Hot and Cold Metal Working Processes

Metal working processes are used to shape metals into desired forms. These processes can be broadly classified into **hot working** and **cold working**.

Hot Working

Hot working refers to processes carried out **above the recrystallisation temperature of the metal**, which is typically around 30-40% of its melting point [1].

Examples of hot working processes include:

- **Forging:** Shaping metal using compressive forces applied through dies and tools. Forging can be open-die, where the metal is compressed between two flat dies, or impression-die, where dies with the inverse of the desired part shape are used [2-5].
- **Rolling:** Reducing the thickness of metal by passing it between two rotating rolls. Rolling can be flat or shape rolling depending on the desired outcome [6-8].
- **Extrusion:** Forcing metal through a die to create a specific shape. Extrusion can be direct, indirect, hydrostatic or impact extrusion [9, 10].

Advantages of hot working:

- **Lower force requirements:** Less force is needed to deform the metal at elevated temperatures [1].
- **Refined grain structure:** Hot working refines the grain structure, leading to improved mechanical properties [1].
- **No residual stress:** Recrystallisation during hot working eliminates internal stresses [1].
- **Suitable for all metals:** Hot working can be used for a wide range of metals [1].

Disadvantages of hot working:

- **Poor surface finish:** Due to oxidation and scaling at high temperatures, hot worked parts typically have a rough surface finish [1].
- **Lower dimensional accuracy:** Achieving precise dimensions is difficult in hot working due to thermal expansion and contraction [1].
- **High tooling and handling cost:** The tools and equipment used in hot working are typically expensive due to the high temperatures involved [11].

Cold Working

Cold working processes occur below the recrystallisation temperature, often at room temperature [11].

Examples of cold working processes include:

- Drawing: Reducing the cross-section of a metal rod, wire or tube by pulling it through a die [12, 13].
- Squeezing: Shaping metal by compressing it between a punch and die, including coining and embossing processes [14-16].
- Bending: Straining sheet metal around a straight axis to create a permanent bend [17].

Advantages of cold working:

- Better surface finish: Cold working produces a smoother surface finish compared to hot working [18].
- Higher dimensional accuracy: Closer tolerances and more precise dimensions can be achieved in cold working [18].
- Suitable for mass production: Cold working processes are generally faster and more automated than hot working, making them suitable for large-scale production [18].

Disadvantages of cold working:

- Higher force requirements: Greater force is needed to deform the metal at lower temperatures [11].
- Residual stress: Internal stresses can build up in the metal due to the lack of recrystallisation [18].
- Limited formability: Cold working can make the metal harder and less ductile, limiting its ability to undergo further deformation [11].

Strain Hardening

Strain hardening, also known as work hardening, is a phenomenon that occurs during cold working. As the metal is deformed, dislocations within its crystal structure increase and interact, making it more difficult for further deformation to occur [19]. This results in an increase in the metal's strength and hardness but a decrease in its ductility [19].

Annealing

Annealing is a heat treatment process used to soften metals that have been hardened by cold working [20]. This involves heating the metal to a specific temperature and then slowly cooling it to allow for recrystallisation and stress relief [20]. Annealing can also be used to improve machinability and electrical conductivity [21].

Conclusion

Both hot and cold working processes play essential roles in shaping and strengthening metals. The choice between hot and cold working depends on factors such as the desired properties of the final product, the complexity of the shape, production volume and cost considerations.

Types of Forging and Forging Defects

Forging Methods

- Open-die forging: This method involves compressing the workpiece between two flat dies. [1, 2] This deformation process reduces the height and increases the diameter of the workpiece. [2] It is also known as upsetting or upset forging. [2]
- Impression-die forging: This method involves compressing the workpiece using dies that have the inverse of the desired part shape. [3] Excess metal, called flash, flows beyond the die cavity into the gap between the die plates. [3] Flash helps constrain the material to fill the die cavity. [3]
- Flashless forging: This method compresses the workpiece in punch and die tooling that doesn't allow for flash. [4] The starting volume of the workpiece must precisely match the die cavity volume. [4] It is often considered a precision forging process and is best for simple, symmetrical geometries. [5]

Specific Forging Operations

- Upset forging: A type of open-die forging used to form heads on nails, bolts, and similar hardware. [2, 6] It is often performed cold, warm, or hot on machines called headers or formers. [6]
- Heading: A subset of upset forging used to create heads on fasteners. [2, 6] The process involves feeding wire or bar stock into a machine, heading the end, and then cutting the piece to length. [6]
- Trimming: A shearing process used to remove flash after impression-die forging. [7]

Forging Equipment

- **Forging hammers (drop hammers):** These apply an impact load to the workpiece. [5] There are two types: gravity drop hammers, which use the falling weight of a ram, and power drop hammers, which accelerate the ram using pressurised air or steam. [5]
- **Forging presses:** These apply gradual pressure for compression. [8] Types include mechanical presses, hydraulic presses, and screw presses. [8]

