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Introduction to Stamping Part Design and Surface Treatment



- 1** Basic forming processes for stamped parts
- 2** Design considerations for stamped parts
- 3** Surface treatment of stamped parts



1

Basic forming processes for stamped parts

This document introduces the principles of sheet metal stamping and its process classifications.

- Stamping is a forming process that uses a press and a die to apply external force to **sheet metal, strip metal, tubes, and profiles**, causing them to undergo plastic deformation or separation, thereby obtaining workpieces (stamped parts) with the desired shape and dimensions.
- Stamping is mainly **classified by process**, and can be divided into two main categories: **separation processes** and **forming processes**.



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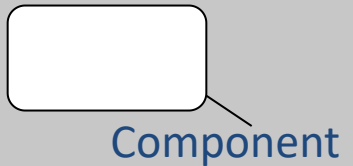
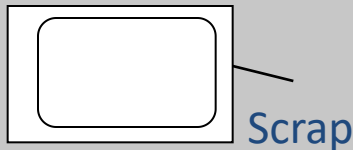
Separation process (blanking process)

The purpose is to separate the stamped part from the sheet metal along a specific contour line, while ensuring the required quality of the separated surface.

Separation processes: blanking (cutting out, punching), shearing, notching, trimming, slitting.

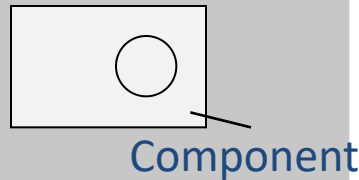
Separation process (blanking/stamping)

Falling material



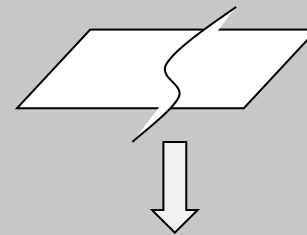
Using a die, a part is cut out along a closed curve. The cut-out portion is the finished part. This process is used to manufacture various flat-shaped parts.

Punching



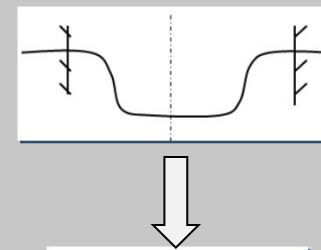
Using a die, material is punched out along a closed curve; the punched-out portion is waste material. This process is used to manufacture various flat-shaped parts.

Cut off



Separation is achieved by using a die to cut along an open curve.

Trimming



The edges of the molded parts are trimmed or cut into a specific shape.



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The deformation process of the sheet metal during blanking.

Deformation process

When the die clearance is normal, the metal stamping process can be divided into three stages.

Elastic deformation stage

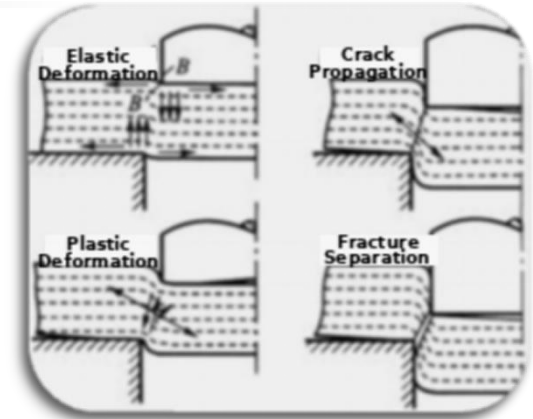
The sheet metal undergoes deformations such as elastic compression, bending, and stretching.

Plastic deformation stage

When the stress in the sheet metal reaches the yield limit, the sheet metal begins to undergo plastic shear deformation.

Fracture and separation stage

The formed cracks extend into the material along the direction of maximum strain rate, developing in a wedge shape.



The deformation process of the sheet metal during blanking.

Elastic deformation

When a material is subjected to an external force, it undergoes deformation or a change in size, and the deformation that is reversible is called elastic deformation.

Plastic deformation

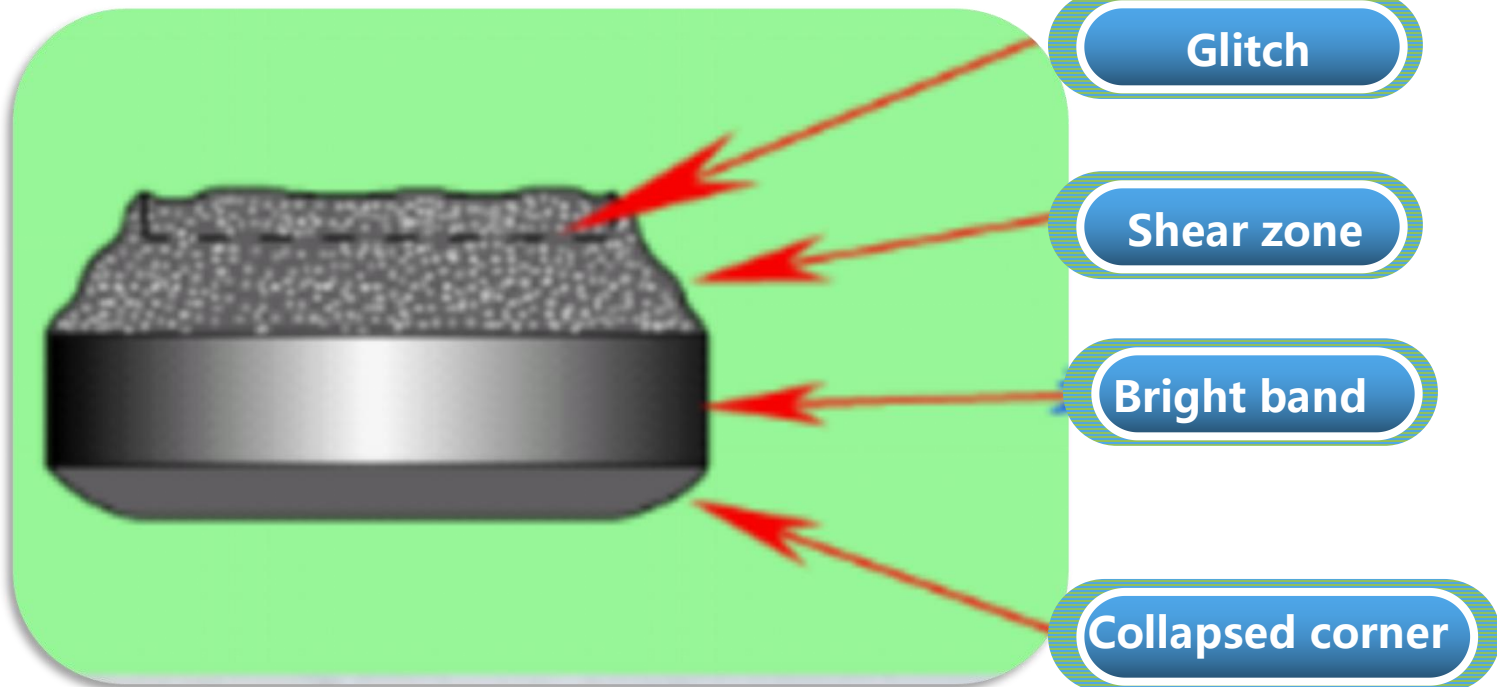
This refers to the deformation of a material that occurs under the action of an external force and does not recover after the external force is removed.



