SHEET METAL FABRICATION

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ABSTRACT

The paper deals with to recognize common manufacturing processes of Sheet Metal Fabrication. To recognize common material used in the industry and understand the principles of design and fabricate of sheet metal products. It also gives information about limitation of manually operated sheet bending machine and power operated sheet bending machine.

Key Words: Shape, Bending, Penetration, Automatic, Hoppers, Frame, Fabrication, Production

I. INTRODUCTION

The term 'sheet metal fabrication' is generally applied to the making of articles in metal or alloy sheets within a range from 10 Gauge (3.25 mm) to 32 Gauge (0.274 mm). Broadly speaking, sheet metal fabrication may include shaping and forming of sheet metals by use of punching machines and presses. Sheet metal plays an essential role in all aspects of our everyday lives. Its many applications include use in home appliance, building construction, air conditioning, and all kinds of transportation system. Although there is a requirement for high labour content and although plastic materials are replacing sheet metal, sheet metal work is still growing. This happening related to CNC processing equipment has opened up new opportunities for the engineers as such equipment reduces the labour content in sheet metal work and improves productivity.

II. SHEET METAL GAUGE

Gauge sizes are numbers that indicate the thickness of a piece of sheet metal, with a higher number referring to a thinner sheet. The equivalent thicknesses differ for each gauge size standard, which were developed based on the weight of the sheet for a given material. The Manufacturers' Standard Gage provides the thicknesses for standard steel, galvanized steel, and stainless steel. The Brown and Sharpe Gage, also known as the American Wire Gage (AWG), is used for most non ferrous metals, such as Aluminum and Brass.

III. GAUGE TABLE OF GALVANIZED STEEL

S.NO	Thickness			Weight Per Area	
	Gauge	in	mm	lb/ft²	kg/m²
01	10	0.1382	3.510	5.638	27.527
02	11	0.1233	3.132	5.030	24.559
03	12	0.1084	2.753	4.422	21.591
04	13	0.0934	2.372	3.810	18.603

05	14	0.0785	1.994	3.202	15.636
06	15	0.0710	1.803	2.896	14.143
07	16	0.0635	1.613	2.590	12.648
08	17	0.0575	1.461	2.346	11.453
09	18	0.0516	1.311	2.105	10.278
10	19	0.0456	1.158	1.860	09.083
11	20	0.0396	1.006	1.6151	07.888
12	21	0.0366	0.930	1.493	07.290
13	22	0.0336	0.853	1.371	6.692
14	23	0.0306	0.777	1.248	6.095
15	24	0.0276	0.701	1.126	5.497
16	25	0.0247	0.627	1.008	4.920
17	26	0.0217	0.551	0.885	4.322
18	27	0.0202	0.513	0.824	4.023
19	28	0.0187	0.475	0.763	3.725
20	29	0.0172	0.437	0.702	3.426
21	30	0.0157	0.399	0.640	3.127
22	31	0.0142	0.361	0.576	2.828
23	32	0.0134	0.340	0.547	2.669

COMMON SHEET METAL MATERIALS

A large quantity of material used in sheet metal work is steel rolled into sheets of various thickness and then coated with different protective materials, such as black oxide, zinc, and tin. The purpose of such a coating is to protect the steel from corroding and therefore make it last longer.

BLACK IRON SHEET

Black iron sheet is steel sheet coated with a thin layer of oxide to provide moderate protection against rusting. The sheets are normally used for objects that are to be painted.

GALVANIZED STEEL SHEET

Galvanized sheet metal consists of soft steel sheets coated with zinc. They can be easily recognized by its typical spangled appearance. Zinc coating is highly resistant to corrosion as long as it remains intact on the sheet. Galvanized steel will have high corrosion resistance which prevents galvanic corrosion (rusting) of the base materials, steel. The effect of this is that the zinc is consumed first as a sacrificial anode, so that it cathodically protects exposed steel. This means that in case of scratches through the zinc coating, the exposed steel will be cathodically protected by the surrounding zinc coating. Good quality galvanized steel can be bent and straightened out several times without the zinc peeling from the sheet. However, if the zinc is damaged through welding, grinding, or any other process, then the steel will be exposed and this portion of the sheet will rust through very quickly. For this reason, galvanized sheet metal is seldom used in applications requiring welded joints. Of all the sheet metals, galvanized is one of the least expensive. It is probably the most commonly used of all types of sheets in the general sheet metal shop.

ALUMINIUM SHEET

Aluminium sheet can easily be recognized by its whitish appearance and by its lightness. It is often used in the sheet metal shops because of its pleasing appearance, corrosion resistance and lightness. Aluminium has also found extensive use in thousands of mass production items such as kitchenware, trailer bodies, and thousands of small parts. Pure aluminium is very soft and ductile, therefore aluminium alloy form to be used in commercial products. Aluminium alloys are from 1000 series to 7000 series. For example, the 1000 series is up to 99% pure aluminium. The most common space aluminium alloy is the 2000 series.

