SME 2713
Manufacturing Process

METAL FORMING – 4

(Extrusion process)

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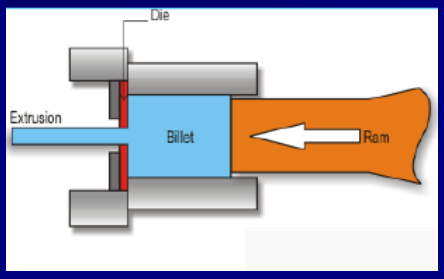
Outline

1. Introduction
2. Classification of extrusion processes
   1. Direct and indirect extrusion
   2. Hot and cold extrusion
   3. Horizontal and vertical extrusion
   4. Tube extrusion
   5. Impact extrusion
   6. Hydrostatic extrusion
3. Extrusion Equipment
4. Extrusion defects

1. Introduction

- Extrusion is the process by which a block/billet of metal is reduced in cross-section by forcing it to flow through a die orifice under high pressure
- In general, extrusion is used to produce cylindrical bars or hollow tubes or for the starting stock for drawn rod, cold extrusion or forged products

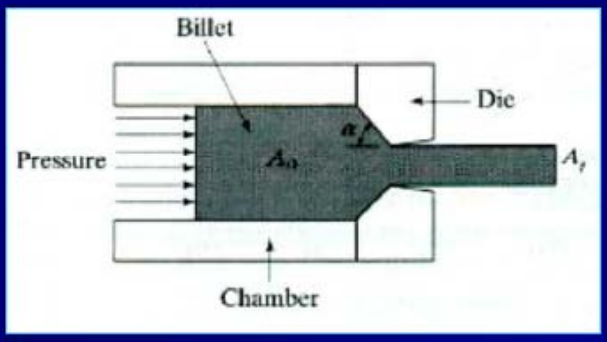


1. Introduction

- Most metals are hot extruded due to large amount of forces required in extrusion. Complex shapes can be extruded from the more readily extrudable metals such as aluminium.
- The products obtained are also called extrusion

1. Introduction

- The reaction of the extrusion billet with the container and die results in high compressive stresses which are effective in reducing cracking of materials during primary breakdown from the ingot

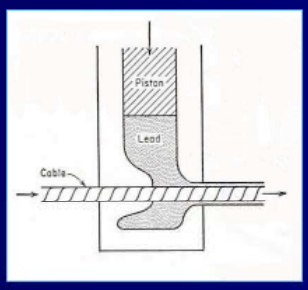


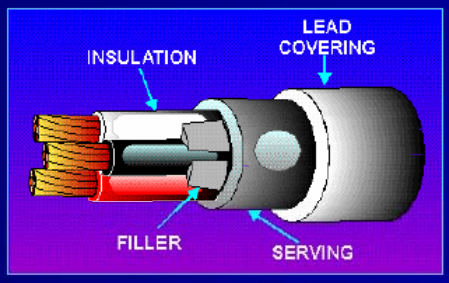
1. Introduction

- This helps to increase the utilization of extrusion in the *working of metals that are difficult to form* like stainless steels, nickel-based alloys, and other high-temperature materials
- Similar to forging, lower ram force and a fine grained recrystallised structure are possible in hot extrusion.
- However, better surface finish and higher strengths (strain hardened metals) are provided by *cold extrusion.*

1. Introduction

Extrusion was originally applied to the making of lead pipe and later to the lead sheathing on electrical cable.





Extrusion of lead sheath on electrical cable.

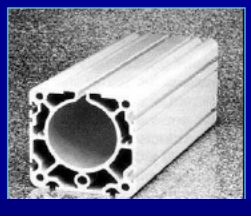
Extrusion products

Typical parts produced by extrusion are trim parts used in automotive and construction applications, window frame members, railings, aircraft structural parts.

