Plasticity and Deformation Process

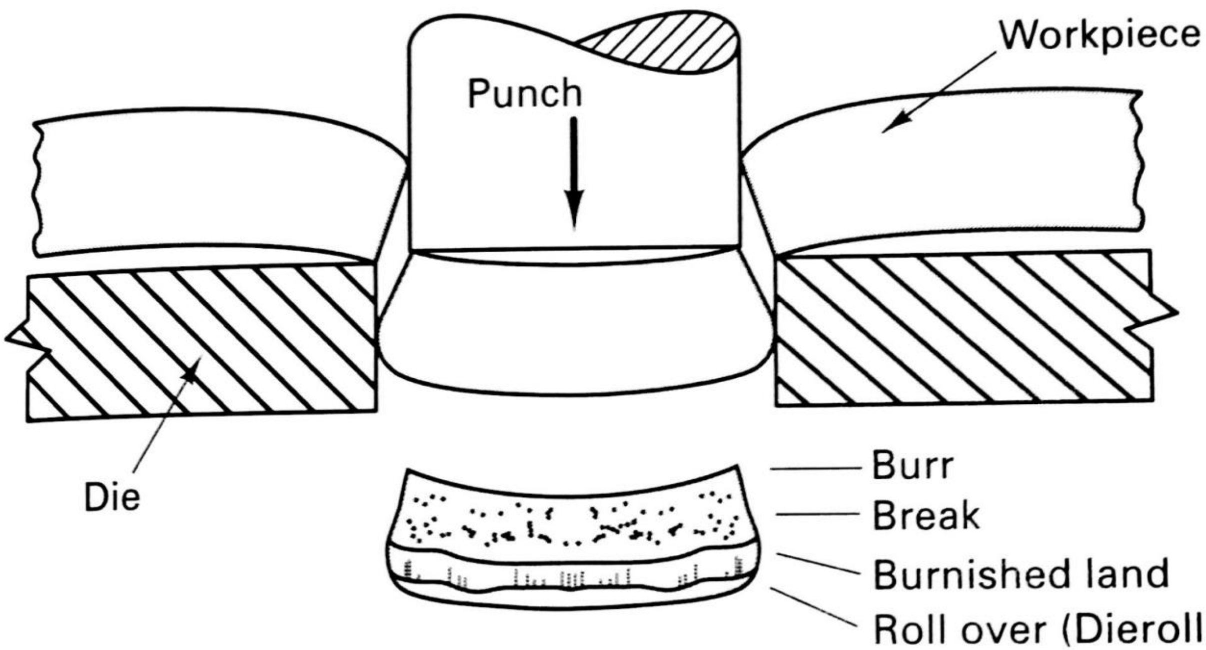
Shearing processes

Shearing is the mechanical cutting of materials without the formation of chips

It is a cold process that is used to prepare materials for subsequent operations

It is called shearing when two cutting blades are straight

When the blades are curved, the processes have special names such as piercing, blanking, notching and trimming



Blanking is a simple type of shearing operation

Blanking is similar to drawing in the setup such that a punch pushes the metal into the die

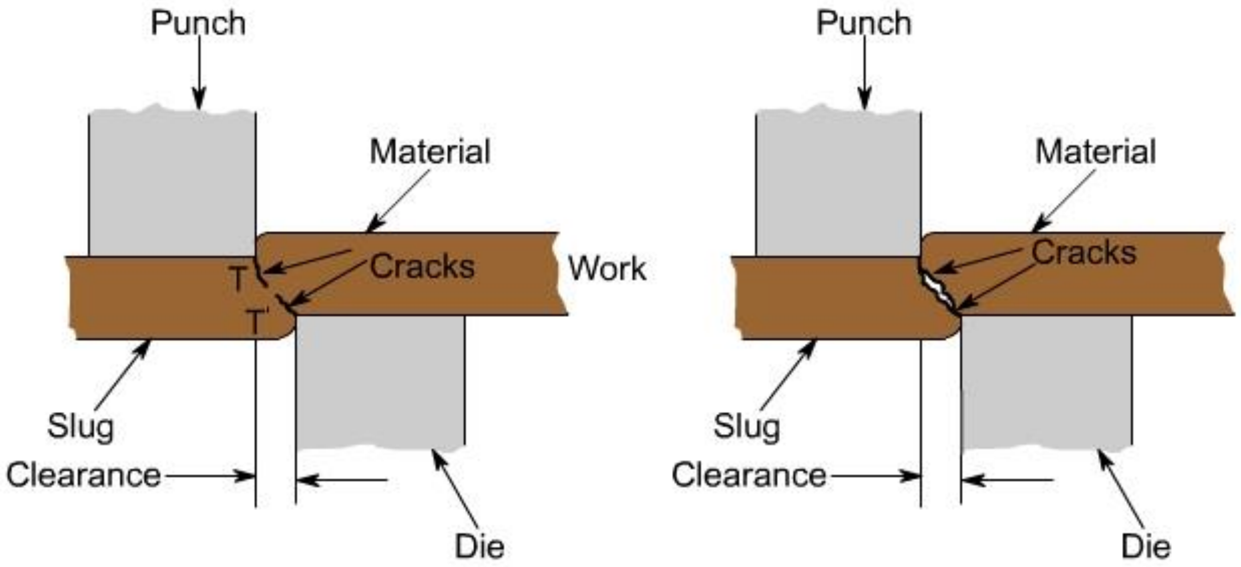
As the punch (upper blade) pushes the workpiece the metal responds by plastically flowing into the die (lower blade)

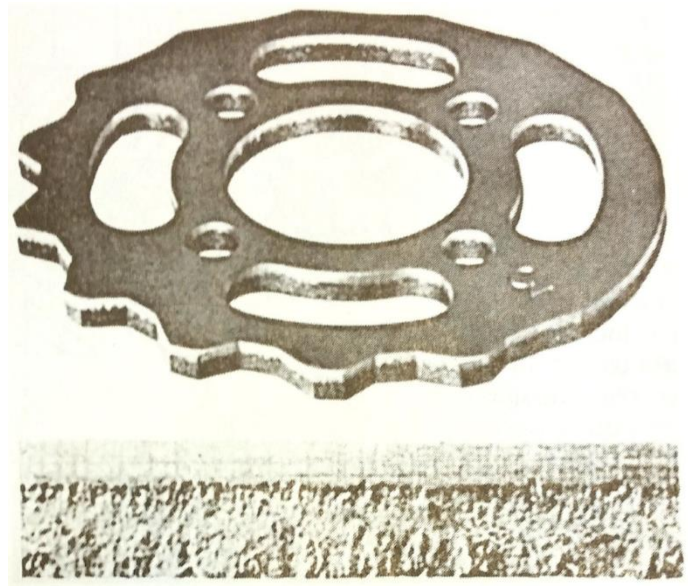
The metal deforms as highly localized shear develops as the metal is pushed down