STAINLESS STEEL SHEET

Stainless steel sheet possesses untarnished surface appearance and corrosion resistance as its main advantages. It can be welded and cut without damaging its corrosion resistance. Stainless steel is very tough, but it can still be readily worked in sheet metal shop. Stainless steel sheet metal ware is extensively used in applications where high corrosion resistance is required. Stainless steel is a high grade steel to which chromium and nickel are added to the steel as the major alloying elements. Stainless steel is classified according to the alloy content and is distributed through three series numbers: the 200 series, the 300 series, and the 400 series.

MANUFACTURING PROCESSES

The manufacturing processes of sheet metal parts can be classified in material removal and material deformation. Material removal process can be a stage of creating a 2D shape such as a development of a sheet metal part by punching, notching, or nibbling. Deformation process can be a stage of bending or stretch sheet metal part into a 3D complex shape.

MATERIAL REMOVAL WITH SHEAR

Shear is a piece of sheet metal separated by applying a force to cause the material to fail. When a great enough shearing force is applied, the shear stress in the material will exceed the ultimate shear strength and the material will fail and separate at the cut location. This shearing force is applied by two tools, one above and one below the sheet. Whether these tools are a punch and die or upper and lower blades, the tool above the sheet delivers a quick downward blow to the sheet metal that rests over the lower tool. A small clearance is present between the edges of the upper and lower tools, which facilitates the fracture of the material. The size of this clearance is typically 2-10% of the material thickness and depends upon several factors, such as the specific shearing process, material, and sheet thickness.

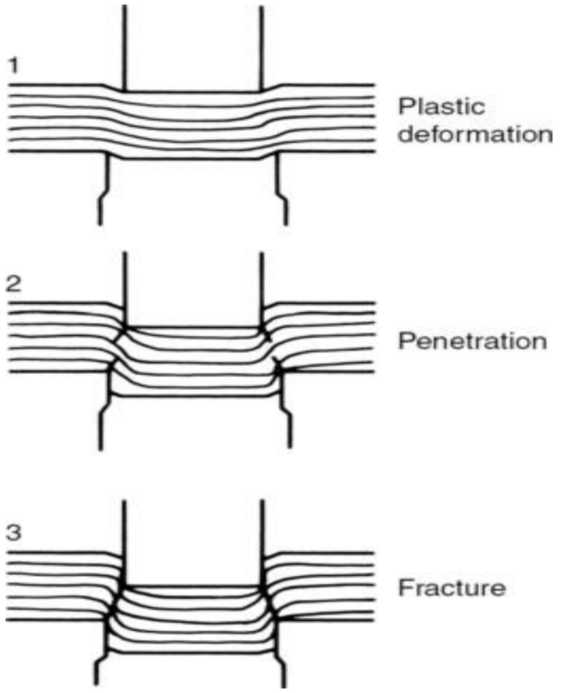
SHEAR ACTION

The material is stressed in shear to the point of fracture while going through three phases:

1. ***Deformation:*** As the cutting edges begin to close on the material, deformation occurs on both sides of the material next to the cut edge.

2. ***Penetration:*** The cutting edges cut or penetrate the material, causing fracture lines.

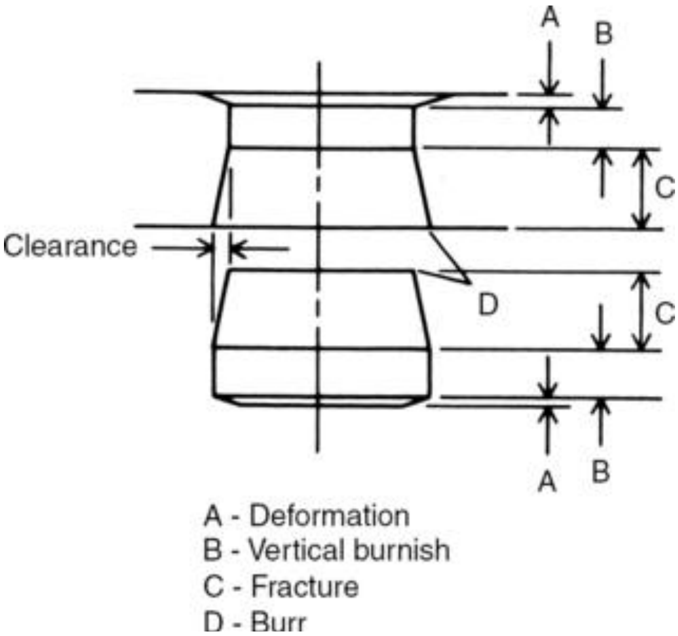
3. ***Fracture:*** The point where the upper and lower fracture lines meet. At this point the work is done, but in punching, the punch must continue to move through the material to clear the slug



The shear cutting action produces four inherent characteristics found on both the parent material and the cut-off (or punched-out) part.

