SINGLE POINT TOOLS

Cutting tools are designed with sharp edges to minimized rubbing contact between the tool and the workpiece. The various angles ground on a tool bit are called the basic tool angles, and compose what is often termed the tool geometry. The signature is a sequence of number listing the various angles, in degrees, and the size of the nose radius.

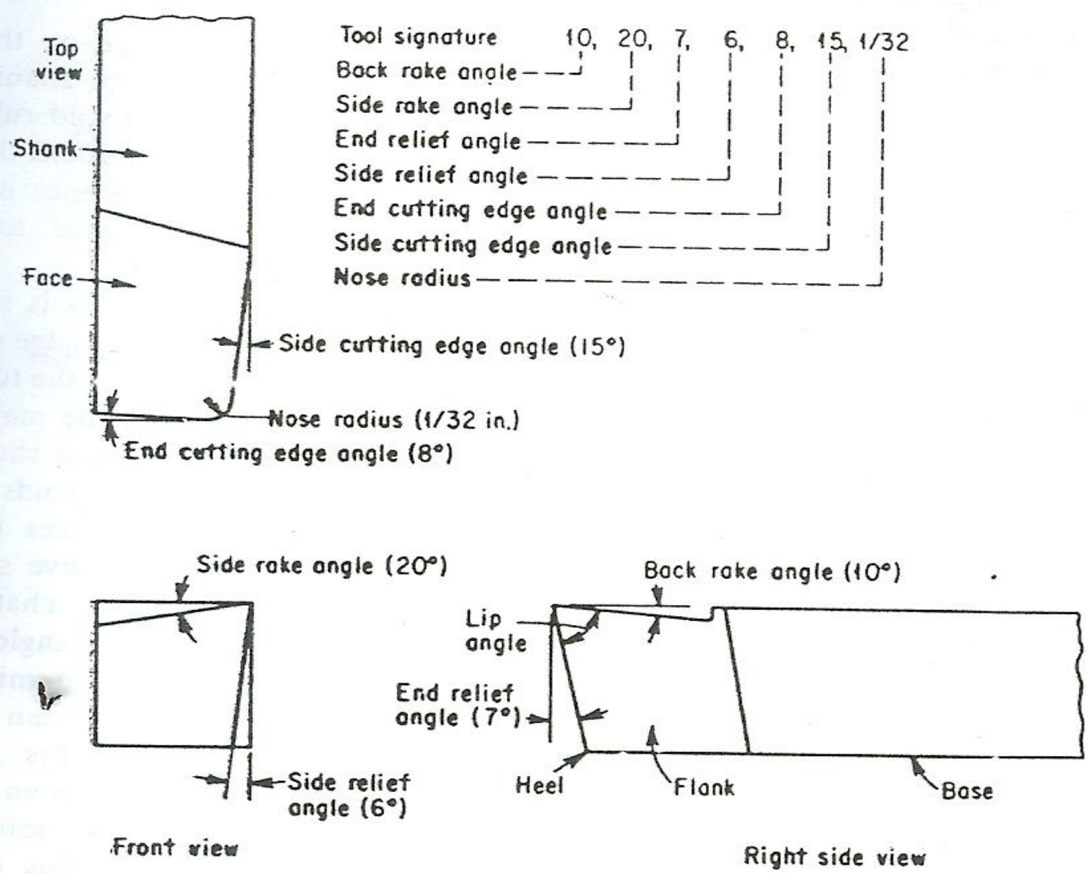


Fig. 1-1. A straight-shank, right-cut, single-point tool, illustrating elements of the tool signature as designated by the ASA. Positive r angles are shown.

Back rake angle. This is the angle between the face of the tool and a line that is parallel to the base of the toolholder. It is measured in a plane that is parallel to the side cutting edge and perpendicular to the base. Variation in the back rake angle affect the direction of chip flow.

Side rake angle. This angle is defined as the angle between the tool face and the plane parallel to the tool base. It is measured in a plane perpendicular to both the base of the holder and the side cutting edge. Variations in this angle affect the direction of chip flow.

End relief angle. This is the angle between the end flank and a line perpendicular to the base of the tool. The purpose of this angle is to prevent rubbing between the workpiece and the end flank of the tool.

Side relief angle. This is the angle between the side flank of the tool and a line drawn perpendicular to the base. For turning operations, the side relief angle must be large enough to allow for the feed helix angle on the shoulder of the workpiece.

End cutting edge angle. This is the angle between the edge on the end of the tool and a plane perpendicular to the side of the tool shank. The purpose is to avoid rubbing between the edge of the tool and the workpiece.