The clearance between the two tools is small, usually between 5 and 10% of the thickness of the metal being cut

The surface entering the die bulges slightly and an instability arises when the penetration is between 15 and 60% of the metal thickness (amount depending on the material ductility and strength)

At that point the applied shear stress exceeds the shear strength and the metal ruptures through the remainder of its thickness





The final shearing does not occur uniformly because of the normal inhomogeneities in a metal and nonuniform clearance between the shear blades

Fracture and tearing begin at the weakest point and proceed to the next weakest location in a manner similar to crack propagation

The result is usually a rough and ragged edge

Sheared edges with sufficient smoothness to permit use without further finishing can be produced if the punch and die have proper clearance

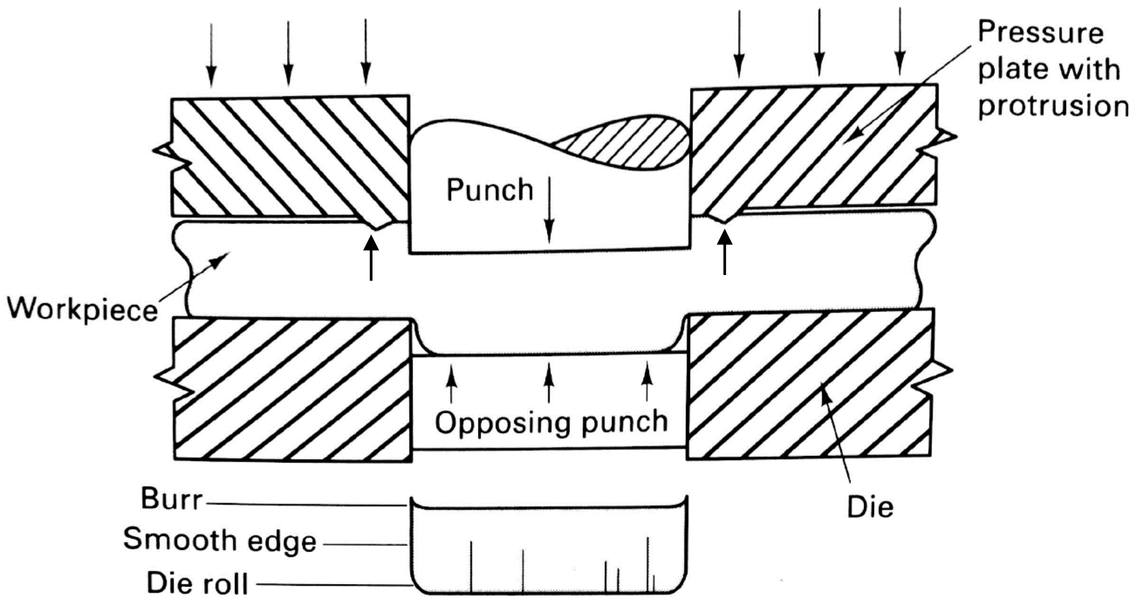
The following approaches improve the quality of the sheared edge:

- Clamping the starting stock firmly against the die
- Maintaining proper clearance and alignment between the punch and the die
- Restraining the movement of the piece by a rubber die cushion that applied opposing pressure from below the workpiece

If the entire shearing operation is performed in a compressive environment, fracture is suppressed and the relative amount of smooth edge produced by deformation is increased

No fracture occurs above a certain pressure and the entire edge is smooth

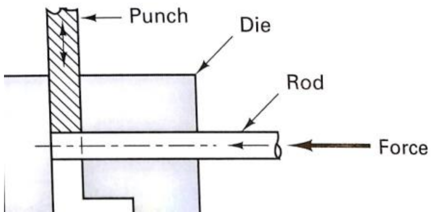
In a process termed fineblanking, a V-shaped protrusion is incorporated into the hold-down or pressure plate at a location slightly outside the contour of the cut

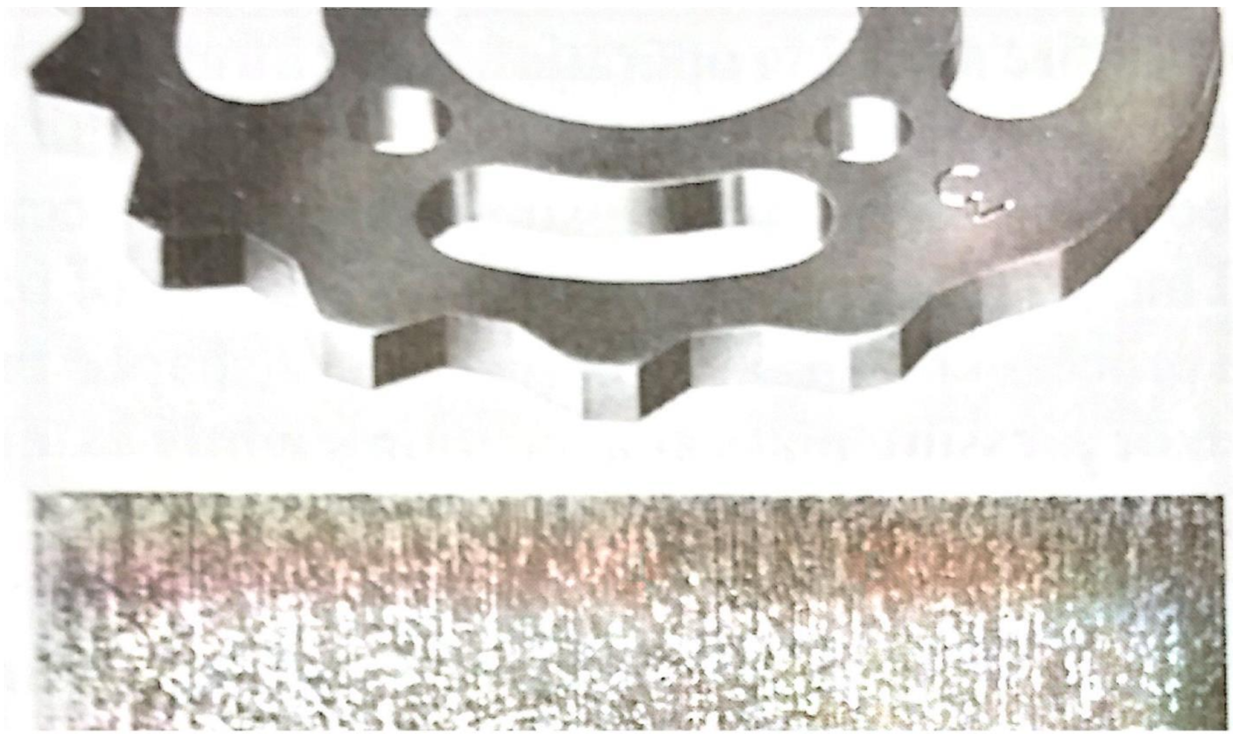


The protrusion is driven into the material as the pressure is applied to the hold-down plate, compressing the region to be cut
Matching upper and lower punches grip the material and slowly extract the desired segment