These characteristics are:

1. Plastic deformation
2. Vertical burnish-cut band
3. Angular fracture
4. Burr caused by the fracture starting above the cutting edge



BLANKING

Blanking is a cutting process in which a piece of sheet metal is removed from a larger piece of stock by applying a great enough shearing force. In this process, the piece removed, called the blank, is not scrap but rather the desired part. Blanking can be used to cut out parts in almost any 2D shape, but is most commonly used to cut work pieces with simple geometries that will be further shaped in subsequent processes. Often times multiple sheets are blanked in a single operation. Final parts that are produced using blanking include gears, jewelry, and watch or clock components. Blanked parts typically require secondary finishing to smooth out burrs along the bottom edge.

PUNCHING

Punching is a cutting process in which material is removed from a piece of sheet metal by applying a great enough shearing force. Punching is very similar to blanking except that the removed material, called the slug, is scrap and leaves behind the desired internal feature in the sheet, such as a hole or slot. Punching can be used to produce holes and cut-outs of various shapes and sizes. The most common punched holes are simple geometric shapes (circle, square, rectangle, etc.) or combinations thereof. The edges of these punched features will have some burrs from being sheared but are of fairly good quality.

NIBBLING

Nibbling is a process which cuts a contour by producing a series of overlapping slits or notches. This allows for complex shapes to be formed in sheet metal part production. Punches are available in various shape and sizes; oblong and rectangular punches are common because they minimize waste and allow for greater distances between strokes, as compared to a round punch.

CNC TURRET PUNCH PRESS

A CNC turret punch press machine bases on the principle of nibbling, features a unified structure into which a die turret and punch turret mounted with various punch dies, and punch respectively and a work sheet positioning mechanism are combined together. Turret punch presses are brought into run, in combination with a CNC unit. With these punch press, work sheet positioning according to the machining dimensions tor an intended product, press working, optimal operation mode selection, die and punch choosing are automatically done, following the CNC commands. Therefore the CNC turret press can undertake sequentially punching different holes in a work sheet with each die and punch indexed automatically at one fixed punching position while relocating the sheet in each cycle of punching. Work sheet positioning and turret drive are optionally, controlled numerically, allowing the press to automatically punch to a complicated profile with ease.

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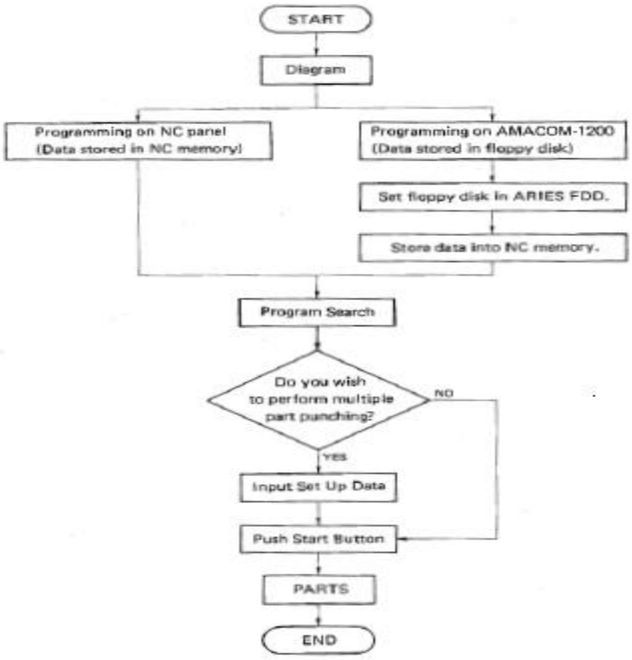
The AMADA Aries 222 Turret Press



The process from diagram to part by the CNC nibbling machine

SHEET METAL CUTTING WITHOUT SHEARING

LASER BEAM CUTTING

Laser cutting uses a high powered laser to cut through sheet metal. A series of mirrors and lenses direct and focus a high-energy beam of light onto the surface of the sheet where it is to be cut. When the beam strikes the surface, the energy of the beam melts and vaporizes the metal underneath. Any remaining molten metal or vapor is blown away from the cut by a stream of gas. The position of the laser beam relative to the sheet is precisely controlled to allow the laser to follow the desired cutting path.

Laser cutting can be performed on sheet metals that are both ferrous and nonferrous. Materials with low reflectivity and conductivity allow the laser beam to be most effective - carbon steel, stainless steel, and titanium are most common. Metals that reflect light and conduct heat, such as aluminum and copper alloys, can still be cut but require a higher power laser. Laser cutting can also be used beyond sheet metal applications, to cut plastics, ceramics, stone, wood, etc.