Side cutting edge angle. This is the angle between the straight cutting edge on bthe side of the tool and the side of the tool shank. This side edge provides the major cutting action and should be kept as sharp as possible.

Nose radius. The nose radius connects the side and end cutting edges and should blend smoothly into each to facilitate grinding.

Tool signature. The seven elements that comprise the signature of a single point cutting tools are always stated in the following order; back rake angle, side rake angle, end relief angle, side relief angle, end cutting edge angle, side cutting edge angle, and nose radius.

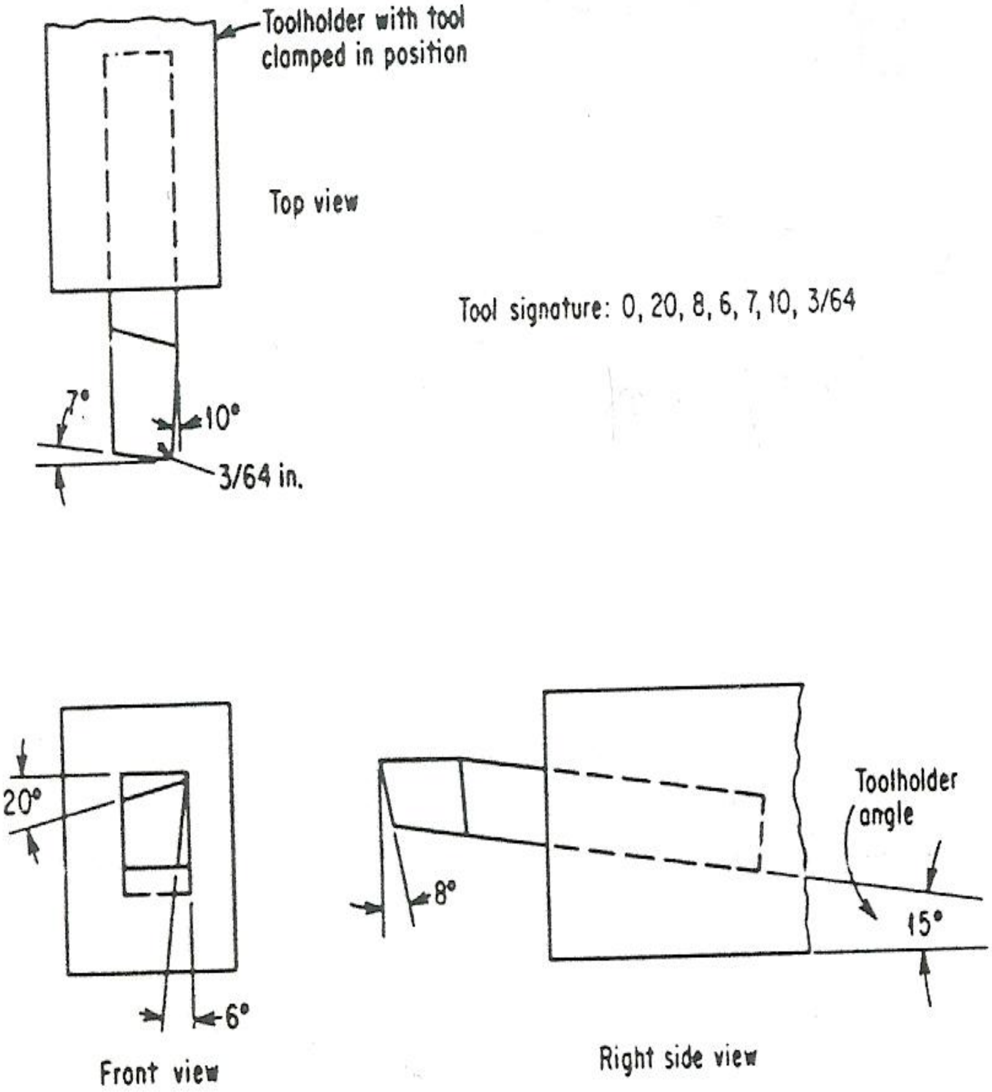


Fig. 1-4. A right-cut, single-point tool mounted in a 15-deg toolholder. Note that the tool signature lists the angles that result when the tool is clamped in the holder.

Figure 1-4 illustrates the effect of using a holder that position the base of the tool in a plane nonparallel with the plane of feeding motion. A 15 degrees toolholder is used, and the tool signature indicates the angle that result when the tool is positioned in the holder.