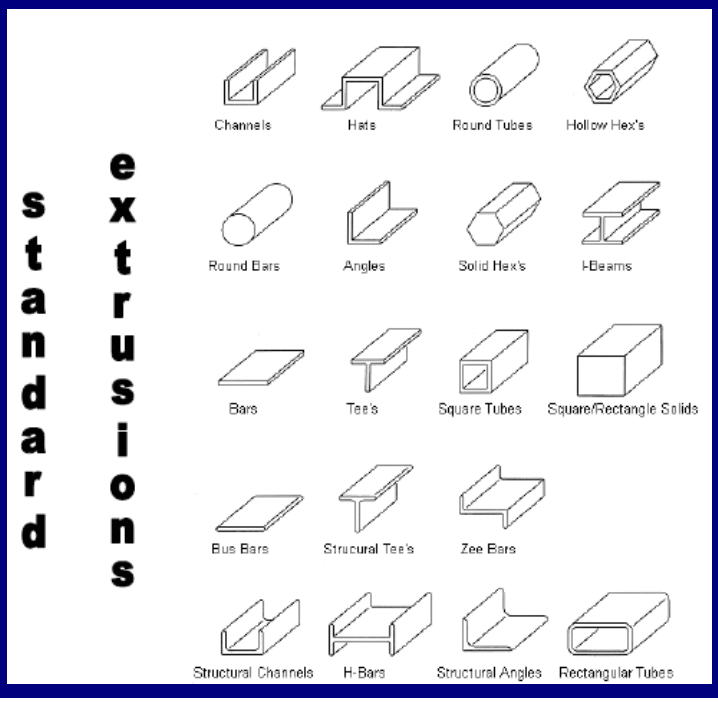
Example: Aluminium extrusions are used in commercial and domestic buildings for window and door frame systems, prefabricated houses/building structures, roofing and exterior cladding, curtain walling, shop fronts, etc. Furthermore, extrusions are also used in transport for airframes, road and rail vehicles and in marine applications.

Aluminium for windows and doors

Aluminium extrusions



Extrusion products

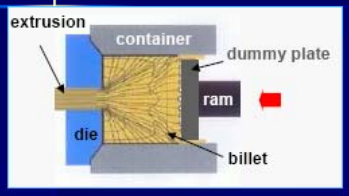


2. Classification of extrusion processes

- Can be classified
  - By direction
    - Direct or indirect extrusion
    - Forward or backward extrusion
  - By operating temperature
    - Hot or cold extrusion
  - By equipment
    - Horizontal or vertical extrusion

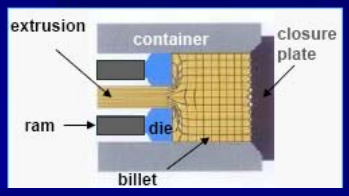
Direct and indirect extrusions

1) Direct extrusion



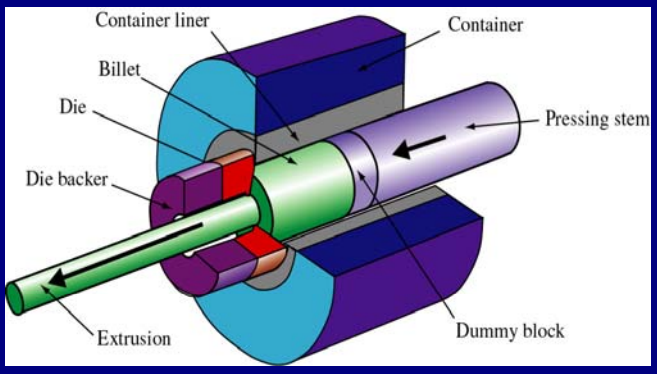
- The metal billet is placed in a container and driven through the die by the ***ram***.
- The ***dummy block*** or pressure plate, is placed at the end of the ram in contact with the billet.
- Friction is at the die and container wall → requires higher pressure than indirect extrusion.

2) Indirect extrusion



- The ***hollow ram*** containing the die is kept stationary and the ***container with the billet*** is caused to move.
- ***Friction*** at the die only (no relative movement at the container wall) → requires roughly constant pressure.
- Hollow ram ***limits*** the applied load.

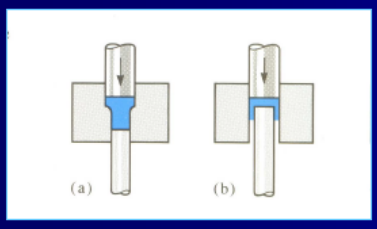
Direct Extrusion



Schematic illustration of the direct extrusion process.