PLASMA CUTTING

Plasma cutting uses a focused stream of ionized gas, or plasma, to cut through sheet metal. The plasma flows at extremely high temperatures and high velocity and is directed toward the cutting location by a nozzle. When the plasma contacts the surface below, the metal melts into a molten state. The molten metal is then blown away from the cut by the flow of ionized gas from the nozzle. The position of the plasma stream relative to the sheet is precisely controlled to follow the desired cutting path.

Plasma cutting is performed with a plasma torch that may be hand held or, more commonly, computer controlled. CNC (computer numerically controlled) plasma cutting machines enable complex and precision cuts to made. In either type of plasma torch, the flow of plasma is created by first blowing an inert gas at high speed though a nozzle pointed at the cutting surface. An electrical arc, formed through the flow of gas, ionizes the gas into plasma. The nozzle then focuses the flow of plasma onto the cut location. As with laser cutting, this process does not require any physical tooling which reduces initial costs and allows for cost effective low volume production.

The capabilities of plasma cutting vary slightly from laser cutting. While both processes are able to cut nearly any 2D shape out of sheet metal, plasma cutting cannot achieve the same level of precision and finish. Edges may be rough, especially with thicker sheets, and the surface of the material will have an oxide layer that can be removed with secondary processes. However, plasma cutting is capable of cutting through far thicker sheets than laser cutting and is often used for work pieces beyond sheet metal.

WATER JET CUTTING

Water jet cutting uses a high velocity stream of water to cut through sheet metal. The water typically contains abrasive particles to wear the material and travels in a narrow jet at high speeds, around 2000 ft/sec. As a result, the water jet applies very high pressure (around 60,000 psi) to the material at the cut location and quickly erodes the material. The position of the water jet is typically computer controlled to follow the desired cutting path.

Water jet cutting can be used to cut nearly any 2D shape out of sheet metal. The width of the cuts is typically between 0.002 and 0.06 inches and the edges are of good quality. Because no burrs are formed, secondary finishing is usually not required. Also, by not using heat to melt the material, like laser and plasma cutting, heat distortion is not a concern.

SHEET METAL FORMING

Sheet metal forming processes are those in which force is applied to a piece of sheet metal to modify its geometry rather than remove any material. The applied force stresses the metal beyond its yield strength, causing the material to plastically deform, but not to fail. By doing so, the sheet can be bent or stretched into a variety of complex shapes. Sheet metal forming processes include the following:

- **Bending**
- **Roll forming**
- **Spinning**
- **Deep Drawing**
- **Stretch forming**

BENDING

Bending is a metal forming process in which a force is applied to a piece of sheet metal, causing it to bend at an angle and form the desired shape. A bending operation causes deformation along one axis, but a sequence of several different operations can be performed to create a complex part. A bend can be characterized by several different parameters, shown in the image below.

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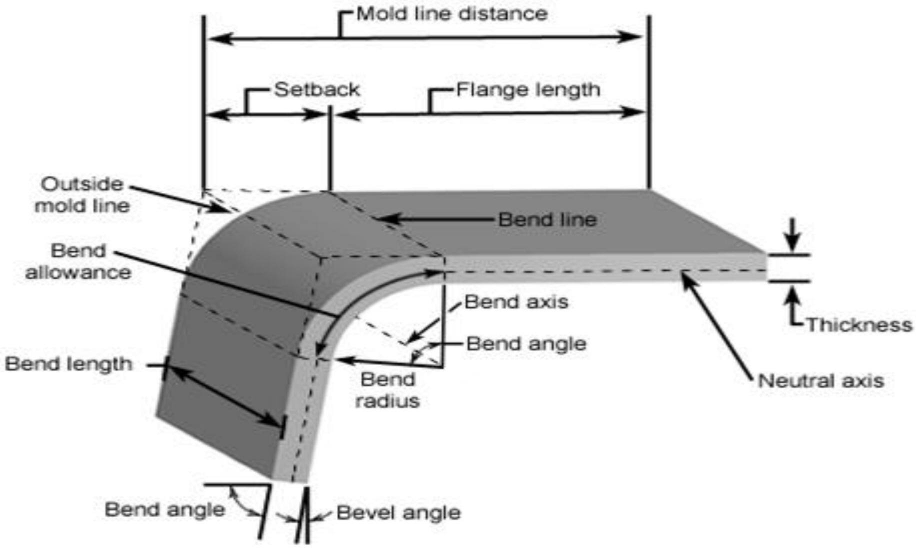
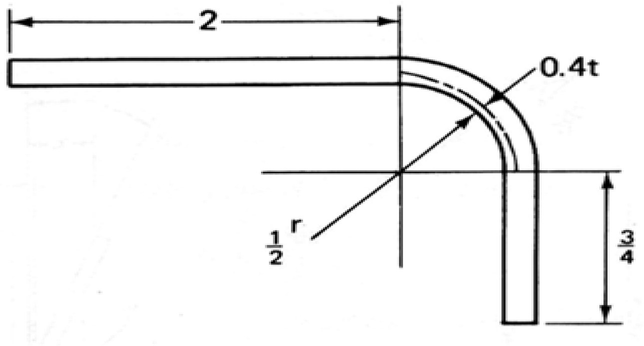