TABLE 1-1. RECOMMENDED ANGLE FOR HIGH-SPEED-STEEL SINGLE-POINT TOOLS

Material	Side-relief angle, deg	Front-relief angle, deg	Back-rake angle, deg	Side-rake angle, deg
High-speed, alloy, and high-carbon tool steels and stainless steel	7 to 9	6 to 8	5 to 7	8 to 10
SAE steels:				
1020, 1035, 1040	8 to 10	8 to 10	10 to 12	10 to 12
1045, 1095	7 to 9	8 to 10	10 to 12	10 to 12
1112, 1120	7 to 9	7 to 9	12 to 14	12 to 14
1314, 1315	7 to 9	7 to 9	12 to 14	14 to 16
1385	7 to 9	7 to 9	12 to 14	14 to 16
2315, 2320	7 to 9	7 to 9	8 to 10	10 to 12
2330, 2335, 2340	7 to 9	7 to 9	8 to 10	10 to 12
2345, 2350	7 to 9	7 to 9	6 to 8	8 to 10
3115, 3120, 3130	7 to 9	7 to 9	8 to 10	10 to 12
3135, 3140	7 to 9	7 to 9	8 to 10	8 to 10
3250, 4140, 4340	7 to 9	7 to 9	6 to 8	8 to 10
6140, 6145	7 to 9	7 to 9	6 to 8	8 to 10
Aluminum	12 to 14	8 to 10	30 to 35	14 to 16
Bakelite	10 to 12	8 to 10	0	0
Brass, free-cutting	10 to 12	8 to 10	0	1 to 3
Red, yellow, bronze—cast, bronze—commercial	8 to 10	8 to 10	0	−2 to −4
Bronze, free-cutting	8 to 10	8 to 10	0	2 to 4
Hard phosphor bronze	8 to 10	6 to 8	0	0
Cast iron, gray	8 to 10	6 to 8	3 to 5	10 to 12
Copper	12 to 14	12 to 14	14 to 16	18 to 20
Copper alloys:				
Hard	8 to 10	6 to 8	0	0
Soft	10 to 12	8 to 10	0 to 2	0
Fiber	14 to 16	12 to 14	0 to 2	0
Formica	14 to 16	10 to 12	14 to 16	10 to 12
Nickel iron	14 to 16	10 to 12	6 to 8	12 to 14
Micarta	14 to 16	10 to 12	14 to 16	10 to 12
Monel and nickel	14 to 16	12 to 14	8 to 10	12 to 14
Nickel silvers	10 to 12	10 to 12	8 to 10	0 to −2
Rubber, hard	18 to 20	14 to 16	0 to −2	0 to −2

Chip formation

Chip formation involves the basic requirements:

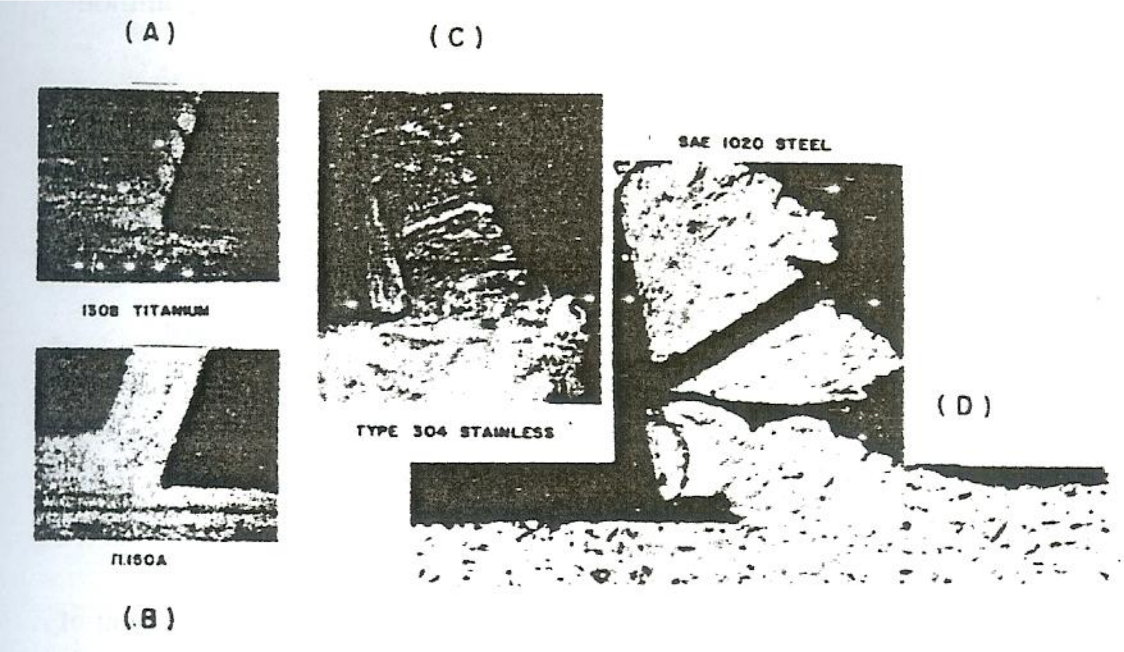
1. their must be a cutting tool that is harder and more wear resistant than the workpiece material.
2. there must be interference between the tool and the workpiece as designated by the feed and depth of cut
3. there must be a relative motion or cutting velocity between the tool and the workpiece with sufficient force and power to overcome the resistance of the workpiece material.