As a result of this fine process the shear edges are smooth and square

A similar shearing operation under compression is smooth shearing rod

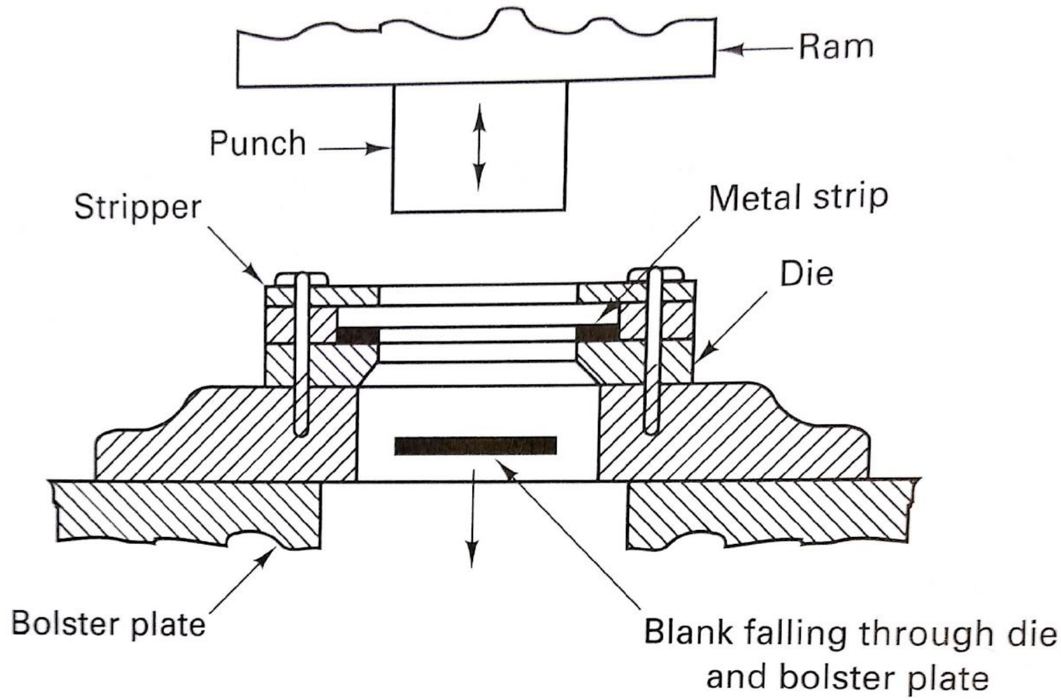




Fineblanking

In fineblanking the clearance between the punch and the die is reduced

The fineblanking force is about 40% greater than conventional blanking



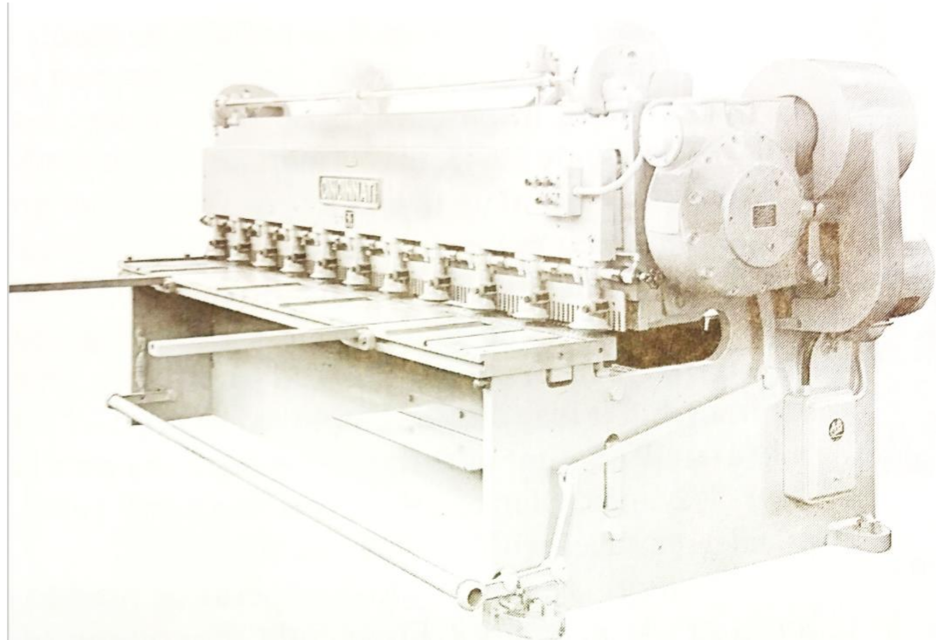
Fineblanked parts are usually less than 6 mm in thickness and typically have complex shaped perimeters

Dimensional accuracy is often within 0.05 mm

Holes, slots, and bends can be incorporated as part of the fineblanking operation

The work hardening that occurs during the shearing process enhances wear resistance and secondary edge finishing is eliminated as a result

When sheets of metal are to be sheared along a straight line, a squaring shear machine is often used



As the upper ram descends, a clamping bar or set of clamping fingers presses the sheet of metal against the machine table

A moving blade then comes down across a fixed blade and shear the metal

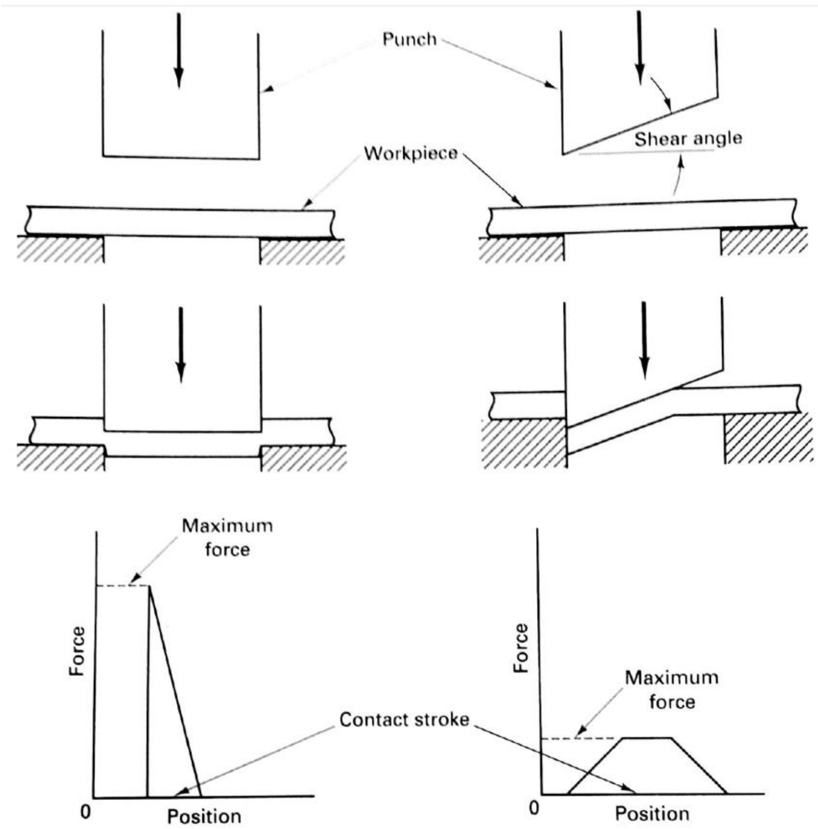
The moving blade is often set at an angle on larger shears, so the cut is made in a progressive way from one side of the material to the other