NEUTRAL AXIS AND DEVELOPMENT LENGTH

The neutral axis is the line of zero stress and strain in a bend with tension on one surface and compression on the other. Before bending, the flat blank is of a certain length, and the length of the neutral axis is exactly equal to this original blank length. During bending, the outside surface of the sheet metal is increased in length, and the inside surface of the sheet metal is decreased in length, but the length of the neutral axis remains the same. Because the neutral axis is a true representation of the original blank length, it is used for blank-development calculations. Following is the formula to calculate the original length of the sheet metal before bending.



Formula for length at bend:

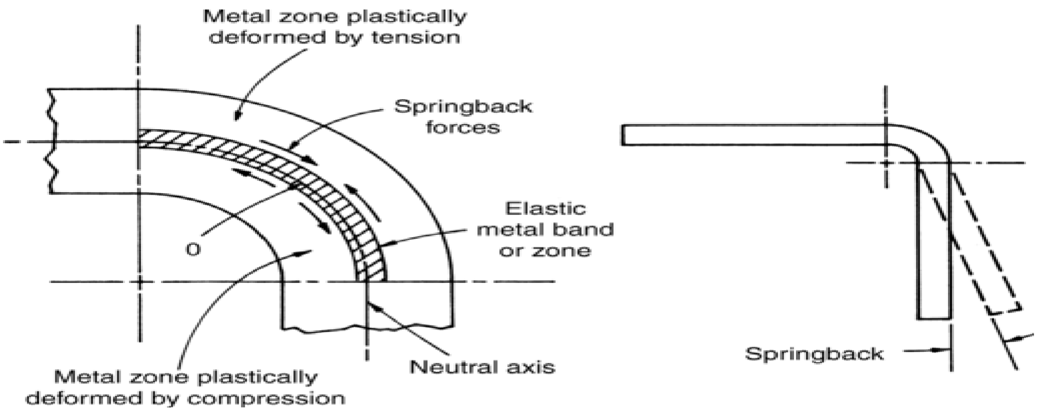
Circumference at neutral axis= $2\pi(r+4t)$

Portion of circumference used= $\frac{degrees\ of\ bend}{360}$

Length of bend = $\frac{degrees\ of\ bend}{360}$ x $2\pi(r+4t)$

Spring Back

The metal nearest the neutral axis has been stressed to values below the elastic limit. This metal creates a narrow elastic band on both sides of the neutral axis; The metal farther away from the axis has been stressed beyond the yield strength, however, and has been plastically or permanently deformed. When the die opens, the elastic band tries to return to the original flat condition but cannot, due to restriction by the plastic deformation zones. Some slight return does occur as the elastic and plastic zones reach an equilibrium, and this return is known as spring back.

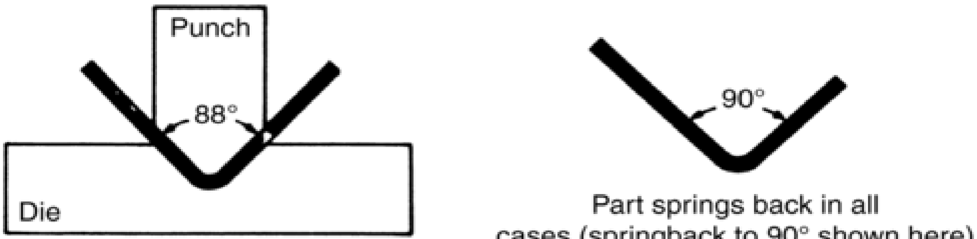


Methods are used to overcome or counteract the effects of spring back:

- Over bending
- Bottoming or setting
- Stretch bending

Over bending:

Over bending may be accomplished by using cams, by decreasing the die clearance, or by setting the punch and die steels at a smaller angle than required in the case of a V-die. When the clearance is reduced below the sheet metal thickness, the burnishing action wipes the metal against an undersized punch or dies steel.

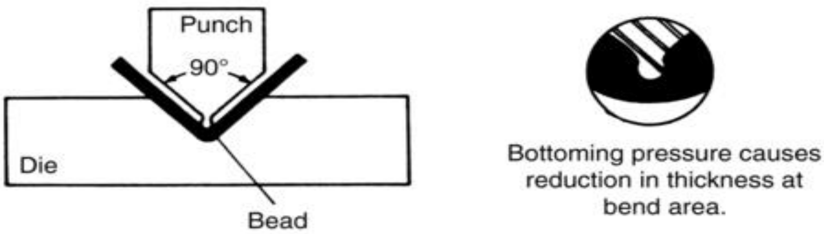


Overbending in a V-die. Punch and die both undersize at 88°.