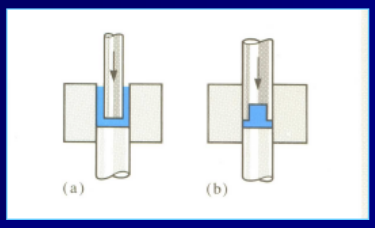
Forward and backward extrusions

1) Forward extrusion



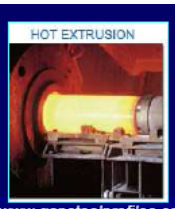
- Metal is forced to ***flow in the same direction*** as the punch.
- The punch closely fits the die cavity to prevent backward flow of the material.

2) Backward extrusion



- Metal is forced to ***flow in the direction opposite*** to the punch movement.
- Metal can also be forced to flow into recesses in the punch, see *Fig*.

Hot extrusion



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Hot extrusion is done at ***fairly high temperatures***, approximately 50 to 75 % of the melting point of the metal. The pressures can range from 35-700 MPa (5076 - 101,525 psi).

- The most commonly used extrusion process is the ***hot direct process***. The cross-sectional shape of the extrusion is defined by the shape of the die.
- Due to the high temperatures and pressures and its ***detrimental effect on the die life*** as well as other components, ***good lubrication*** is necessary. Oil and graphite work at lower temperatures, whereas at higher temperatures glass powder is used.

www.ansoniacb.com

Extrusion Temperature Ranges for Various Metals

	°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

Cold extrusion is the process done at room temperature or slightly elevated temperatures. This process can be used for most materials-subject to designing robust enough tooling that can withstand the stresses created by extrusion.

Cold extrusion

Examples of the metals that can be extruded are ***lead, tin, aluminium alloys, copper, titanium, molybdenum, vanadium, steel***. Examples of parts that are cold extruded are collapsible tubes, aluminium cans, cylinders, gear blanks.

Advantages

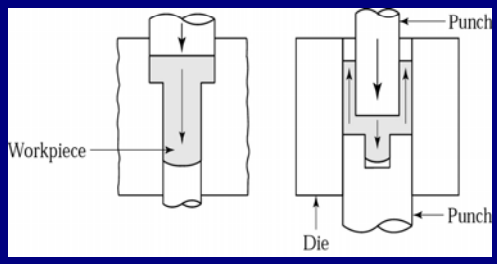
- No oxidation takes place.
- Good mechanical properties due to severe cold working as long as the temperatures created are below the re-crystallization temperature.
- Good surface finish with the use of proper lubricants

Collapsible tubes

Aluminium cans

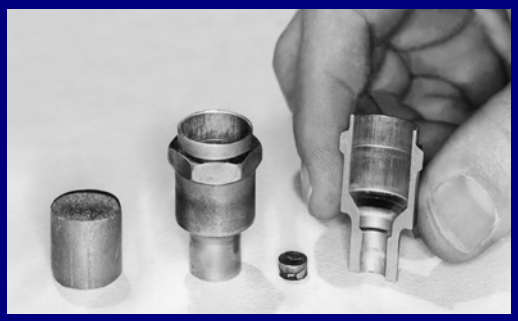
Cold Extrusion

- 1940s
- Comparison to Hot Extrusion
  - Improved mechanical properties
  - Good dimensional tolerance
  - Elimination of billet heating
  - Production rates and costs competetive
    - 2000 parts/hour
  - However, High stress
- Tool and die materials crucial
  - Sufficient strength
  - Sufficient toughness
  - Good Wear and fatigue resistance



Two examples of cold extrusion. Thin arrows indicate the direction of metal flow during extrusion.

Cold Extruded Spark Plug



Production steps for a cold extruded spark plug

A cross-section of the metal part showing the grain flow pattern

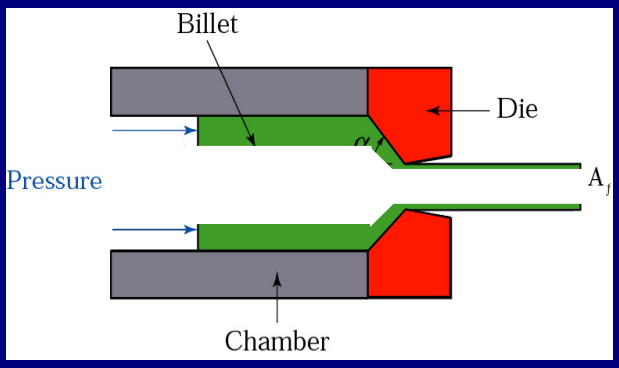
Tube extrusion

Tubes can be produced by extrusion by attaching a **mandrel** to the end of the ram. The clearance between the mandrel and the die wall determines the wall thickness of the tube.