This action significantly reduces the amount of cutting force required but the total expended energy is the same

Since work is equal to force times distance, a low force – long stroke operation can often be used in place of a high force and short stroke

The entire perimeter is cut simultaneously if the face of the punch is normal to the axis of the motion

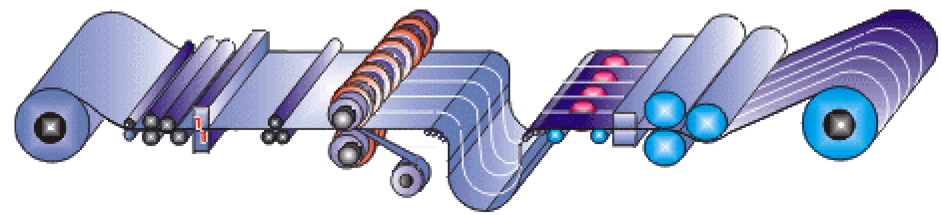
A shear angle is introduced by tilting the punch face, so that the cutting force is reduced substantially



Variation in the shear angle controls the length of cut that is made at a given time and the total stroke that is necessary to complete the operation

Adding shear to a punch reduced the force but increases the stroke (an efficient way to cut thicker and stronger material)

Slitting is the lengthwise shearing process used to cut rolls of sheet metal into several rolls of narrower width



The shearing blades take the form of cylindrical rolls with circumferential mating grooves

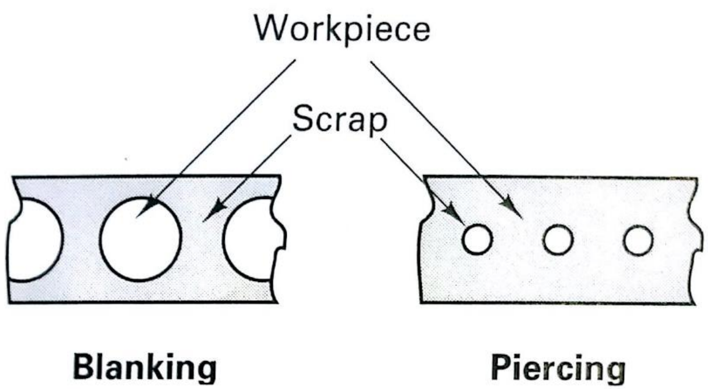
The raised ribs of one roll match the recessed grooves on the other

This process is continuous and can be performed rapidly and efficiently

The resulting strips have more accurate and constant width than that obtained from alternative cutting processes

Piercing and blanking are shearing operations where shear blades are placed along the edges of a punch or die

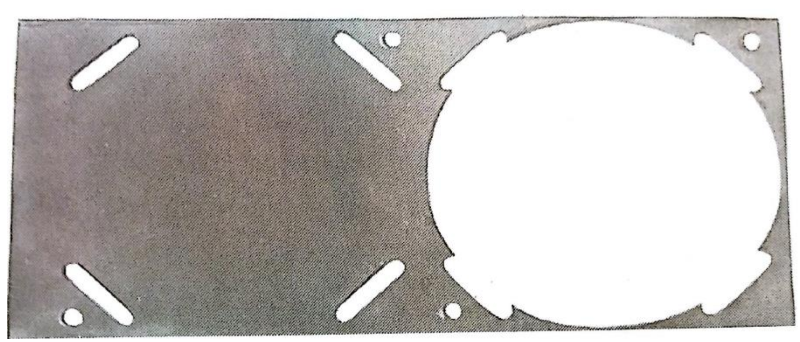
Both involve the same basic cutting action



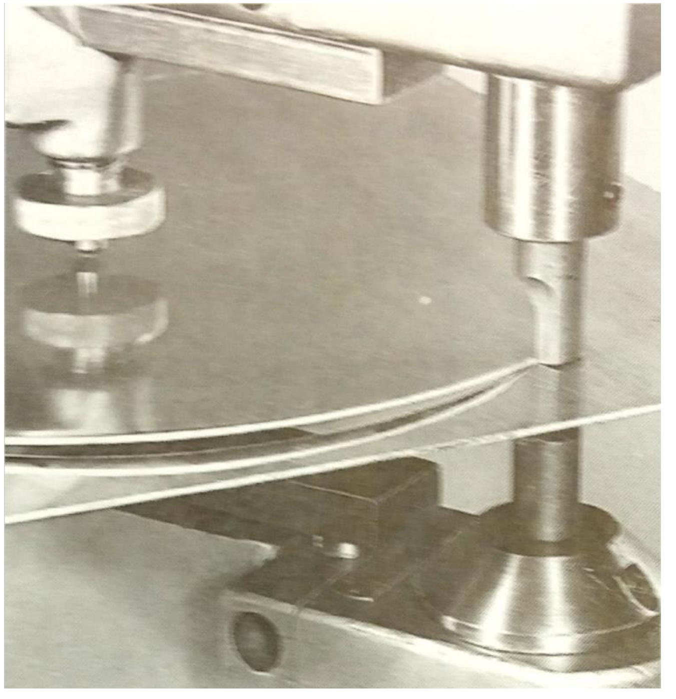
The punched out piece becomes the workpiece in blanking and any undesirable edge features should be left on the remaining strip

Both are done on some form of mechanical press

A variation of piercing and blanking is forming a line cut or hole in the metal to permit the adjacent metal to flow more easily in subsequent forming operations



In nibbling, a contour is cut by producing a series of overlapping slits or notches