Part springs back in all cases (springback to 90° shown here)

Bottoming:

Bottoming or setting consists of striking the metal severely at the radius area. This places the metal under high compressive stresses that set the metal past the yield strength. Bottoming is accomplished by placing a bead on the punch at the bend area. In a wiping die or U-die, the pad must bottom against the shoe or backing plate so that the punch may set the metal at the bend. It would be useless to bottom against the flat areas of sheet metal, because they are not stressed and do not cause spring back. Also, bottoming against these larger areas would require extremely high press tonnages. Bottoming must be carefully controlled when adjusting the press ram, or the forces involved will rise at a rapid rate. Also, if two blanks are accidentally placed in a bending die that bottoms, press or die breakage may result.



Bottoming pressure causes reduction in thickness at bend area.

Bottoming

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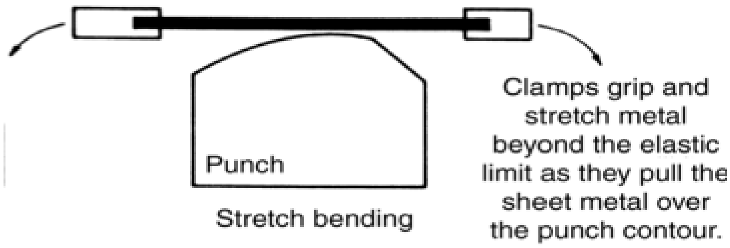
Stretch bending:

Stretch bending consists of stretching the blank so that all the metal is stressed past the yield strength. The blank is then forced over the punch to obtain the desired contour. This pre stressing before bending results in very little spring back. Only relatively large radii are bent by this method, because sharp radii would take the pre stressed metal beyond the ultimate tensile strength. The sheet metal must be uniform in strength. Any weak spots or defects will certainly cause failure. Stretch bending is most frequently done with a special hydraulic machine rather than with a die in a press. Hourly production rates are slower for such machines than for presses.



Press Brakes:

Press Brakes are a common type of equipment for bending metal by delivering an accurate vertical force in a confined longitudinal area. Any metal that can be punched or bent by other processes can be formed on a press brake. Press brakes are manually fed by an operator. The operator holds a metal work piece between a punch and die and against a gage to apply a bend or multiple bends to the metal work piece. Press brakes can have one of several types of back gages, depth stops, and pins to engage holes in the work piece. Gages can be manually placed and adjusted, or computer numerically controlled programmable units can automatically adjust settings after each stroke.

A CNC Press Brake

Roll Forming

Roll forming is a metal forming process in which sheet metal is progressively shaped through a series of bending operations. The process is performed on a roll forming line in which the sheet metal stock is fed through a series of roll stations. Each station has a roller, referred to as a roller die, positioned on both sides of the sheet. The shape and size of the roller die may be unique to that station, or several identical roller dies may be used in different positions. The roller dies may be above and below the sheet, along the sides, at an angle, etc. As the sheet is forced through the roller dies in each roll station, it plastically deforms and bends. Each roll station performs one stage in the complete bending of the sheet to form the desired part. The roller dies must be lubricated to reduce friction between the die and the sheet, thus reducing the tool wear. Also, lubricant can allow for a higher production rate, which will also depend on the material thickness, number of roll stations, and radius of each bend. The roll forming line can also include other sheet metal fabrication operations before or after the roll forming, such as punching or shearing.

Spinning

Spinning, sometimes called spin forming, is a metal forming process used to form cylindrical parts by rotating a piece of sheet metal while forces are applied to one side. A sheet metal disc is rotated at high speeds while rollers press the sheet against a tool, called a mandrel, to form the shape of the desired part. Spun metal parts have a rotationally symmetric, hollow shape, such as a cylinder, cone, or hemisphere. Examples include cookware, hubcaps, satellite dishes, rocket nose cones, and musical instruments.

Spinning is typically performed on a manual or CNC lathe and requires a blank, mandrel, and roller tool. The blank is the disc-shaped piece of sheet metal that is pre-cut from sheet stock and will be formed into the part. The mandrel is a solid form of the internal shape of the part, against which the blank will be pressed. For more complex parts, multi-piece mandrels can be used.