Tubes are produced either by starting with a **hollow billet** or by a two-step extrusion in which a solid billet is first pierced and then extruded.

Extrusion of Tubing

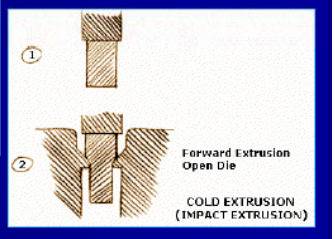
- Tubing extrusion
  - Mandrel to pierce a hole in billets
  - Hollow billets



Impact extrusion

- Produce ***short lengths of hollow shapes***, such as collapsible toothpaste tubes or spray cans.
- Requires ***soft materials*** such as aluminium, lead, copper or tin are normally used in the impact extrusion.
- A small shot of solid material is placed in the die and is impacted by a ram, which causes cold flow in the material. It may be either direct or indirect extrusion and it is usually performed on a ***high-speed mechanical press***.
- Although the process is generally performed cold, considerable heating results from the ***high speed deformation***.

** Small objects, soft metal, large numbers, good tolerances*.*



Extrusion of Hollow Shapes

- Welding-chamber method
  - Metal divides and flows around
  - Then rewelded under high pressure in welding chamber
- Aluminum and its alloys
- No lubrication allowed

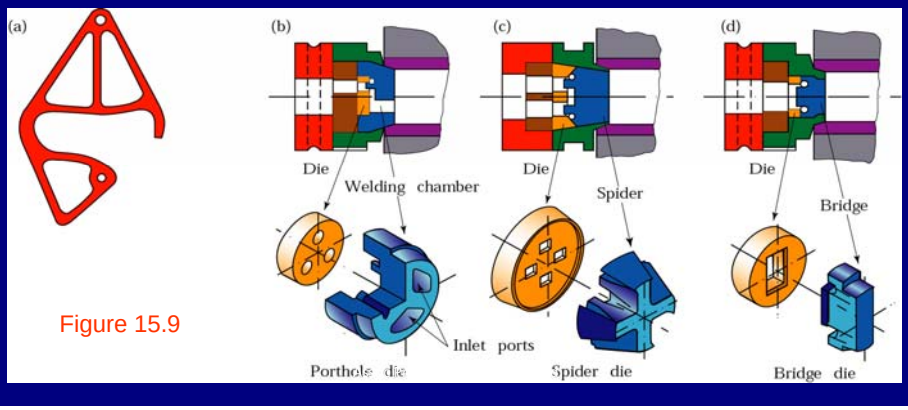
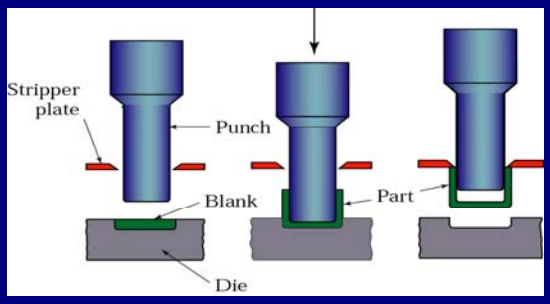


Figure 15.9

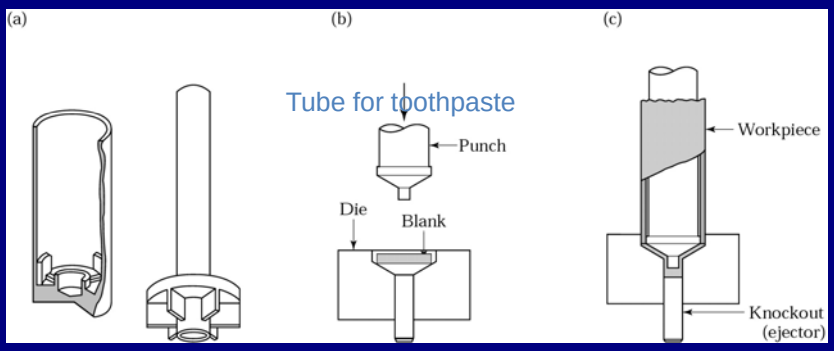
Impact Extrusion

- Similar to indirect extrusion
- Cold extrusion
- Most nonferrous metals at rates of two parts/second
- Thin walled tubular sections possible



Schematic illustration of the impact-extrusion process. The extruded parts are stripped by the use of a stripper plate, because they tend to stick to the punch.