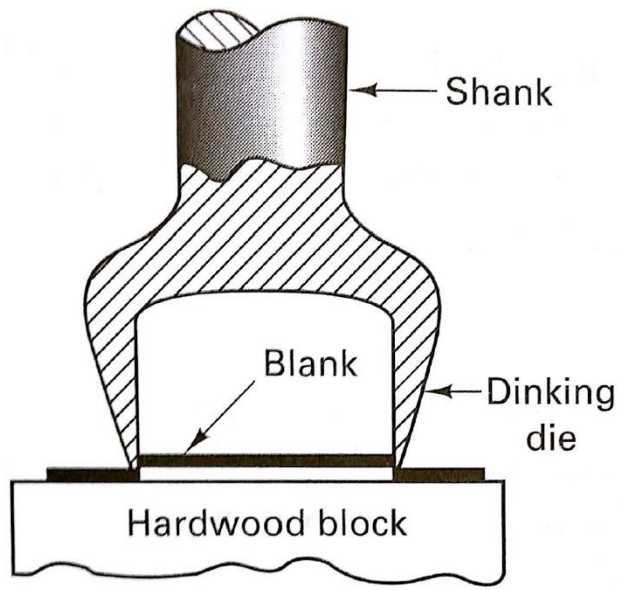


Simple tools can be used to cut a complex shape from sheets of metal up to 6 mm thick by nibbling

The process is useful for parts produced in small quantities

Edge smoothness is determined by the shape of the tooling and the degree of overlap in successive cuts

Dinking is a shearing operation used to blank shapes from low-strength materials such as rubber, fiber or cloth



The shank or stem of the die is either struck with a hammer or the entire die is driven downward by some form of mechanical press

Shaving is a finishing operation in which a small amount of metal is sheared away from the edge of a blanked part

Its primary uses are

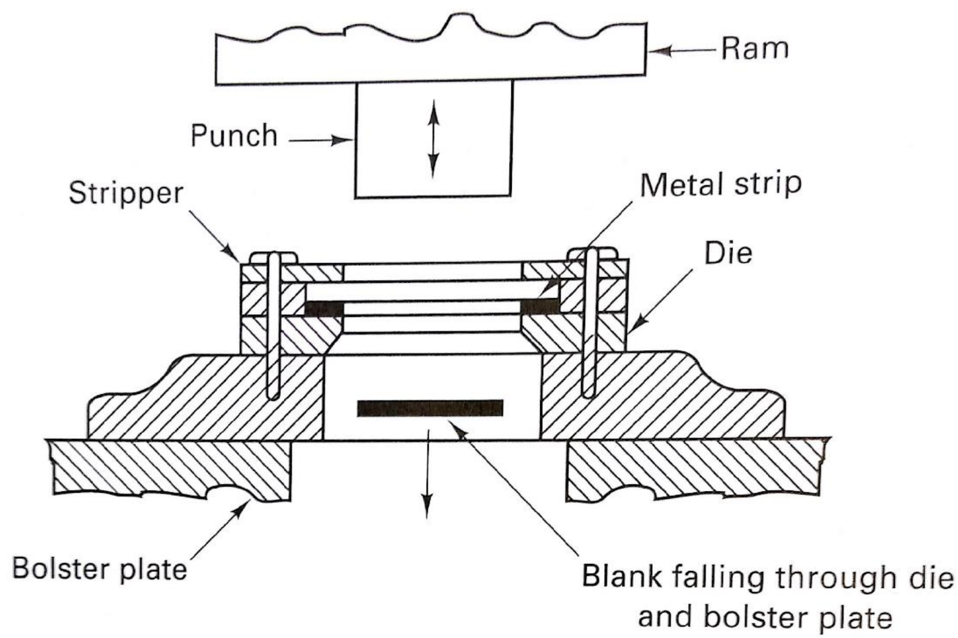
- To obtain greater dimensional accuracy
- To produce a squared or smoother edge

The punches and dies must be made with very little clearance as only a small amount of metal is removed

The basic components of a piercing and blanking die set are a punch, a die and a stripper plate

The stripper plate is attached above the die to keep the strip material from ascending with the retracting punch

It should not interfere with either the horizontal motion of the strip as it feed into position or the vertical motion of the punch



Theoretically the punch should fit within the die with a uniform clearance that approaches zero. It should not enter the die but should stop as its base aligns with the top surface of the die

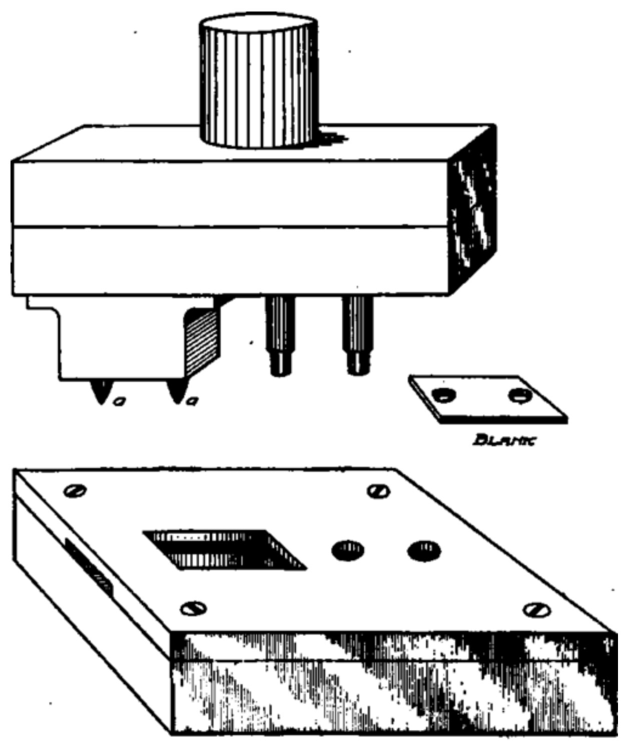
In practice, the clearance is between 5-7% of the material thickness and the punch enters slightly into the die cavity

Punches and dies are usually made of low-distortion, air-hardenable tool steel so they can be hardened after machining with minimal shape change

The die profile is maintained for a depth of about 3 mm from the upper face

An angular clearance is provided beyond that depth to reduce friction between the part and the die, and to permit the part to fall freely from the die after being sheared

The 3 mm depth provides adequate strength and sufficient metal to grind when the die need to be resharpened

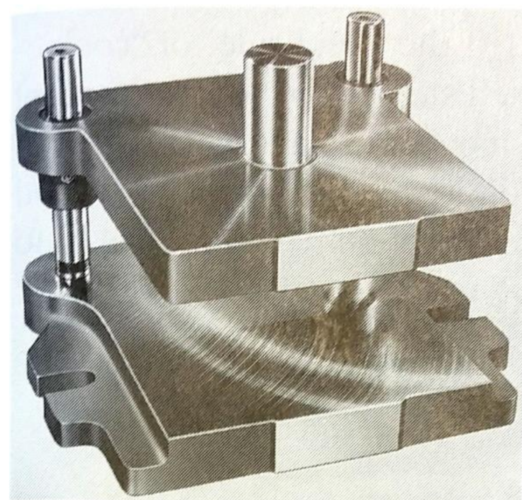


Punches and dies should also be in proper alignment so that a uniform clearance is maintained around the entire periphery

The punch is attached to the movable ram, enabling motion in and out of the die with each stroke of the press

The die is usually attached to the bolster plate of the press and the bolster plate is attached to the main press frame