As long as these three conditions exist, the portion of the material being machined that interferes with free passage of the tool will be displaced to create a chip.

Types of chips

The three most common types of chips are illustrated by the photo micrographs

A. discontinous or segmental
B. continous without built-up edge
C. continous with built-up edge.



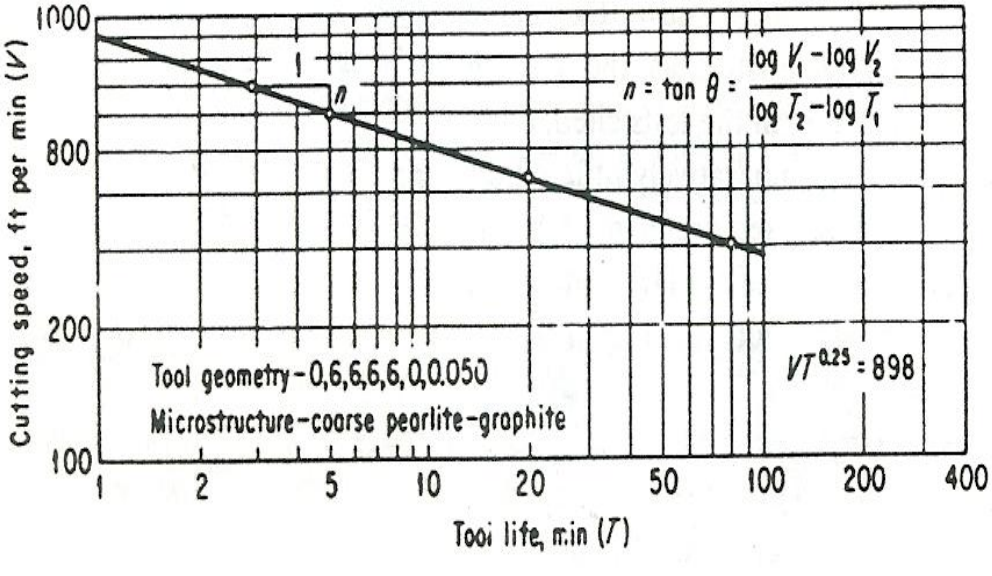
Tool wear

For the sake of recognition and understanding of the fundamentals of metal cutting, the effects of changes in the manipulating factors have been described without regard to their influence upon such criteria as tool wear and tool life. Yet there is no known tool material flat can completely resist contact and rubbing at high temperatures and high pressure, with some changes from its original contours over a period time. It becomes necessary, therefore to think of the effect of the manipulating factors not only upon the cutting process itself, but upon the performance of the cutting tool, which may, in turn, itself affect the cutting process.

Tool life

The types and mechanism of tool failure have been previously described. It was shown that excessive cutting speeds cause a rapid failure of the cutting edge; thus, the tool can be declared to have had a short life. Other criteria are sometimes used to evaluate tool life, these are :

1. change of the quality of the machined surface
2. change in the magnitude of the cutting force resulting in changes in machine and workpiece deflections causing workpiece dimensions to change
3. change in the cutting temperature.



The logarithm of tool life in minutes is plotted against the logarithm of cutting speed in feet perminute. The resulting curve is very nearly a straight line in the most instances. For are practical purposes it can be considered a straight line. This curved is expressed by the following equation :

$VT^n = C$

Where : V = cutting speed, feet per minute
T = tool life, minutes
C = a constant equal to the intercept of the curve and the ordinate or the cutting speed- actually it is the cutting speed for a one minute tool life.
n = slope of the curve.

Machining economics

Althoughts the equation already given will predict the tool life for a given cutting speed with reasonable accuracy, they do not answer the question of what tool life should be obtained for maximum production or for minimum cost per part. The following equations will provide the answers to these questions.