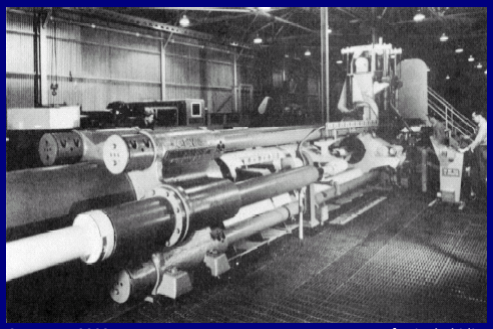
Examples of Impact Extrusion



(a) Two examples of products made by impact extrusion. These parts may also be made by casting, by forging, or by machining; the choice of process depends on the dimensions and the materials involved and on the properties desired. Economic considerations are also important in final process selection. (b) and (c) Impact extrusion of a collapsible tube

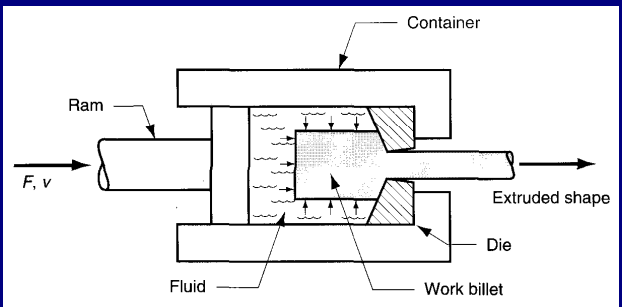
Hydrostatic extrusion

- The pressure required for extrusion is supplied through and incompressible fluid medium surrounding the billet
- Usually carried at room temperature, typically using vegetable oils as the fluid
- Brittle materials are extruded generally by this method
- It increases ductility of the material
- It has complex nature of the tooling



General view of a 9-MN (1000-ton) hydraulic-extrusion press.

Hydrostatic Extrusion



Using hydrostatic system to reduce the friction and lower the power requirement.

Sealing is the major problem.

3. Extrusion equipment

- Extrusion equipment mainly includes presses, dies and tooling
  - ❖Presses
    - Most extrusions are made with hydraulic presses
    - These can be classified on the direction of travel of the ram
      - Horizontal presses
      - Vertical presses
  - ❖Extrusion dies
    - Die design
    - Die materials

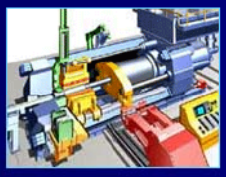
Horizontal extrusion press

(15- 50 MN capacity or upto 140 MN)

- Used for most commercial extrusion of bars and shapes.

Disadvantages:

- deformation is non-uniform due to different temperatures between top and bottom parts of the billet.

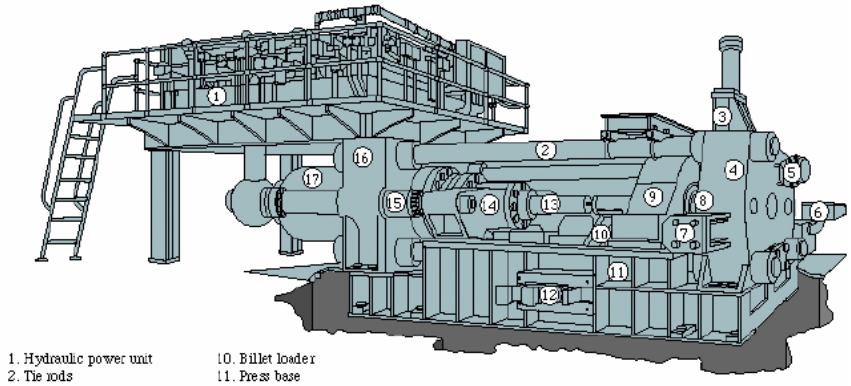


600 Tonne, DUISBURG, HYDRAULIC EXT PRESS

Extrusion press

Extrusion press

Extrusion press



1. Hydraulic power unit
2. Tie rods
3. Butt shear
4. Extrusion platen
5. Container shifting cylinders
6. Swiveling operator's console
7. Die slide
8. Container
9. Container housing
10. Billet loader
11. Press base
12. Billet loader cylinders
13. Pressing stem
14. Crosshead
15. Side cylinder
16. Cylinder platen
17. Main cylinder

Vertical extrusion press (3 – 20 MN)

Chiefly used in the production of thin-wall tubing.