Punches and dies can also be mounted on a separate punch holder and die shoe to create an independent die set



The holder and shoe are permanently aligned by two or more guide pins so that the entire unit can be inserted and replaced into a press without setting or checking the tool alignment

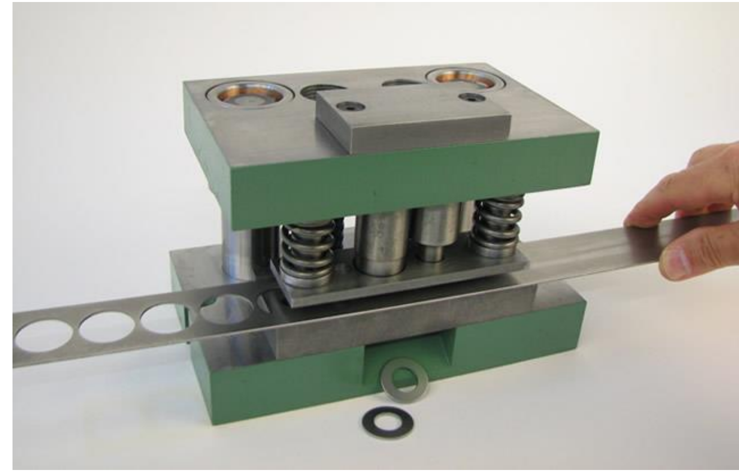
When a punch and die are no longer needed, they can be removed and new tools can be attached to the shoe and holder assembly

Springs can be incorporated on smaller die sets to provide the upward motion in place of a moving ram

The press ram contacts the top of the punch holder and forces it downward

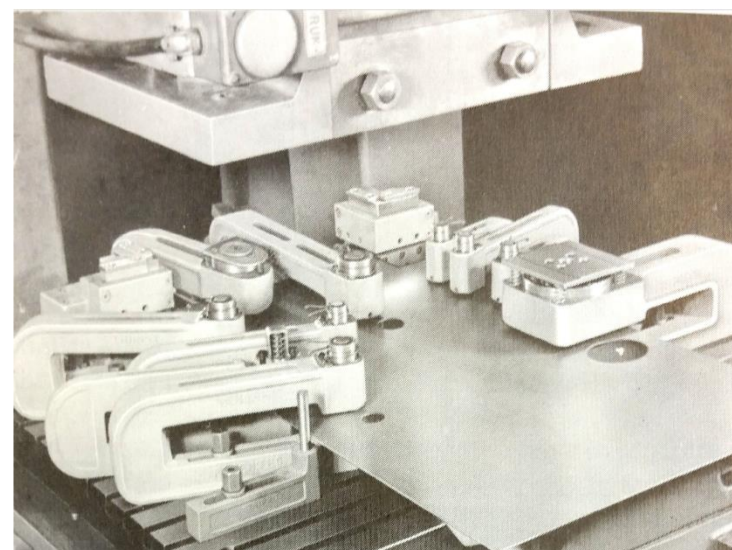
The springs cause the punch to return to its starting position as the ram retracts

Such fully self-contained dies can be rapidly inserted and removed from a press, reducing setup time



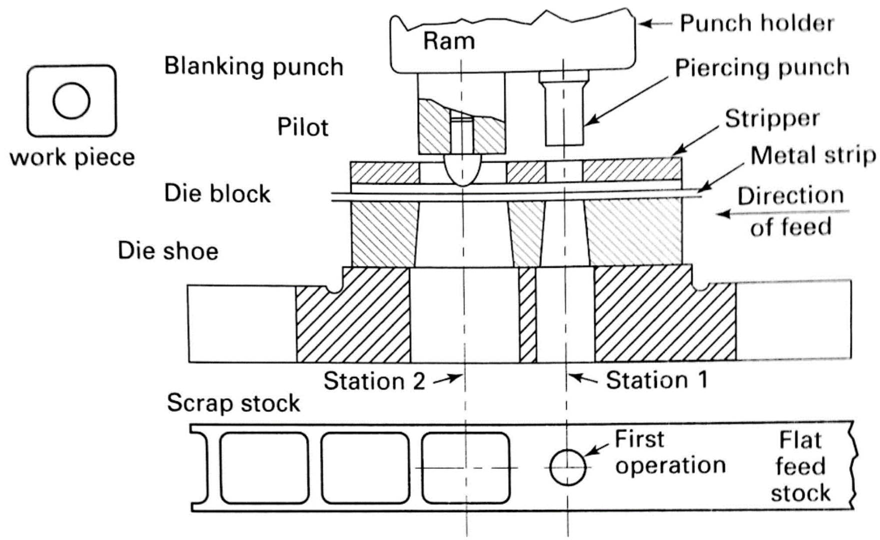
Standardized, self-contained dies that are known as sub-press dies have many varieties

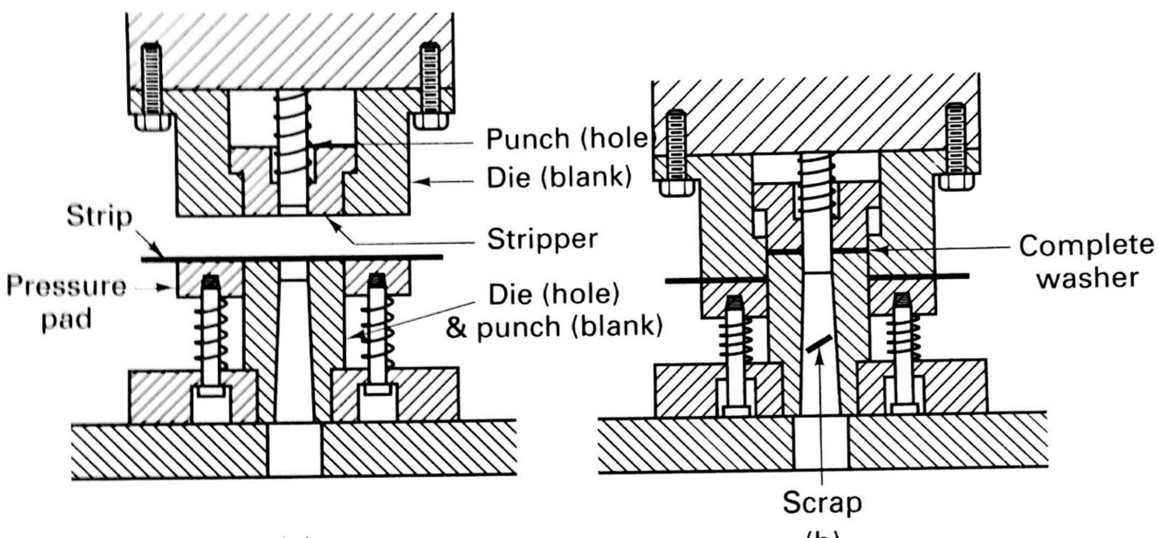
They can be assembled and combined on the table of a press to pierce or blank large parts that would otherwise require large and costly complex die sets