Tool life for maximum production :

$$T = \left(\frac{1}{n} - 1\right) K_2$$

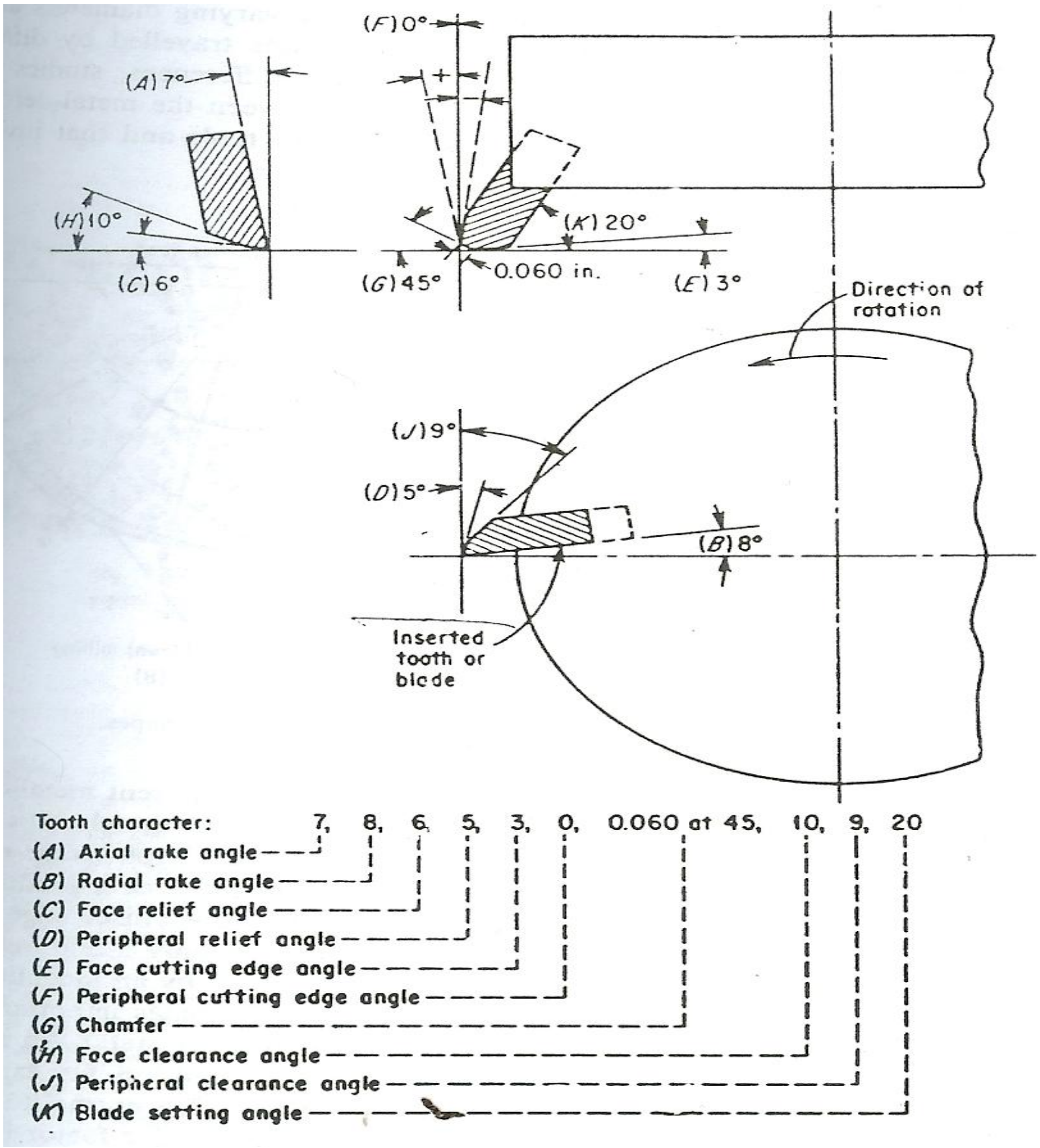
Tool life for minimum cost per part:

$$T = \left(\frac{1}{n} - 1\right)\left(\frac{K_2 K_3 + K_4}{K_3}\right)$$

Where : T = tool life,minutes
N = slope of the tool life curve
K2 = tool changing time per tool, minutes
K3 = machine labor plus burden cost, dollars perminute.
K4 = tool regrinding cost, dollars per cutting edge plus original cost of tool, devided by the number of available cutting edges per tool.