Advantages:

- Easier alignment between the press ram and tools.
- Higher rate of production.
- Require less floor space than horizontal presses.
- uniform deformation, due to uniform cooling of the billet in the container.

Requirements:

- Need considerable headroom to make extrusions of appreciable length.
- A floor pit is necessary.

Vertical extrusion machine

Ram speed

- Require high ram speeds in high-temperature extrusion due to heat transfer problem from billet to tools
- ***Ram speeds*** of 0.4 – 0.6 m/sec for refractory metals, requires a hydraulic accumulator with the press
- ***Ram speeds*** of few mm/sec for aluminium and copper due to hot shotness, requires direct-drive pumping systems to maintain a uniform finishing temperature

Die design

- ***Die design*** is at the heart of efficient extrusion production.
- Dies must withstand considerable amount of stresses, thermal shock, and oxidation.

Die design

Die design
↓
CAD/CAM
↓
Milling
↓
Wire sparkling erosion
↓
Finishing
↓
Inspection

Die design consideration

- ***Wall thickness:*** different wall thicknesses in one section should be avoided.
- ***Simple shapes:*** the more simple shape the more cost effective.
- ***Symetrical:*** more accurate.
- ***Sharp or rounded corners***: sharp corners should be avoided.
- ***Size to weight ratio:***
- ***Tolerlances:*** tolerances are added to allow some distortions (industrial standards).

Die materials

- Dies are made from ***highly alloy tools steels*** or ***ceramics*** ***(zirconia, Si_3N_4)***. (for cold extrusion → offering longer tool life and reduced lubricant used, good wear resistance).
- ***Wall thickness*** as small as 0.5 mm (on flat dies) or 0.7 mm (on hollow dies) can be made for aluminium extrusion.
- ***Heat treatments*** such as nitriding are required (several times) to increase hardness (1000-1100 H_v or 65-70 HRC). This improves die life. → avoiding unscheduled press shutdown.

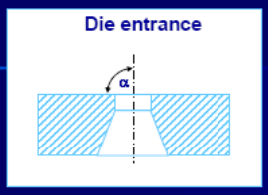
Ceramic extrusion dies


steel extrusion dies

There are two general types of extrusion dies:

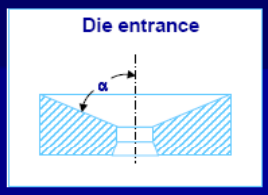
1) Flat-faced dies
2) Dies with conical entrance angle.

1) Flat-faced dies



- Metal entering the die will form a dead zone and shears internally to form its own die angle.
- A parallel land on the exit side of the die helps strengthen the die and allow for ***reworking*** of the flat face on the entrance side of the die without increasing the exit diameter.

2) Dies with conical entrance angle



- requires good lubricants.
- decreasing ***die angle*** → , increasing ***homogeneity***, lower ***extrusion pressure*** (but beyond a point the friction in the die surfaces becomes too great.
- for most operation, $45^o < \alpha < 60^o$

Remarks: transfer equipment (for hot billets) is required. prior heating of the container.

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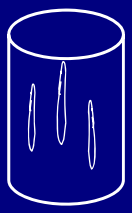
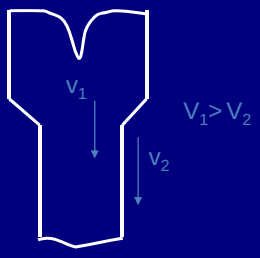
4. Common Defects in Extrusion

- Surface cracking
  - Often along grain boundaries
  - Due to high temperatures, high friction and high velocities
  - Or due to sticking of the product to the die surface



- Piping
  - Draw surface oxides and impurities toward the center of the billets
  - Remove oxides by Machining, etching or use smaller ram leaving "skull" inside



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- Cheveron (internal cracking)
  - Increases with increasing impurities, die angle
  - Decrease with increasing E.R. and friction