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After punching, the cross-section of the sheet metal is divided into four parts.





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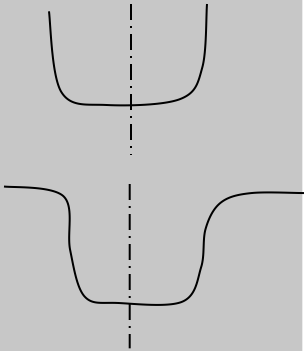
Forming process

It involves causing plastic deformation of the sheet metal without damaging it, thereby forming workpieces of the desired shape and size.

Forming processes: bending, rolling, twisting, deep drawing, thinning deep drawing, flanging (hole flanging, outer edge flanging), necking, expanding, corrugating, hemming, bulging, spinning, shaping, straightening, stamping, extrusion (forward extrusion, backward extrusion, compound extrusion).

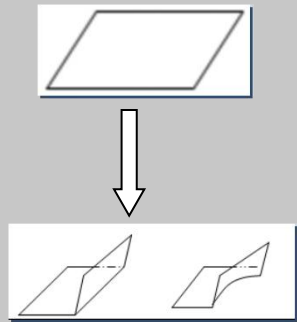
Forming process

Drawing



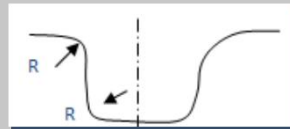
The sheet metal blanks are formed into various open, hollow parts.

Hemming



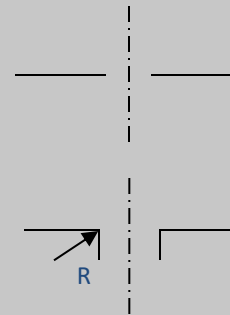
The edges of the sheet metal or semi-finished product are formed along a specific curve with a specific curvature to create an upright edge.

Plastic surgery



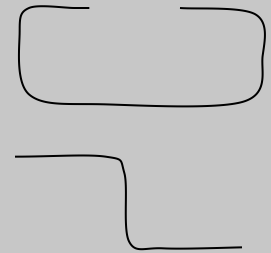
This is a forming method used to improve the accuracy of already formed parts or to obtain small fillet radii.

Drilling holes



A raised edge is formed on pre-punched sheet metal or semi-finished products.

Bending and stretching



The sheet metal is bent along a straight line into various shapes.



2

Design considerations for stamped parts

Introduction to various forming and stamping processes.

The stampability of stamped parts in the blanking and stamping process.

The stampability of bent parts.

The stampability of deep-drawn parts

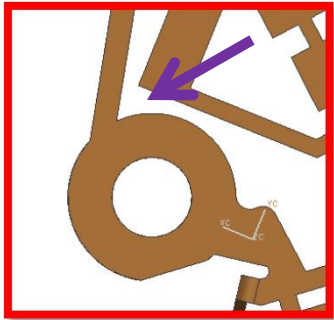
Introduction to forming processes such as necking, flanging, and expansion.

**Design
Highlights**

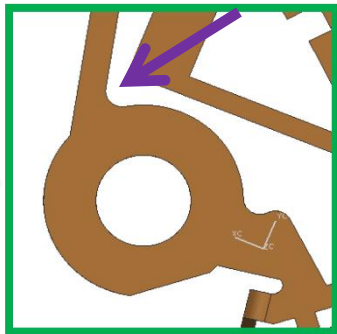
- The stampability of stamped parts in the blanking and stamping process.

1) .The shape and angles of the stamped parts.

- The shape design of stamped parts should be as simple and symmetrical as possible to minimize waste during layout.
- The corners of stamped parts should avoid sharp angles and should have appropriate rounded edges.



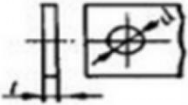
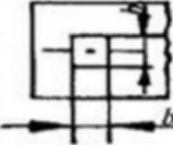

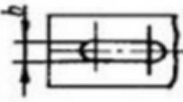
unreasonable



Reasonable

Connection Angle	$\alpha > 90^\circ$	$\alpha < 90^\circ$	$\alpha > 90^\circ$	$\alpha < 90^\circ$
Diagram				
Low Carbon Steel	0.30 t	0.50 t	0.35 t	0.60 t
Brass, Aluminum	0.24 t	0.35 t	0.20 t	0.45 t
High Carbon Steel, Alloy Steel	0.45 t	0.70 t	0.50 t	0.90 t

2) .Minimum hole diameter for punching (**the hole diameter should not be too small during punching**). The minimum dimensions are shown in the table below.

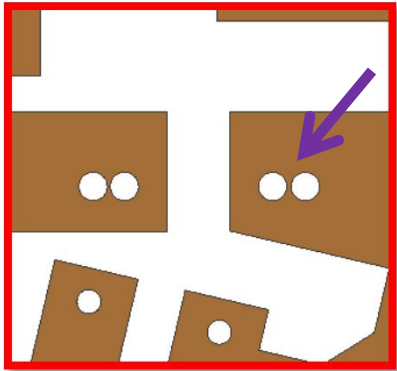
Material				
Steel $\tau_k \geq 685$ MPa	$d \geq 1.5 t$	$b \geq 1.35 t$	$b \geq 1.2 t$	$b \geq 1.1 t$
Steel $\tau_k \approx 390-685$ MPa	$d \geq 1.3 t$	$b \geq 2.2 t$	$b \geq 1.0 t$	$b \geq 0.9 t$
Steel $\tau_k \approx 390$ MPa	$d \geq 1.0 t$	$b \geq 0.9 t$	$b \geq 0.8 t$	$b \geq 0.7 t$
Brass, Copper	$d \geq 0.9 t$	$b \geq 0.8 t$	$b \geq 0.7 t$	$b \geq 0.6 t$
Aluminum, Zinc	$d \geq 0.8 t$	$b \geq 0.7 t$	$b \geq 0.6 t$	$b \geq 0.5 t$

The structural dimensions of stamped parts (such as hole diameter, hole spacing, etc.) must take into account the material thickness.