Basic Principles Of Multiple Point Tools

Multiple-point cutting tools are basically a series of single point tools mounted in or integral with a holder or body and operated in such a manner that all the teeth follow essentially the same path across the work piece. Multiple point tools may be of either the linear-travel or the rotary type.



WORKHOLDING DEVICES

The term workholder embraces all devices that hold, grip or chuck a workpiece in a prescribed manner of firmness and location, to perform on it a manufacturing operation. The holding force may be applied mechanically, electrically, hydraulically or pneumatically.

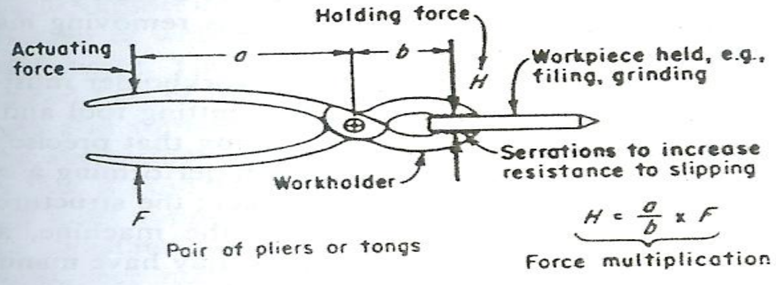


Fig. 2-2. Muliplication of holding force.

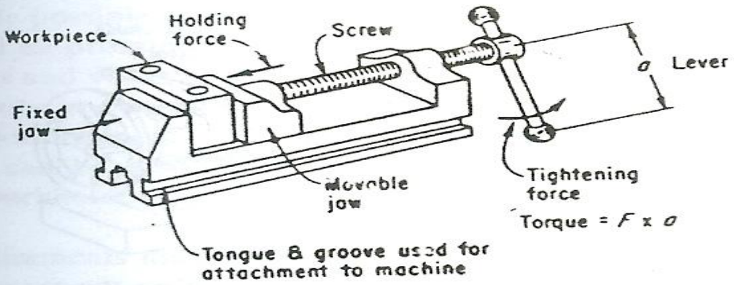


Fig. 2-3. Elementary workholder (vise).

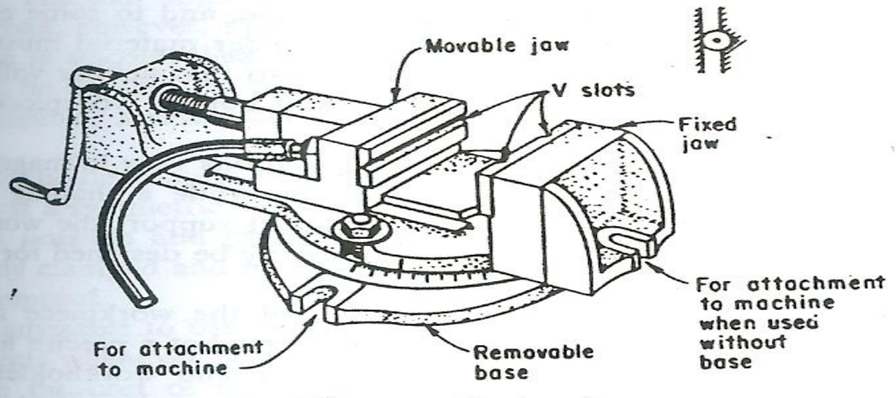


Fig. 2-4. Vise with hydraulic clamping.

Evolution of workholders

Direction of forces. The application of any metal removal process to a specific workpiece will result in a distinctive combination of forces. It is possible to list the many processes and anticipate forces to some extent. The torque of a drilling operations or the thrust of a shaping operations can be readily visualized.

Magnitude of forces. The workholder must support the workpiece ina precise location while it is subjected to the cutting forces. The workholder must therefore be designed to withstand forces of specific direction and magnitude.