Dies can be made in a single piece or they can be made in component section that are assembled on the punch holder and die shoe

The latter process simplifies production and enables the replacement of single section in case of wear or fracture





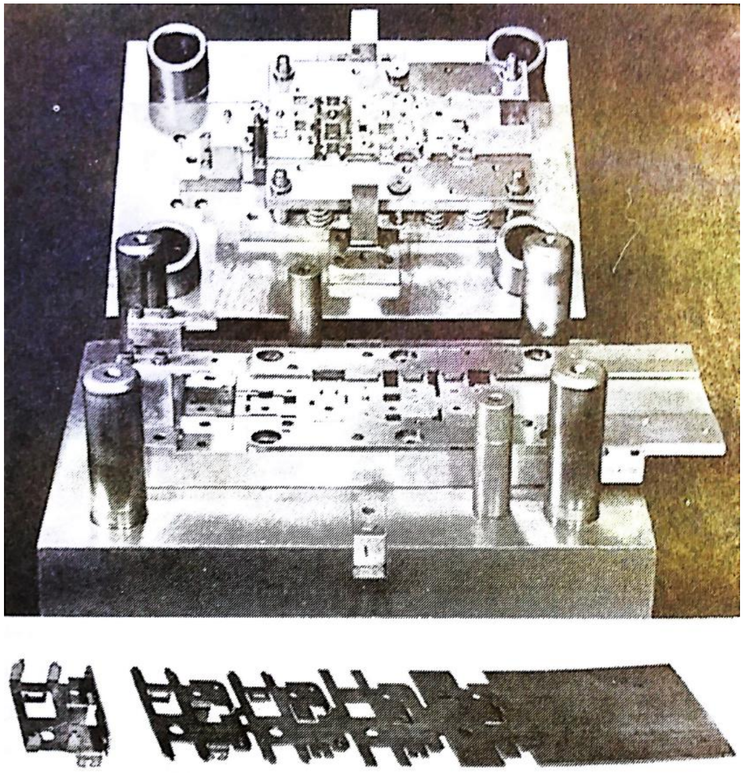
Complex dies can be assembled from many standardized punch and die components

Efficiency of the process greatly increases by modifying the design of parts to enable the use of standard die components

Another advantage of this approach is that the components can be removed and used to construct tooling for another product when the die is no longer needed

Progressive die sets that are produced from standardized components are both simple and efficient in many ways

Basically it consists of two or more sets of punches and dies mounted in tandem



Progressive dies can be used for many combinations of piercing, blanking , forming, lancing and drawing:

They are relatively simple to construct and are economical to maintain and repair

A defective punch or die does not require replacement of the entire die set

The material moves through a progressive die in the form of a continuous strip

The products are attached to the strip until the final cutoff operation

Attachment enables quick and accurate positioning of material in each of the die segments

However it restricts some of the forming operations and prevents part reorientation between steps

On the other hand compound dies enable a more accurate alignment of the various operations

Piercing, blanking and other combinations of operations occur sequentially during a single stroke of the ram.

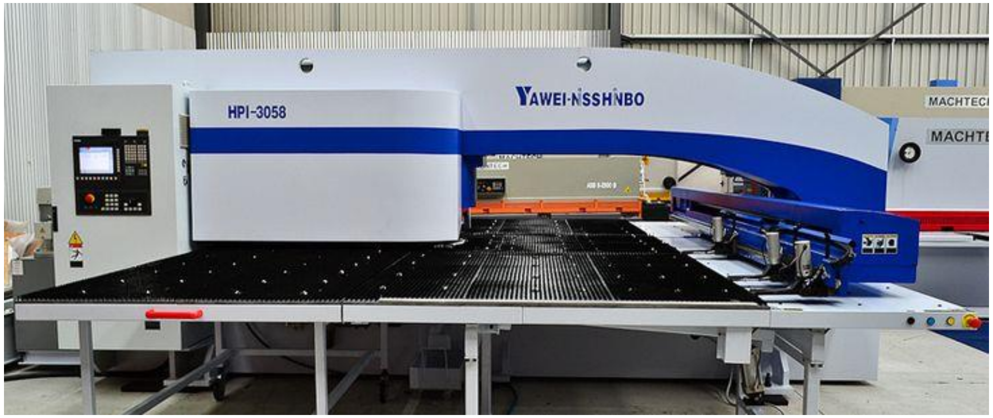
These dies are more precise but also more expensive and more susceptible to breakage

When many holes of varying sizes and shapes are to be placed in sheet components, numerically controlled turret-type punch presses may be used

As many as 60 separate punches and dies are contained within a turret in these machines

They are quickly rotated to provide the specific tooling required for operation

The workpiece is repositioned between operations, through numerically controlled X-Y movements of the worktable



Design for piercing and blanking

Following are the key points in design of dies for efficient use and long lifespan