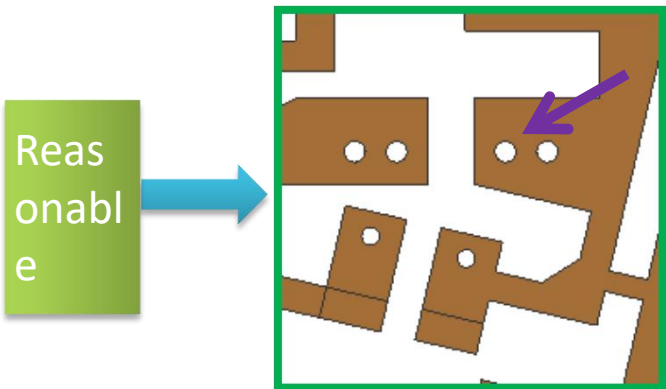
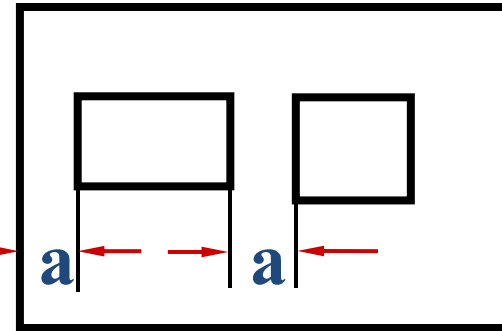
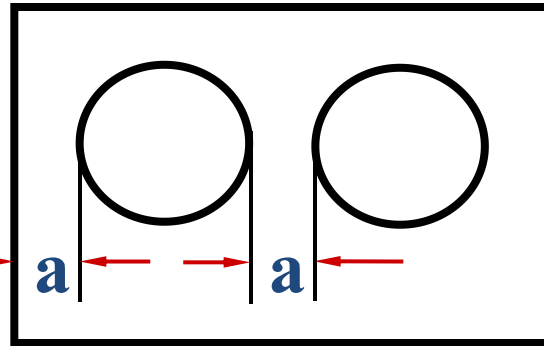


3) Minimum hole spacing and hole edge distance

➤ The distance between holes and between holes and edges in stamped parts should not be too small.



unreasonable



Reasonable

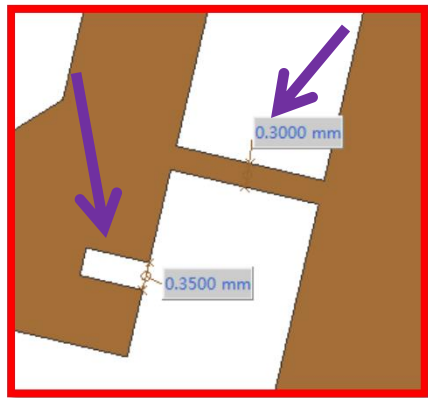
Hard steel: $a = (1.3 \sim 1.5) * t$

Brass, mild steel: $a = (0.9 \sim 1.0) * t$

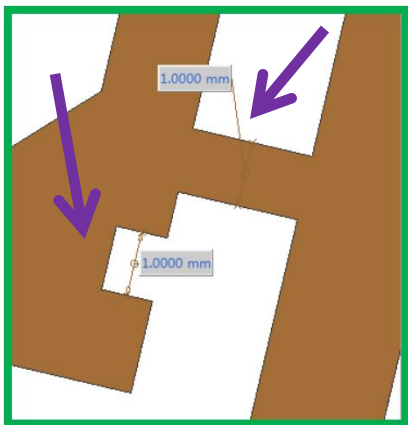
Copper, aluminum, zinc: $a = (0.75 \sim 0.8) * t$

4) . The minimum width of the protruding cantilever and the groove.

➤ The protruding cantilever and groove width of the stamped parts should not be too small; otherwise, it will reduce the mold life and workpiece quality.



unreasonable



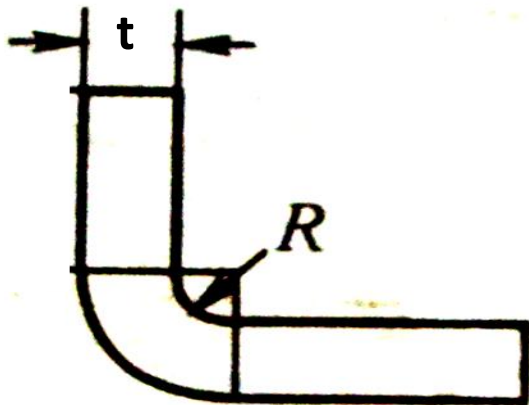
Reasonable

Material	Width b
Hard Steel	$(1.5 \sim 2.0)t$
Brass, Mild Steel	$(1.0 \sim 1.2)t$
Copper, Aluminum	$(0.8 \sim 0.9)t$



The stampability of bent parts.

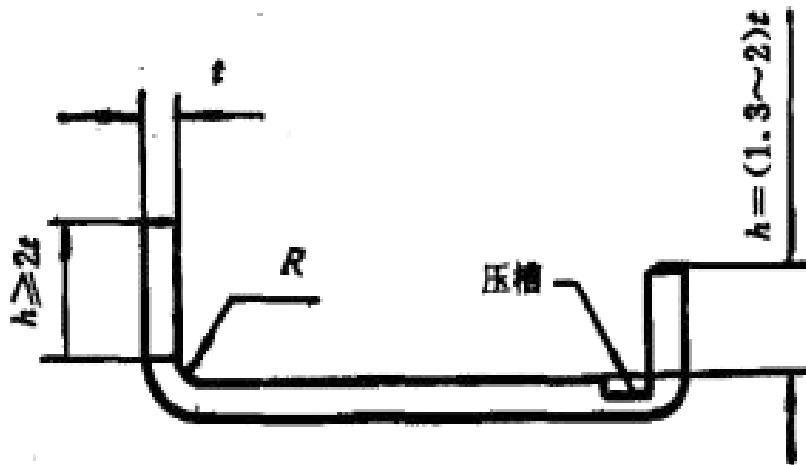
- 1) .When a material is bent, if the bending radius exceeds the material's yield strength, cracks and fractures will occur. Therefore, excessively small bending radii should be avoided.
- 2) The radius of the rounded corner (R-value) should ideally not exceed 1.5 times the material thickness. This is because an excessively large radius will result in significant springback after bending.



Material (Thickness t)	Normalized / Annealed		Cold-Work Hardened	
	Bend Line Orientation			
	Perp. to Grain	Parallel to Grain	Perp. Grain	Par. Grain
08L 10	0.1t	0.4t	0.4t	0.8t
15 20	0.1t	0.5t	0.5t	1.0t
25 30	0.2t	0.6t	0.6t	1.2t
35 40	0.3t	0.8t	0.8t	1.5t
45 50	0.5t	1.0t	1.0t	1.7t
55 60	0.7t	1.3t	1.3t	2.0t
Aluminum	0.1t 0.35t 0.5t			1.0t
Copper	1.35t 1.0t			2.0t
Soft Brass		0.35t	0.35t	0.8t
Half-hard Brass	0.1t 0.35t 0.5t			1.2t

- 3) .The bending height of the bent part should not be too long, and at the same time, H should not be too small, especially when the material thickness $t > 2\text{mm}$. A very small H (**remember this**) will make bending difficult and it will be hard to obtain parts with accurate shapes.

When the bending angle of a bent part is 90° , to facilitate forming, the height of the straight edge of the bent part should be $h > 2t$. When $h = 1.3t - 2t$, R should be approximately 0, or bending methods such as using a die with a groove should be employed (see the figure below).



4). The bend line of a bent part should ideally not be designed at a location where the width changes abruptly (as shown in the figure below), to avoid tearing.

If it is absolutely necessary to design the feature at a location where the width changes abruptly, process holes or grooves can be pre-punched at the point of width change.