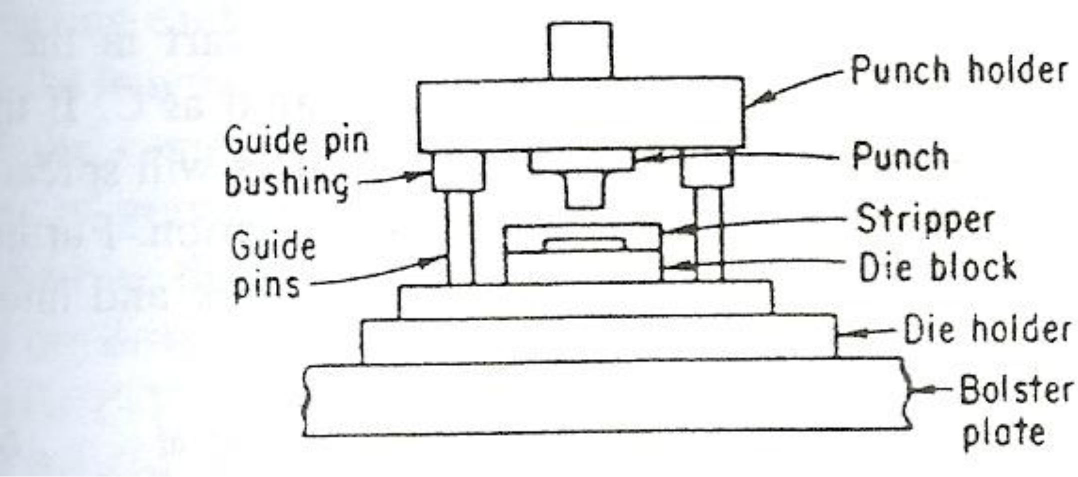
Combined methods. The cut and try approach in itself is neither efficient nor sale. The resulting workholders may be either much stronger than required or may be on the brink of failure with potential danger to personnel. The analytical approach in itself is not practical. Complete determination of the magnitude and direction of all forces coupled with virgin design of all fixture components would in most cases be economically impossible. A workholder would probably have fasteners of different diameter at each attachment point to match the anticipated load, and therefore would be impractical from maintenance standpoint.

DESIGN OF PRESSWORKING TOOLS

Power pressed

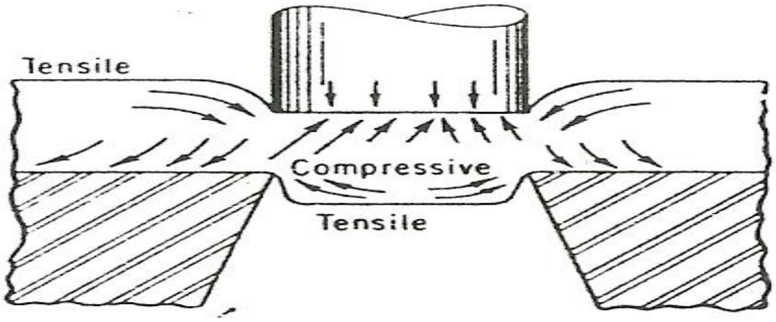
Energy stored in the rotating flywheel of a mechanical press or supplied by a hydraulic system in a hydraulic press is transferred to the ram for its linear movement. An open back incenable (OBI) press, widely used, has C shaped frame which allows access to its working space.

Cutting (shearing)operations



Shear action in die cutting operations

The cutting of metal between die components is a shearing process in which the metal is stressed in shear between two cutting edges to the point of fracture or beyond its ultimate strength.