Forging Defects

- **Fracture:** Occurs when the material's ductility is exhausted, often leading to inter-granular fracture. [9]
- **Barreling:** This defect is caused by friction between the workpiece and die surfaces, which constrains the lateral flow of the metal. [10] This is more pronounced in hot forging due to heat transfer near the dies, cooling the metal and increasing its resistance to deformation. [10]
- **Solutions to barreling:** Limiting the deformation per step and process annealing between steps. [9]

Advantages of Impression-Die Forging

- Higher production rates. [4]
- Less metal waste. [4]
- Greater strength. [4]
- Favourable grain orientation. [4]

Limitations of Impression-Die Forging

- Inability to achieve close tolerances. [4]
- Machining is often necessary for required accuracies and features. [4]

Extrusion Explained: Types and Defects

Extrusion is a metal forming process where a material, called a billet, is pushed through a die to create a long product with a uniform cross-section [1, 2]. Imagine squeezing toothpaste out of a tube – that's similar to how extrusion works. Products like railings, tubes, and structural shapes are commonly made using extrusion [2].

Types of Extrusion

- Direct Extrusion (Forward Extrusion): The billet is placed in a container and a hydraulic ram forces it through the die opening [2]. This is the most common type of extrusion.
- Indirect Extrusion (Backward Extrusion): Here, the die moves towards the billet, causing the metal to flow in the opposite direction of the ram [3]. This method requires less force because there's less friction between the billet and container.
- Hydrostatic Extrusion: In this method, a fluid surrounds the billet and provides the pressure for extrusion [4]. This is especially useful for extruding brittle materials, as the fluid helps increase the material's ductility.
- Impact Extrusion: A high-speed punch strikes the blank, forcing the material to flow backwards through the die [5]. This is similar to indirect extrusion.
- Hot Extrusion: The billet is heated above its recrystallization temperature before extrusion [5].
- Cold Extrusion: The billet is extruded below its recrystallization temperature [5].

Factors Affecting Extrusion Force

The force required for extrusion is influenced by several factors [6]:

- Friction: Friction between the billet and die increases the force needed.
- Material Properties: Stronger materials require higher forces.
- Reduction in Area: Greater reduction in the billet's cross-sectional area requires more force.
- Speed: Higher extrusion speeds demand greater force.
- Temperature: Higher temperatures generally reduce the force needed.

Extrusion Defects

Extrusion defects can compromise the quality and integrity of the final product [7]. Common defects include:

- Centre-burst: An internal crack that forms due to high tensile stress at the centre of the extruded product. This can be caused by factors like a large die angle or a low extrusion ratio.
- Piping: A sinkhole that appears at the end of the billet in direct extrusion. This occurs when the metal in the centre of the billet doesn't flow properly.

- Surface Cracking: Cracks that form on the surface of the extruded product due to high temperatures and strain rates. This often happens when extrusion speed is too low.

Advantages of Extrusion

Extrusion offers several advantages [8]:

- Versatility: Can create a wide variety of shapes.
- High Production Rates: Suitable for mass production.
- Improved Microstructure: Extrusion can refine the grain structure and improve the material's mechanical properties.
- Close Tolerances: Can achieve high dimensional accuracy.
- Cost-Effectiveness: Efficient and economical process.
- Design Flexibility: Offers a wide range of design possibilities.

Limitation of Extrusion

The main limitation of extrusion is that the part's cross-section must remain uniform throughout its length [8].

Tube Extrusion

Tubes or pipes are made by extruding the material through a die with a mandrel in the centre [4]. The mandrel shapes the hollow interior of the tube.

Understanding Die Angle

The die angle in extrusion refers to the angle of the die's opening [4]. A smaller die angle requires more force but produces a better surface finish. A larger die angle reduces the force but can lead to surface defects.

All About Rolling

Rolling is a metalworking process where a workpiece's thickness is reduced by compressive forces from two opposing rolls. [1] It's like squeezing dough with a rolling pin! This process is essential in manufacturing, often the first step in transforming raw materials into finished products. [1-3]

Types of Rolling

Rolling can be classified in a few ways:

- Based on workpiece geometry:Flat rolling: Reduces the thickness of rectangular cross-sections. Imagine flattening a block of dough. [4, 5]
- Shape rolling: Transforms a square cross-section into a specific shape, such as an I-beam, using contoured rolls. Think of shaping dough into letters. [5, 6]
- Based on work temperature:Hot rolling: The most common type due to the large deformation required, it occurs above the material's recrystallization temperature. [1, 4] This method helps refine the grain structure and increase ductility. [7]
- Cold rolling: Performed below the recrystallization temperature, it creates finished sheet and plate stock with better surface finish and dimensional accuracy. [5]

Rolling Mills

These are the machines that do the rolling, and they come in various configurations:

