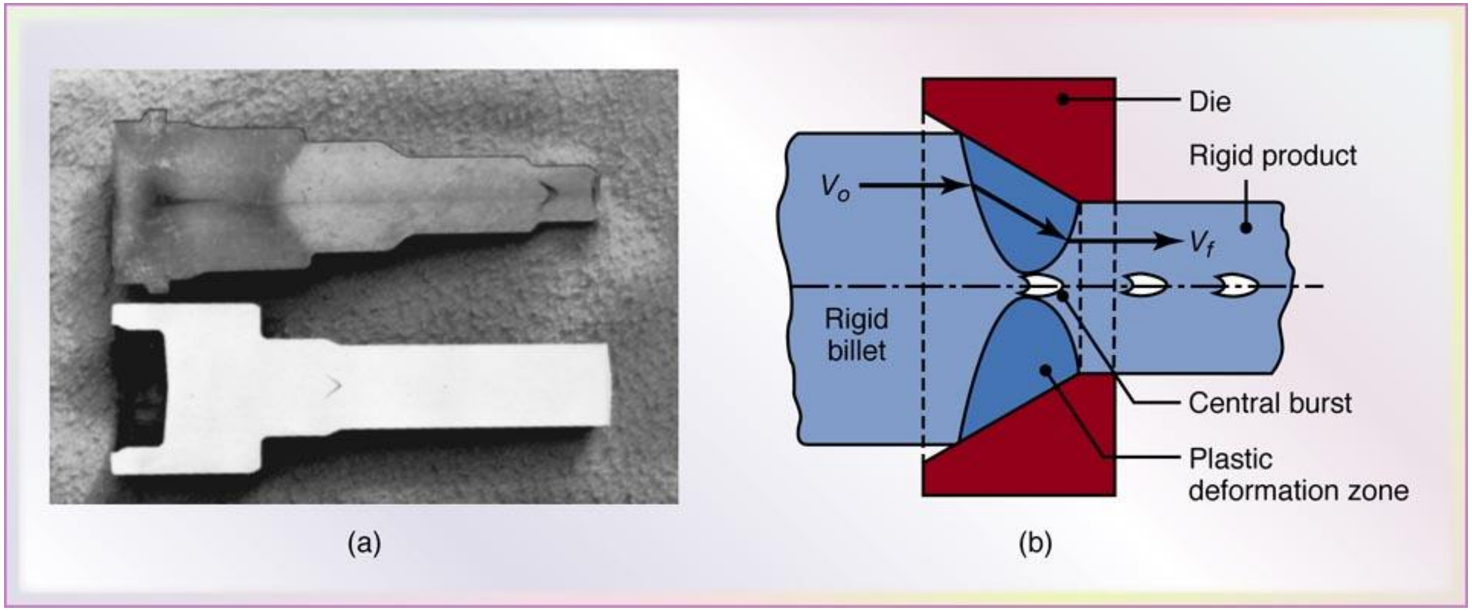
3. Internal cracking

– Cracks developed at the center of extruded products

– Names called center cracking, center burst, arrowhead fracture or chevron cracking



Examples of Extrusion Defects (continue)

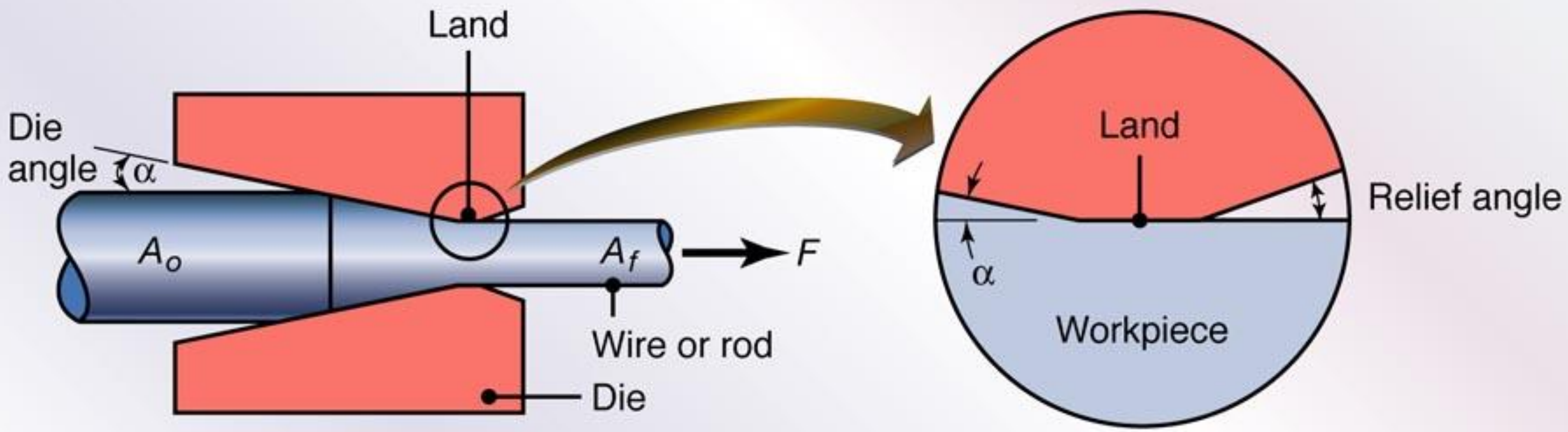


(a) **Chevron cracking (central burst)** in extruded round steel bars. Unless the products are inspected, such internal defects may remain undetected and later cause failure of the parts in service. This defect can also develop in the drawing of rod, of wire, and of tubes. (b) Schematic illustration of rigid and plastic zones in extrusion. The tendency toward chevron cracking increases if the two plastic zones do not meet. Note that the plastic zone can be made larger either by decreasing the die angle or by increasing the reduction in cross-section (or both). *Source*: After B. Avitzur.

Drawing Process

- It is an operation in which the cross section of **solid rod, wire, or tubing** is reduced and changed in shape by pulling it through a die.
- The major variables in drawing are similar to those in extrusion:
  - reduction in cross-sectional area
  - die angle
  - friction along the die-workpiece interfaces
  - drawing speed

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*.

Source by Kalpakjian Book, 2014

Drawing Force

- The drawing force, F, under ideal and frictionless condition can be calculated as:

$$F = Y_{avg} A_f \ln (A_o/A_f)$$

  - Y_{avg} = true stress
  - A_o and A_f = Initial and final area
- Drawing force under friction:

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

  - α = die angle

Drawing Practice

- Successful drawing requires the careful selection of process parameters such as:
  - Reductions in the cross-sectional area should be less than 45% from the original dimension
  - Drawing speed may be in the range 1-2.5 m/s to 50 m/s (depends on the size)
  - Different materials are drawn at different temperatures (depends on the application)

Examples of Drawing Defects

- Typical defects in a drawn rod are similar to those in extrusion process.
- Other examples of drawing defects include:
  - Seams: longitudinal scratches or folds in the material
  - Residual stresses: due to non-uniform deformation

End of sub-chapter
Bulk Metal Deformation Processes
(Extrusion & Drawing Operations)