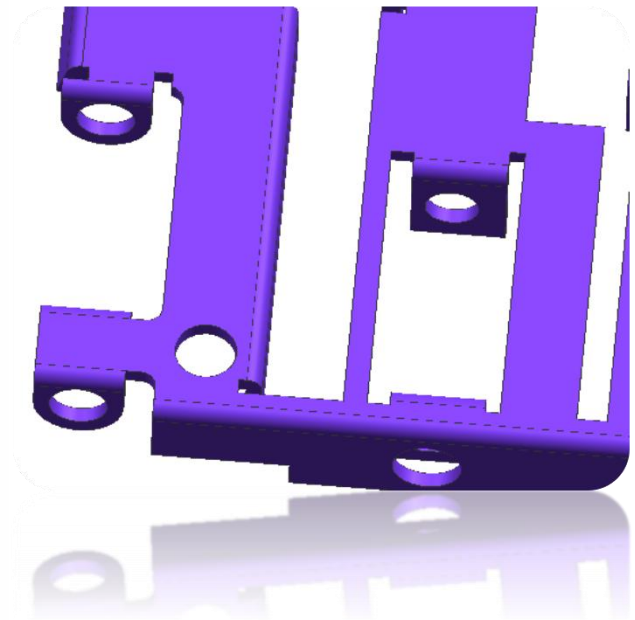
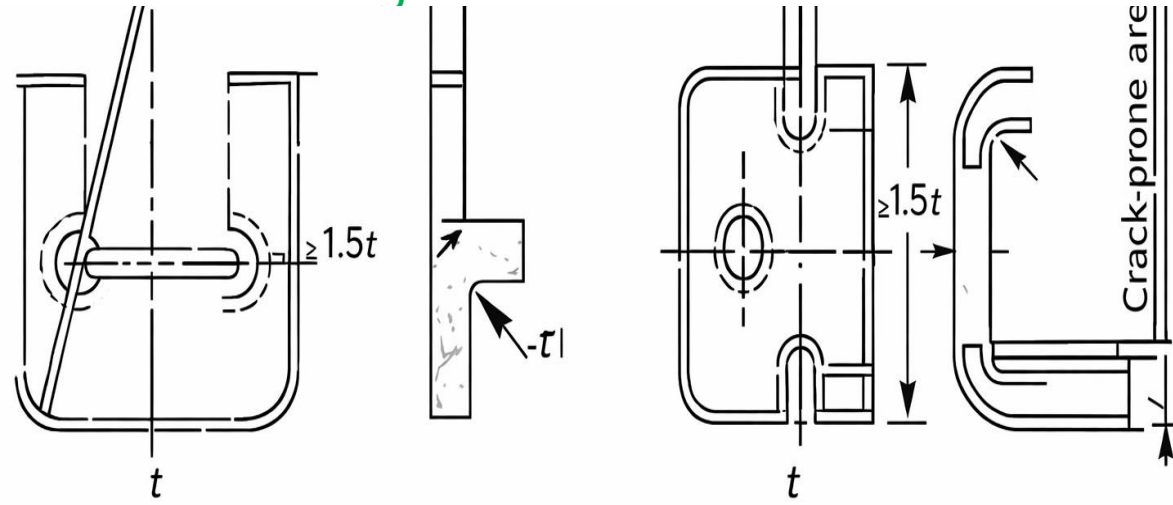


Fig. 2-4 Measures to Prevent Cracking at Bends

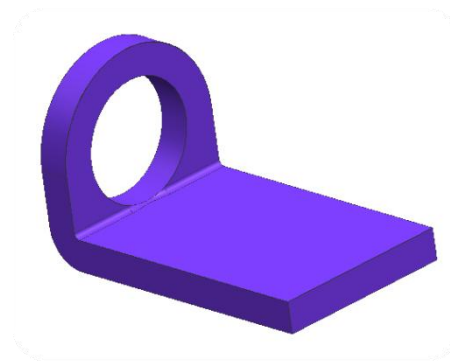
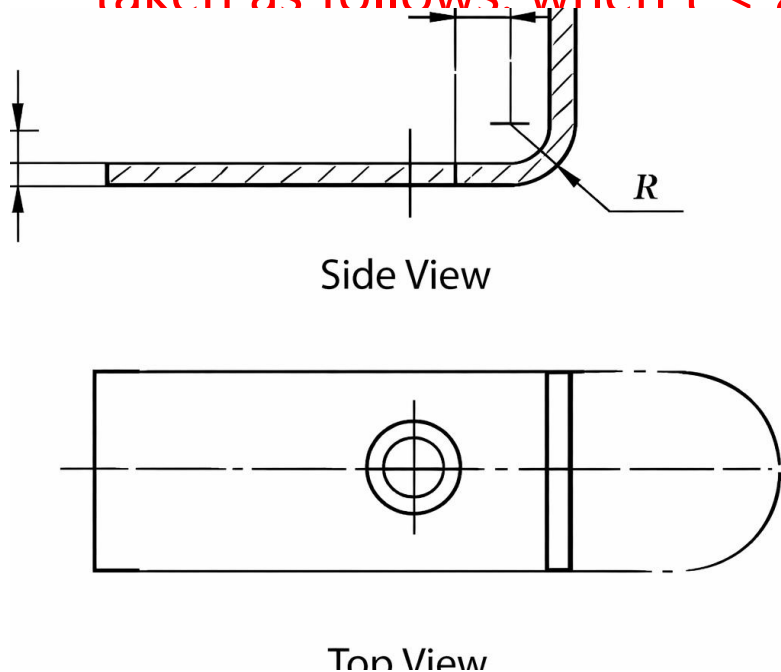
a) Relief hole

b) Relief slot

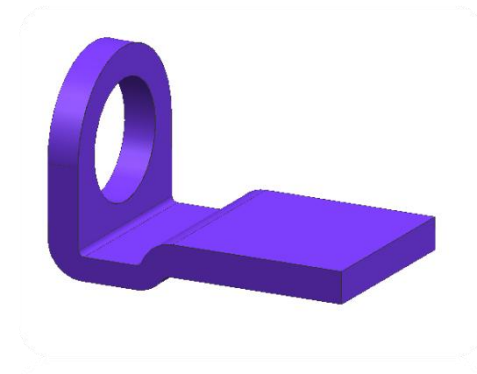
5) .For curved parts with holes, if the holes are located near the bend, the bending process will cause the holes to deform.

Solution: Ensure these holes are located outside the deformation zone.

As shown in the figure below, for bent parts, the distance from the edge of the hole to the center of the bending radius R is taken as follows: when $t < 2\text{mm}$, $l \geq t$; when $t \geq 2\text{mm}$, $l \geq 2t$.



Faulty design



Suggested design

6) .When the bent part consists of both wide and narrow sections, the distance at the transition point L must be greater than or equal to R , as shown in the figure below.