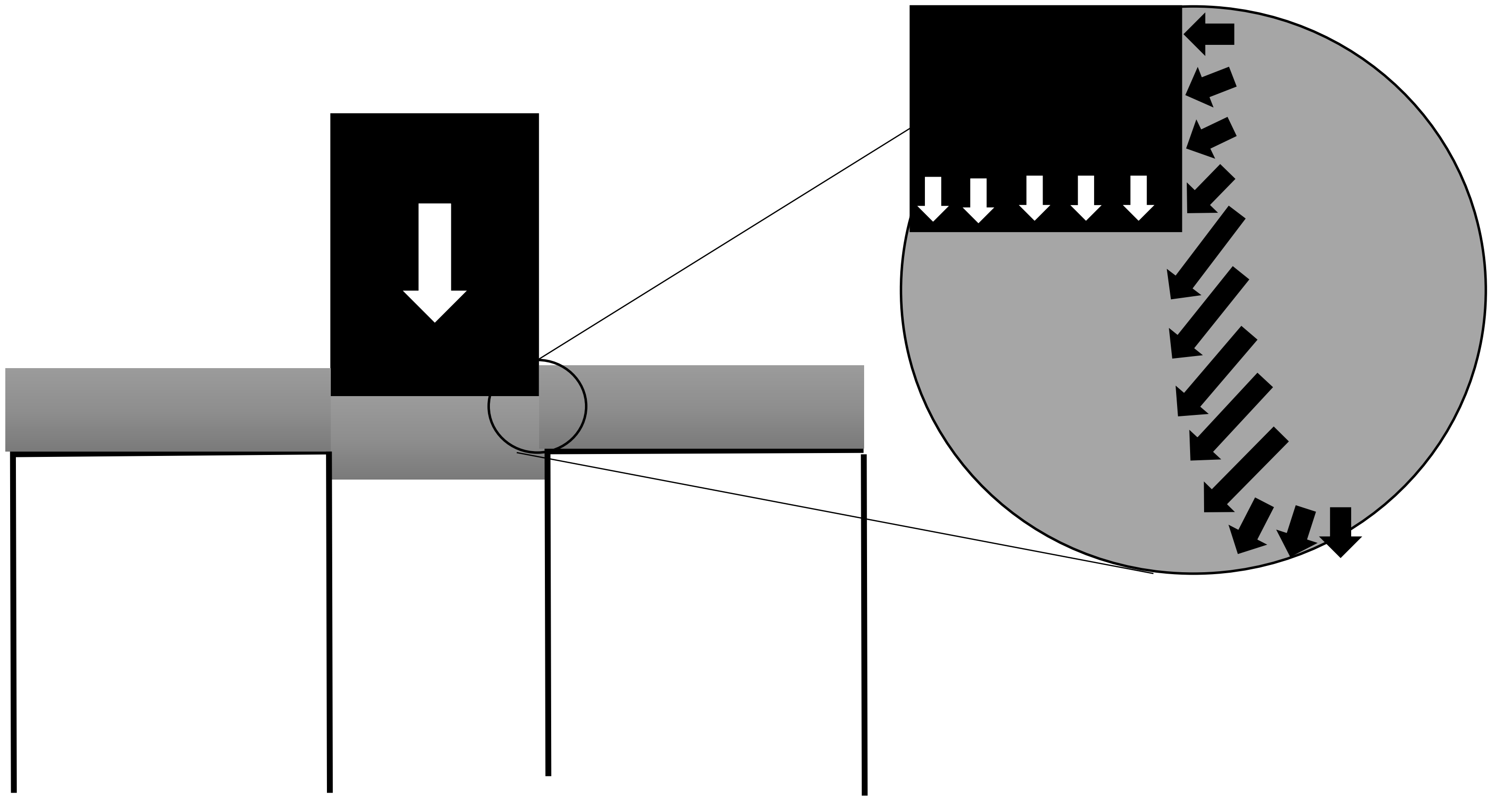
1. Diameters of pierced holes should not be less than the thickness of the metal. Smaller holes than 0.3 mm can be made but with difficulty
2. The minimum distance between holes, or between a hole and the edge of the stock should be at least equal to the metal thickness
3. The width of any projection or slot should be at least equal to the metal thickness and never less than 2.5 mm
4. Tolerances should be kept as large as possible. Tolerances below $\pm$0.075 mm requires shaving
5. Arrange the pattern of parts on the strip to minimize scrap

Process analysis

Blanking of sheet metal is done using a punch and die that have very low clearance between

Metal thickness reduces to a critical value as applied shear stress reaches the shear strength of the material

Instability at that point causes rapid rupture of metal under the punch perimeter

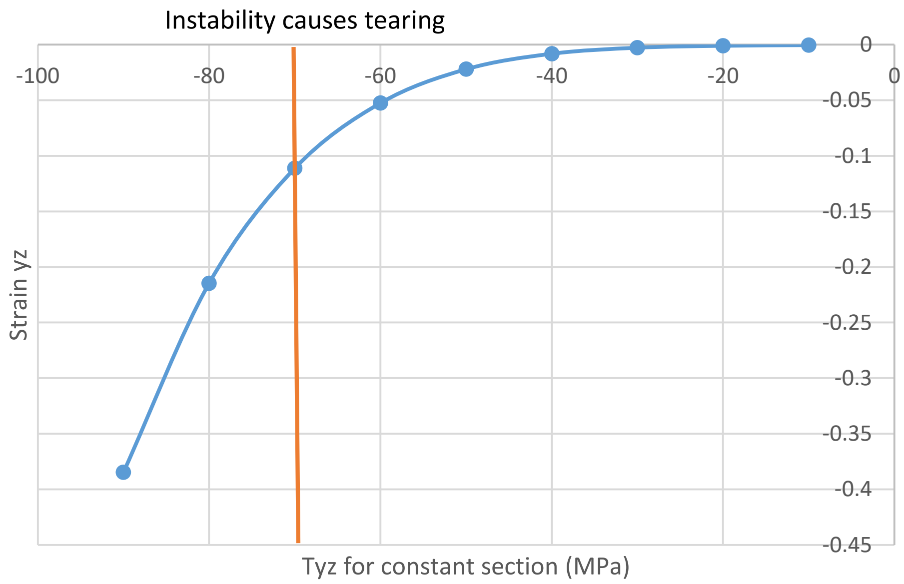


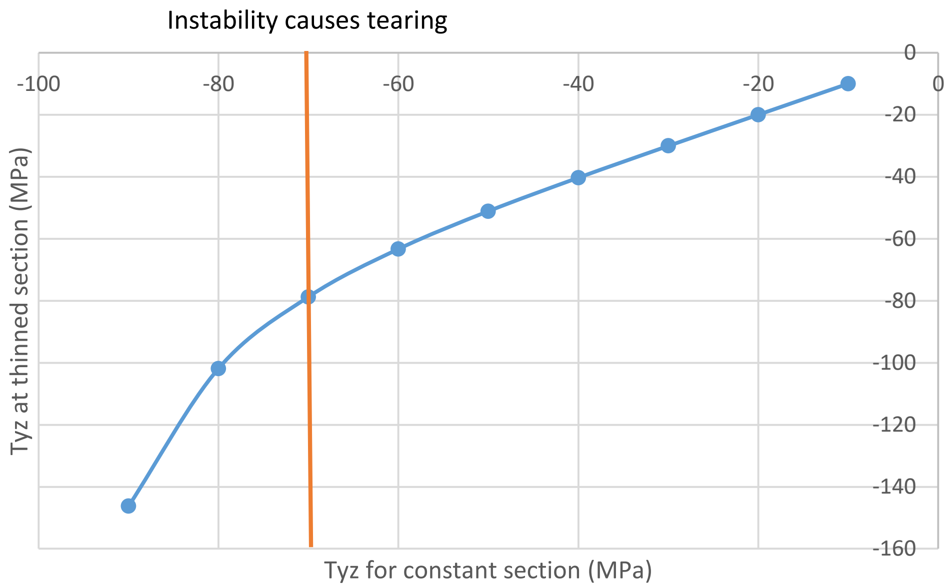
Consider blanking an aluminum sheet that is 1 mm in thickness, 1 m in width and length, with the following mechanical properties

$$\sigma_Y = 30\ MPa, \qquad \varepsilon_Y = 0.000429, \qquad E = 70\ GPa, \qquad \nu = 0.35, \qquad G = 25\ GPa, \qquad \tau = 70\ MPa$$

As the punch descends by a compressive force, it applies a shear stress in the metal cross section and causes shear strain and finally tearing

Only shear stress is taken into account to calculate the effective stresses





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Ramberg-Osgood model was used to calculate the strains and secant modulus with n=5 (strain hardening metal)