- Two-high: Two opposing rolls, the simplest setup. [8]
- Three-high: Work passes through rolls in both directions, increasing efficiency. [8]
- Four-high: Smaller work rolls are supported by larger backing rolls for better control and less deflection. [8]
- Cluster mill: Multiple backing rolls on smaller rolls provide even more support and precision. [8]
- Tandem rolling mill: A sequence of two-high mills allows for continuous rolling and greater reduction in thickness. [8, 9]

Rolling mills are massive and expensive, reflecting the heavy-duty work they perform. [8]

Rolling Defects

Sometimes, things can go wrong during rolling. Here are some common defects:

- Waviness: Caused by improper roller speeds, it results in an uneven surface. [9]
- Zipper cracks: Occur when there is excessive rolling in the center of the workpiece, leading to cracks. [9]
- Edge cracks: Similar to zipper cracks but happen on the outside edges due to too much rolling. [9]
- Alligatoring: Caused by excessive tensile stress in the part, it leads to the workpiece splitting and resembling an alligator's scales. This can also be caused by defects in the material itself. [9]

Importance of Rolling

Rolling is crucial for producing a wide array of products, including:

- Blooms: Large, square or rectangular pieces used for further processing. [3, 7]
- Billets: Smaller, square or circular pieces used for various shapes like rods and bars. [2, 3]
- Slabs: Rectangular pieces rolled into plates, sheets, and strips. [2, 3]
- Construction shapes: I-beams, L-beams, U-channels, and rails. [6]
- Round and square bars and rods. [6]
- Threads on bolts and screws (thread rolling). [6]

Rolling provides numerous advantages:

- Higher production rates compared to machining. [10]
- Less material waste. [10]
- Greater strength due to work hardening. [6, 10]
- Favorable grain orientation for enhanced properties. [10]
- Improved microstructure and physical properties. [11]
- Close tolerances are possible, especially with cold rolling. [11]
- Economical for mass production. [11, 12]

Overall, rolling is a vital and versatile process in modern manufacturing, playing a key role in shaping the world around us

Sheet Metal Operations and Shearing Operations

Sheet metal operations involve working with relatively thin sheets of metal, typically between 0.4 mm and 6 mm thick [1]. Anything thicker than 6mm is considered plate stock [1]. These operations are usually performed cold and result in products with high strength, good dimensional accuracy, and a better surface finish [1].

Sheet metal operations can be broadly categorised as either cutting or forming: [2]

- Cutting (Shearing) operations: Involve separating or removing material from the sheet. The metal is stressed beyond its ultimate strength [3].

- Forming operations: Change the contour of the sheet without removing material [4]. The stresses applied are below the metal's ultimate strength [4].

Shearing Operations

Shearing is a cutting operation where sheet metal is separated between two sharp cutting edges [3, 5]. Think of it like using scissors to cut paper.

The sources list many types of shearing operations, including: [3, 6-8]

- Punching (Piercing): Creating holes of various shapes in the sheet. The punched-out material is considered waste.
- Blanking: Cutting a specific shape from the sheet. The cut-out shape is the desired product, and the remaining sheet is waste.
- Notching: Removing a piece of metal from the edge of a sheet or blank.
- Perforating: Creating multiple small, closely spaced holes in the sheet.
- Slitting: Making incomplete holes in the sheet.
- Lancing: Partially cutting a hole and bending one side down to form a tab. This operation doesn't produce scrap.
- Parting: Cutting a sheet metal strip using a punch with two cutting edges.
- Shaving: Removing a thin strip of metal from the edge of a blanked part to achieve accurate dimensions and a smooth edge.
- Fine Blanking: Blanking sheet metal parts in one step to achieve close tolerances and smooth edges.
- Trimming: Removing excess material from the edges of a previously formed component.

Shearing Dies

Shearing operations are performed using dies. The clearance between the punch and die is crucial for the quality of the sheared edge and the force required for the operation [9].

- Typical clearances: Range from 2% to 8% of the sheet thickness [9]. Thicker sheets generally require larger clearances [9].
- Impact of clearance: Smaller clearances result in better edge quality but require higher forces [9].
- Beveled edges: To reduce shearing force, especially for thick sheets, the punch and die surfaces can be beveled [10]. This controls the area being sheared at any given time [10].

Types of Shearing Dies

Different types of shearing dies are used for various applications and production volumes: [11, 12]

- **Progressive dies:** Used for high-volume production where multiple operations (punching, blanking, notching) are performed in sequence on a single strip of metal.
- **Compound dies:** Perform several operations simultaneously on the same strip at a single station. Suitable for simpler shearing operations.
- **Transfer dies (Combination dies):** The sheet metal is moved through different stations arranged in a line or circle, with each station performing a specific operation.

This information from the sources explains the basics of sheet metal operations, focusing on the cutting processes involved in shearing.