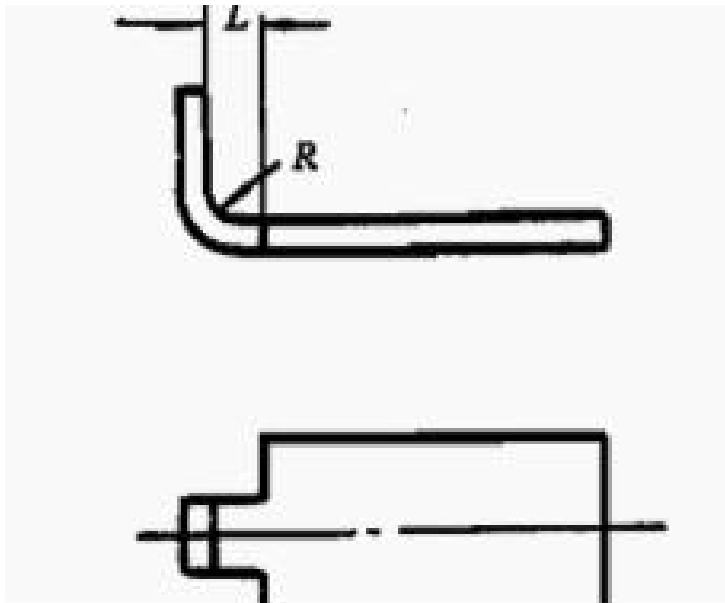


Fig. 2-28 Transition Distance

7).For symmetrical parts, the bending radii on both sides should be identical to ensure balanced forces during the bending process and prevent slippage, as shown in the figure below.

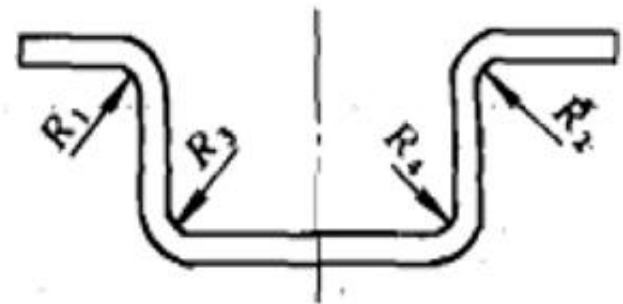


Fig. 2-8 Symmetrical Bent Part
Corner Radii: $R_1 = R_2$; $R_3 = R_4$

8) .When designing bent parts, due to the irregular shape of the bend and the overall stamped part, it is necessary to design reference holes or reference edges on the stamped part and specify tolerances based on these references.

For example, surfaces, edges, and holes can be used as datum features, but try to avoid setting datum features in locations that are difficult to measure, such as the center of a space or elements that are difficult to define, as shown in the figure below.

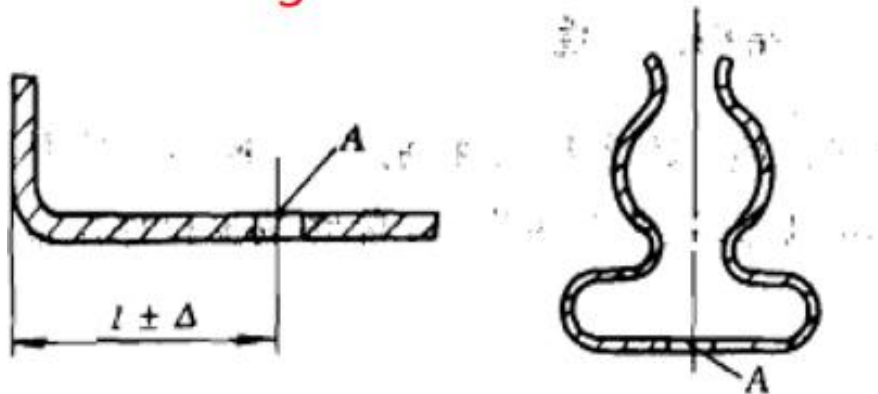


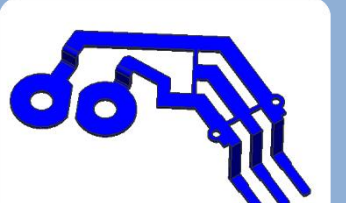
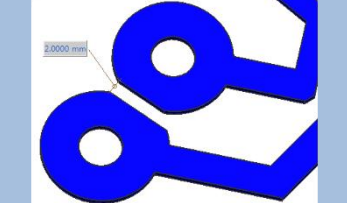
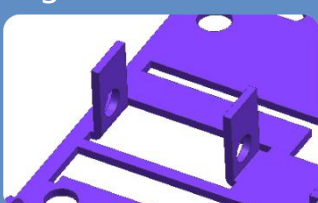
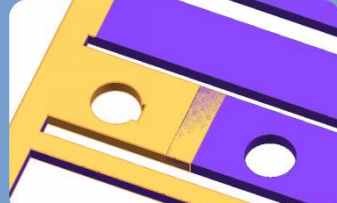
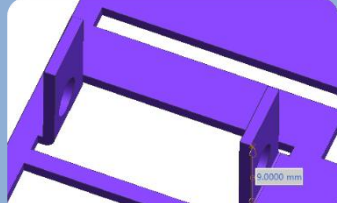
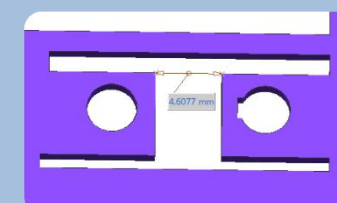


Fig. 2-9 Process Locating Hole for Bent Parts
A — Process Locating Hole

9) .When designing bent parts, it's important to consider whether there is enough space for the material to unfold before bending (the distance between the two pieces should be greater than t).