Deep drawing

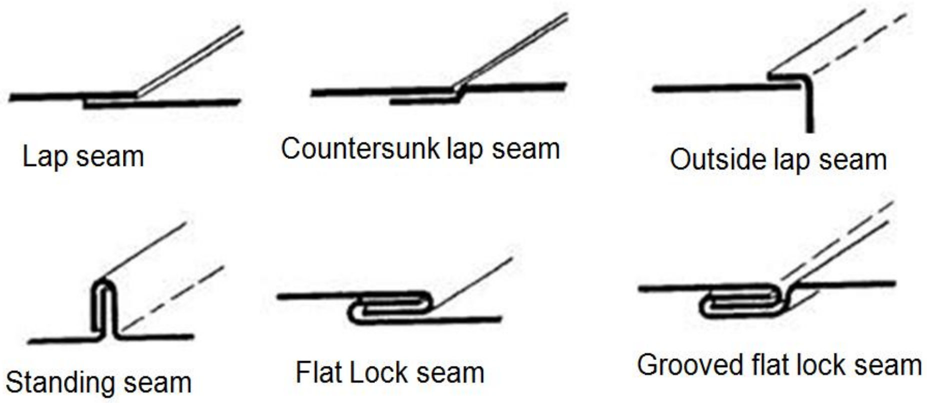
Deep drawing is a metal forming process in which sheet metal is stretched into the desired part shape. A tool pushes downward on the sheet metal, forcing it into a die cavity in the shape of the desired part. The tensile forces applied to the sheet cause it to plastically deform into a cup-shaped part. Deep drawn parts are characterized by a depth equal to more than half of the diameter of the part. These parts can have a variety of cross sections with straight, tapered, or even curved walls, but cylindrical or rectangular parts are most common. Deep drawing is most effective with ductile metals, such as aluminum, brass, copper, and mild steel. Examples of parts formed with deep drawing include automotive bodies and fuel tanks, cans, cups, kitchen sinks, and pots and pans.

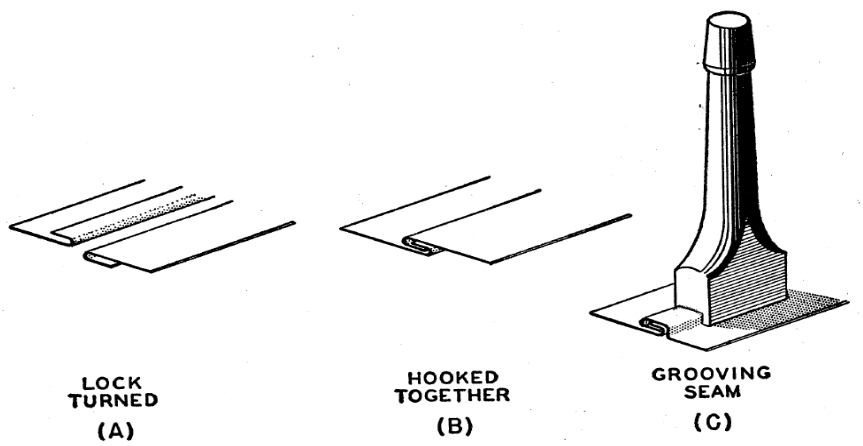
Stretch forming

Stretch forming is a metal forming process in which a piece of sheet metal is stretched and bent simultaneously over a die in order to form large contoured parts. Stretch forming is performed on a stretch press, in which a piece of sheet metal is securely gripped along its edges by gripping jaws. The gripping jaws are each attached to a carriage that is pulled by pneumatic or hydraulic force to stretch the sheet. The tooling used in this process is a stretch form block, called a form die, which is a solid contoured piece against which the sheet metal will be pressed. The most common stretch presses are oriented vertically, in which the form die rests on a press table that can be raised into the sheet by a hydraulic ram. As the form die is driven into the sheet, which is gripped tightly at its edges, the tensile forces increase and the sheet plastically deforms into a new shape. Horizontal stretch presses mount the form die sideways on a stationary press table, while the gripping jaws pull the sheet horizontally around the form die.

Seam Joints

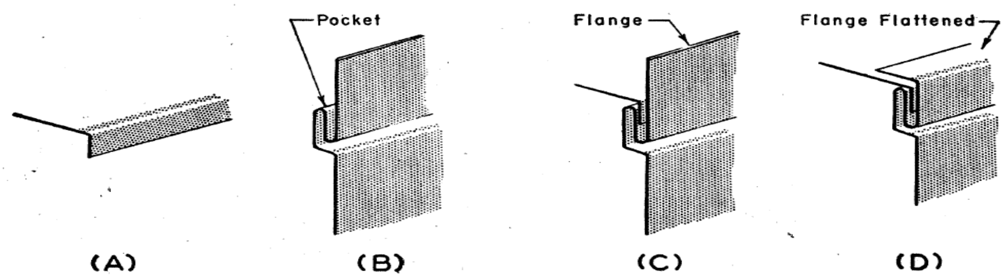
In sheet metal construction there are a variety of methods for joining the edges of sheet metal. These methods may be classified as mechanical and welded. The choice of the seam is determined primarily by the thickness of the metal, the kind of metal, the cost of fabrication, and the equipment available for making the seam. However, it is obvious that the mechanical seam is used when joining light and medium gage metal, and that for heavier metal, a riveted or welded seam is necessary.