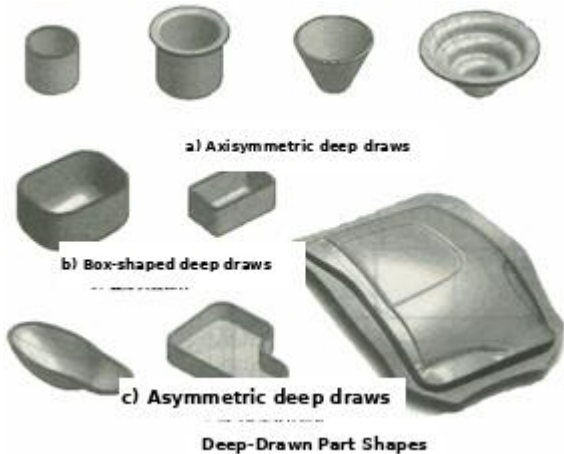
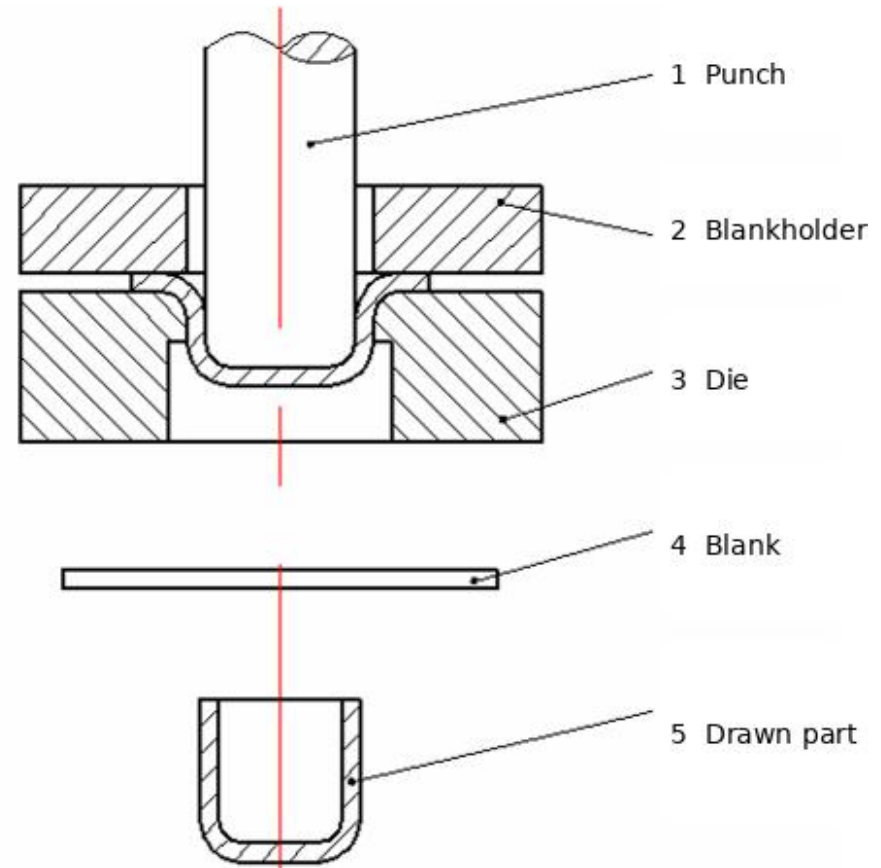
<p>① Incorrect bending direction design.</p> 	<p>② Interference occurs after unfolding.</p> 
<p>Bending Direction</p>	
<p>③ The expansion direction is correct.</p> 	<p>④ No interference after unfolding.</p> 

<p>① Bending height design error</p> 	<p>② There is interference after expansion.</p> 
<p>Bending Distance</p>	
<p>③ The bending direction is correct.</p> 	<p>④ No interference after unfolding.</p> 

● The stampability of stretched parts.

1) Deep drawing concept

This is a stamping process that uses molds to press flat blanks into hollow parts with various openings, or to press already-made hollow parts with openings into other shapes and sizes.



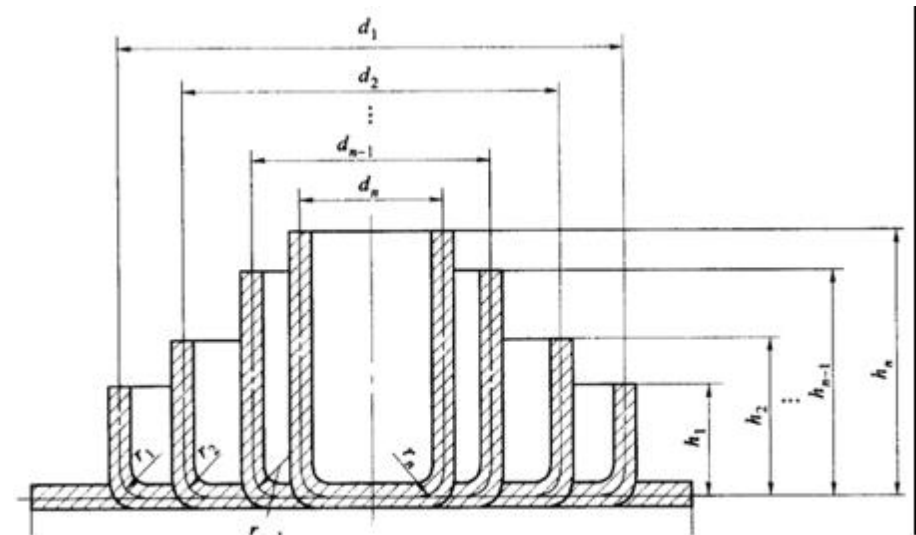
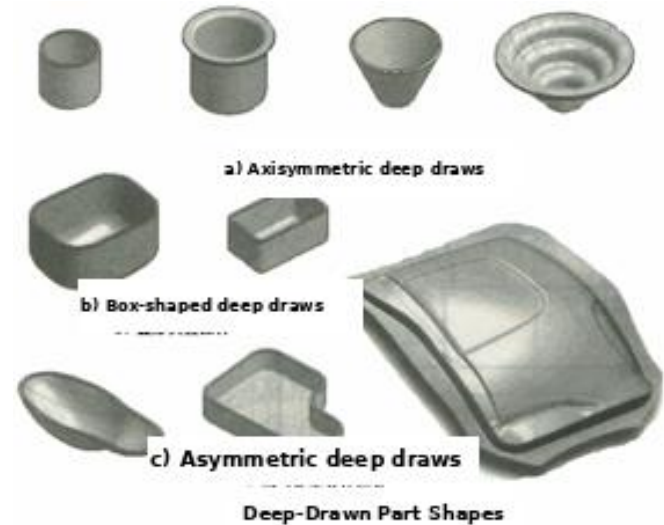
- **Classification of deep drawing processes**

- 1) Classified by wall thickness variation:

- ① General deep drawing (where the workpiece wall thickness remains unchanged)
- ② Thinning during deep drawing (the workpiece wall thickness is reduced)

- 2) Classified by the shape of the blank used:

- ① First drawing operation (using a flat blank)
- ② Subsequent drawing operations (using open, hollow parts as blanks)