Pittsburgh Seam

This seam is sometimes called a hammered lock or hobo lock. It is used as a longitudinal corner seam for variously shaped pipes. The seam consists of two parts, the single lock as in (A) of Fig. 18, and the pocket lock at (B). The single lock is placed in the pocket lock, (C) and the flange is hammered over.



Riveting

Rivet joints are used where strength is required or when the metal sheet is too thick to be handled by seam joints. A successful riveting depends on the condition and size of the rivet holes and on the correct size and spacing of the rivet. The hole of the rivet may be punched or drilled, depending on the thickness of the metal. Thin sheet metal is usually punched, while the heavier metal thicker metal is drilled. Riveting may be done by hand or by machine.

Type of rivets

There are many types of rivets used in sheet metal work. The four most common types are the tanners' flathead, roundhead, and countersunk head. The countersunk head is used when a flush surface is desired, and the roundhead when exceptional strength is required.

Sheet metal riveting is carried out in four steps.

1. Drilling. Drill or punch the holes through the metals to be joined.

2. Drawing. Insert the rivet into the metal and place it on a stake. Centre the hole in the rivet set over the rivet and tap the set a few times with the hammer. This operation will draw the rivet and the metal tightly together.

3. Upsetting. Tap the shank of the rivet with a hammer until the shank spreads to the approximate size of the head required.

4. Heading. Place the dimple of the rivet set over the rivet. Tap the rivet set over the rivet. Tap the rivet set with the hammer until the head is formed on the rivet.

Blind rivets

Blind rivets are mainly used when access to the joint is only available from one side. The rivet is placed in a pre-drilled hole and is set by pulling the mandrel head into the rivet body, expanding the rivet body and causing it to flare against the reverse side. As the head of the mandrel reaches the face of the blind side material, the pulling force is resisted, and at a predetermined force, the mandrel will snap at its break point, also called "Blind Setting". A tight joint formed by the rivet body remains, the head of the mandrel remains encapsulated at the blind side, although variations of this are available, and the mandrel stem is ejected.

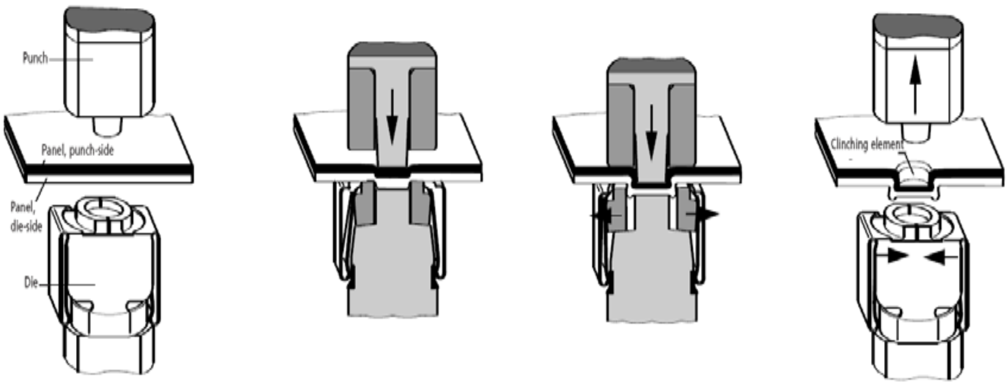
Spot welding

Spot welding is a resistance welding method used to join two to three overlapping metal sheets, studs, projections, electrical wiring hangers, some heat exchanger fins, and some tubing. Usually power sources and welding equipment are sized, to the specific thickness and material being welded together. The thickness is limited by the output of the welding power source and thus the equipment range due to the current required for each application. Care is taken to eliminate, contaminates between the faying surfaces. Usually, two copper electrodes are simultaneously used to clamp the metal sheets together and to pass current through the sheets. When the current is passed through the electrodes to the sheets, heat is generated due to the higher electrical resistance where the surfaces contact each other. As the electrical resistance of the material causes heat build-up in the work between the copper electrodes, the rising temperature causes a rising resistance, and results in a molten pool contained most of the time between the electrodes.

Clinching

Clinching is a mechanical fastening method to join sheet metal without additional components using special tools to plastically form a mechanical interlock between the sheet metals. The tools consist typically of a punch and a die. There are two primary types of dies: solid "fixed cavity" dies, and dies with moving components. The punch forces the two layers of sheet metal into the die cavity forming a permanent connection. The pressure exerted by the punch forces the metal to flow laterally.

Clinching is used primarily in the automotive, appliance and electronic industries, where it replaces spot welding very often. Clinching is a cold forming process and does not require electricity or cooling of the electrodes commonly associated with spot welding. Also, clinching does not generate sparks and fumes. In addition, the strength of a clinched joint can be tested nondestructively using a simple measuring instrument to measure the remaining thickness at the bottom of the joint or the diameter of the produced button depending on the type of tools being used. Life expectancy for clinching tools is in the hundreds of thousands of cycles making it a very economical process.



Clinching Processes

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