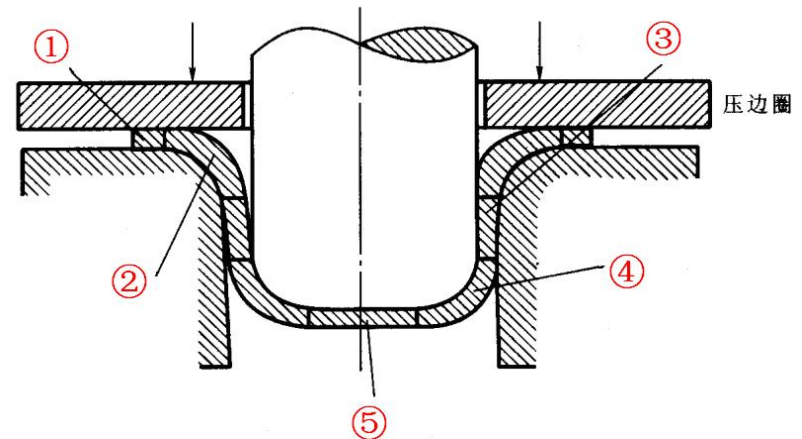
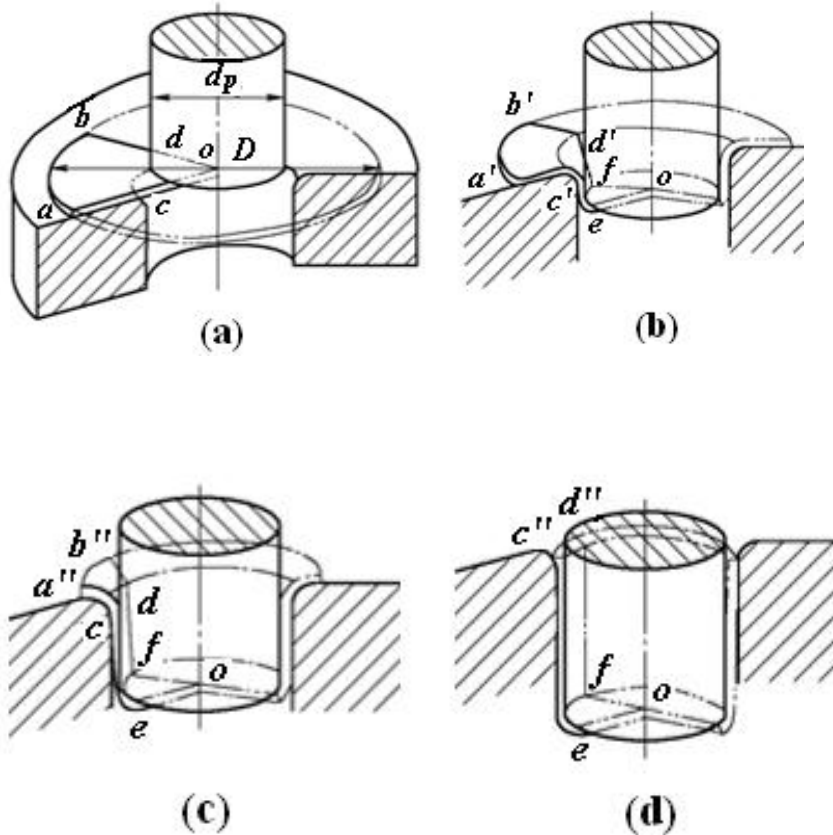


Multi-stage Deep Drawing of a Cylindrical Part

3) Deep drawing deformation process:

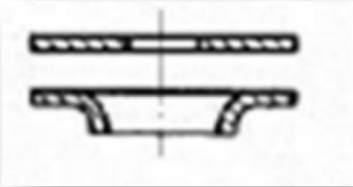
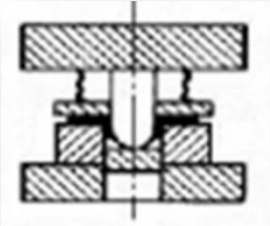
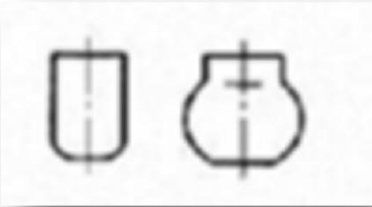
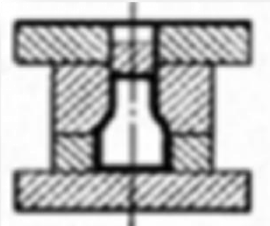
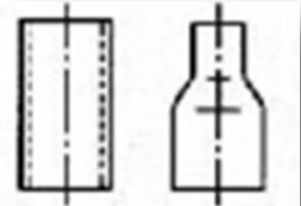
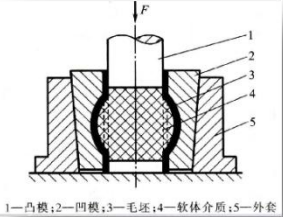
4) Changes in different parts of the workpiece during the deep drawing process:

- ① Flat flange section (main deformation zone)
- ② The rounded portion (transition area) of the die.
- ③ Cylinder wall section (deformation zone)
- ④ The rounded portion (transition area) of the punch.
- ⑤ Bottom of the cylinder (small deformation zone)





- Introduction to forming processes such as necking, flanging, and expansion.

Forming category	Simplified diagram	Forming Principle	Mold schematic diagram
Hemming		This is a forming process in which a mold is used to create a straight wall or flange with a specific angle along a closed or open curved edge on the flat or curved surface of a workpiece.	
Narrowing		Swaging is a forming process in which a pre-formed cylindrical part or tube blank is reduced in diameter at its opening using a swaging die.	
Expansion		A forming process that uses a mold to apply outward radial force to a hollow part, causing a localized expansion of its diameter.	 <p>1—凸模;2—凹模;3—毛坯;4—软体介质;5—外套</p>



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- **Key design considerations for stamped parts**

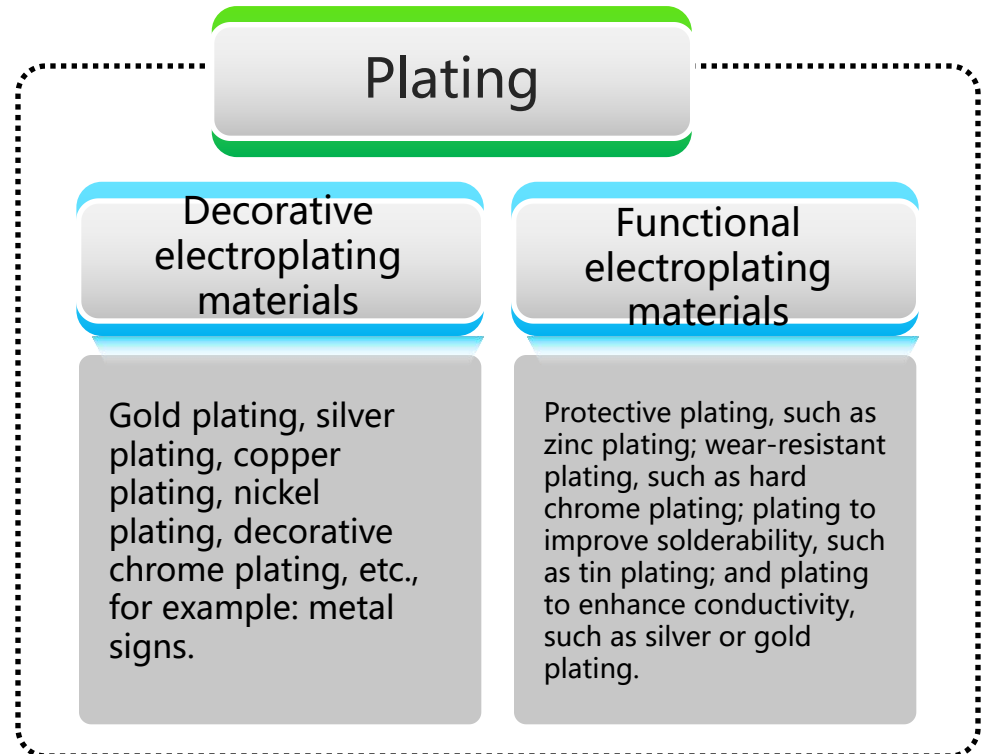
- 1、 Avoid right angles; use curved transitions.
- 2、 There is sufficient distance between holes, between holes and edges, and between holes and curved sections.
- 3、 The bending radius should not be too small, and the bending height should be appropriate.
- 4、 Thin plates can have their stiffness and strength increased through the use of reinforcing ribs.
- 5、 Pay attention to the fiber direction of the sheet material.

3 Surface treatment of stamped parts

Introduction to different types of surface treatments for stamped parts.

- Surface treatments for stamped products include electroplating (zinc, cadmium, copper, chromium, tin, nickel, gold, silver, etc.), electrostatic powder coating, painting, electrophoresis, and screen printing.
- Widely used applications include powder coating, spray painting, blackening, electrophoresis, galvanizing, and nickel plating.

- The most widely used surface treatment method is electroplating.



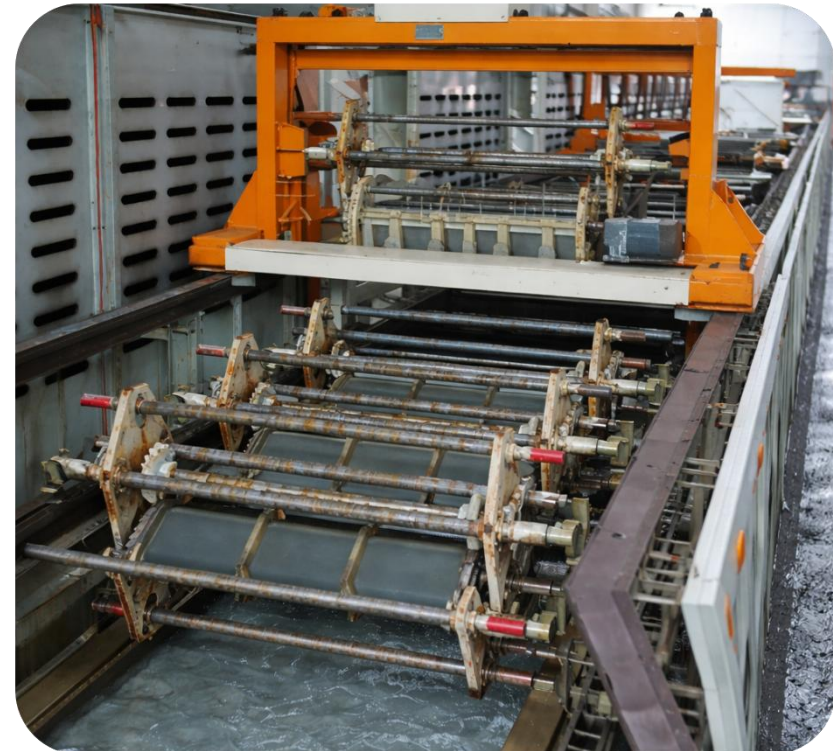


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Plating:

In electroplating, the anode is made of the plating metal or other insoluble material, and the workpiece to be plated serves as the cathode. The cations of the plating metal are reduced on the surface of the workpiece to form the plating layer. To eliminate interference from other cations and ensure a uniform and strong plating layer, a solution containing the plating metal cations is used as the electroplating solution to maintain a constant concentration of the plating metal cations. The purpose of electroplating is to deposit a metal coating on the substrate, changing the surface properties or dimensions of the substrate. Electroplating can enhance the corrosion resistance of metals (the plating metal is often a corrosion-resistant metal), increase hardness, prevent wear, improve conductivity, lubricity, heat resistance, and surface aesthetics.





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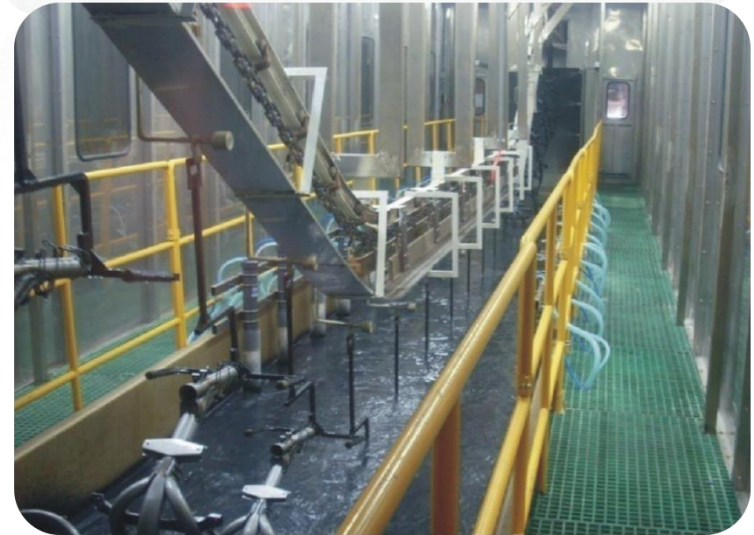
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Electrophoresis:

Electrophoresis involves applying a voltage to electrophoretic paint between the anode and cathode. The charged paint ions migrate to the cathode and, through an alkaline reaction at the cathode surface, form an insoluble substance that deposits on the workpiece surface.

Characteristics of the electrophoretic surface treatment process:

The electrophoretic paint film has the advantages of being full, uniform, flat, and smooth. The hardness, adhesion, corrosion resistance, impact resistance, and penetration performance of the electrophoretic paint film are significantly superior to other coating processes.





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Turning black:

The surface blackening treatment of steel parts, also known as bluing, works by rapidly oxidizing the surface of the steel product to form a dense protective oxide film, thereby improving the steel part's rust resistance. Currently, the commonly used methods for blackening treatment include the traditional alkaline heating method and the more recently developed room-temperature blackening method.



Galvanized, tinned:

Galvanizing and tinning refer to surface treatment techniques that involve coating the surface of metals, alloys, or other materials with a layer of zinc for aesthetic purposes, corrosion protection, and other benefits. The main method used today is hot-dip galvanizing.



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Phosphidation:

Phosphating is a process of forming a phosphate chemical conversion coating through chemical and electrochemical reactions. The resulting phosphate conversion coating is called a phosphating film. The main purposes of phosphating are: to provide protection to the base metal, preventing corrosion to a certain extent; to serve as a primer before painting, providing adhesion and corrosion resistance to the paint film; and to act as a friction-reducing lubricant in metal cold working processes.





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Spraying:

This process uses pressure or electrostatic force to apply paint or powder to the surface of a workpiece, providing it with corrosion protection and decorative effects.



Baked paint:

The substrate is coated with a primer and then a topcoat. After each coat of paint is applied, it is sent to a dust-free, temperature-controlled drying room for baking.



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Passivation:

The passivation mechanism can be explained by the thin film theory, which posits that passivation is due to the interaction between the metal and an oxidizing agent. This interaction produces a very thin, dense, and well-covering passivation film that is firmly adsorbed onto the metal surface. This film exists as an independent phase, usually a compound of the metal oxide, and acts to completely separate the metal from the corrosive medium, preventing contact between the metal and the corrosive agent. This effectively stops the dissolution of the metal, resulting in a passivated state and providing corrosion protection.



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Thank you all
for watching.