Cutting forces

The pressure P required to cut (shear) work material is

$$P = \pi . D . St \ (\textit{for round holes})$$

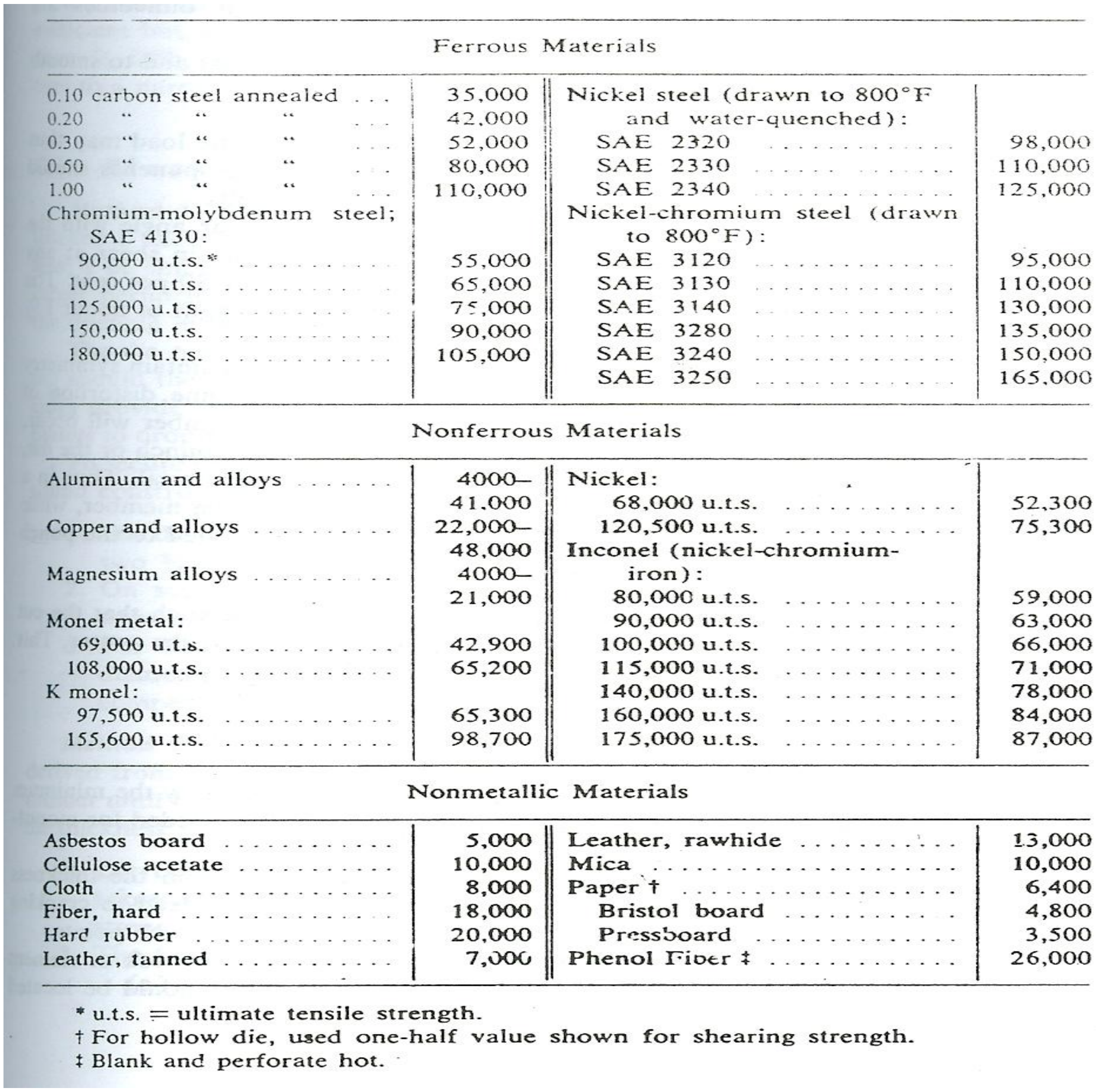
$$P = SLt \ (\textit{for other contours})$$

Where : S = shear strength of material, Psi

D = hole diameter, in.

L = shear length,in.

T = material thickness,in.



Ferrous Materials			
0.10 carbon steel annealed . . .	35,000	Nickel steel (drawn to 800°F and water-quenched):	
0.20 " " " . . .	42,000		
0.30 " " " . . .	52,000	SAE 2320	98,000
0.50 " " " . . .	80,000	SAE 2330	110,000
1.00 " " " . . .	110,000	SAE 2340	125,000
Chromium-molybdenum steel; SAE 4130:		Nickel-chromium steel (drawn to 800°F):	
90,000 u.t.s.*	55,000	SAE 3120	95,000
100,000 u.t.s.	65,000	SAE 3130	110,000
125,000 u.t.s.	75,000	SAE 3140	130,000
150,000 u.t.s.	90,000	SAE 3280	135,000
180,000 u.t.s.	105,000	SAE 3240	150,000
		SAE 3250	165,000
Nonferrous Materials			
Aluminum and alloys	4000–41,000	Nickel:	
		68,000 u.t.s.	52,300
Copper and alloys	22,000–48,000	120,500 u.t.s.	75,300
		Inconel (nickel-chromium-iron):	
Magnesium alloys	4000–21,000	80,000 u.t.s.	59,000
Monel metal:		90,000 u.t.s.	63,000
69,000 u.t.s.	42,900	100,000 u.t.s.	66,000
108,000 u.t.s.	65,200	115,000 u.t.s.	71,000
K monel:		140,000 u.t.s.	78,000
97,500 u.t.s.	65,300	160,000 u.t.s.	84,000
155,600 u.t.s.	98,700	175,000 u.t.s.	87,000
Nonmetallic Materials			
Asbestos board	5,000	Leather, rawhide	13,000
Cellulose acetate	10,000	Mica	10,000
Cloth	8,000	Paper †	6,400
Fiber, hard	18,000	Bristol board	4,800
Hard rubber	20,000	Pressboard	3,500
Leather, tanned	7,000	Phenol Fiber ‡	26,000

* u.t.s. = ultimate tensile strength.

† For hollow die, used one-half value shown for shearing strength.

‡ Blank and perforate hot.

Types of die cutting operations

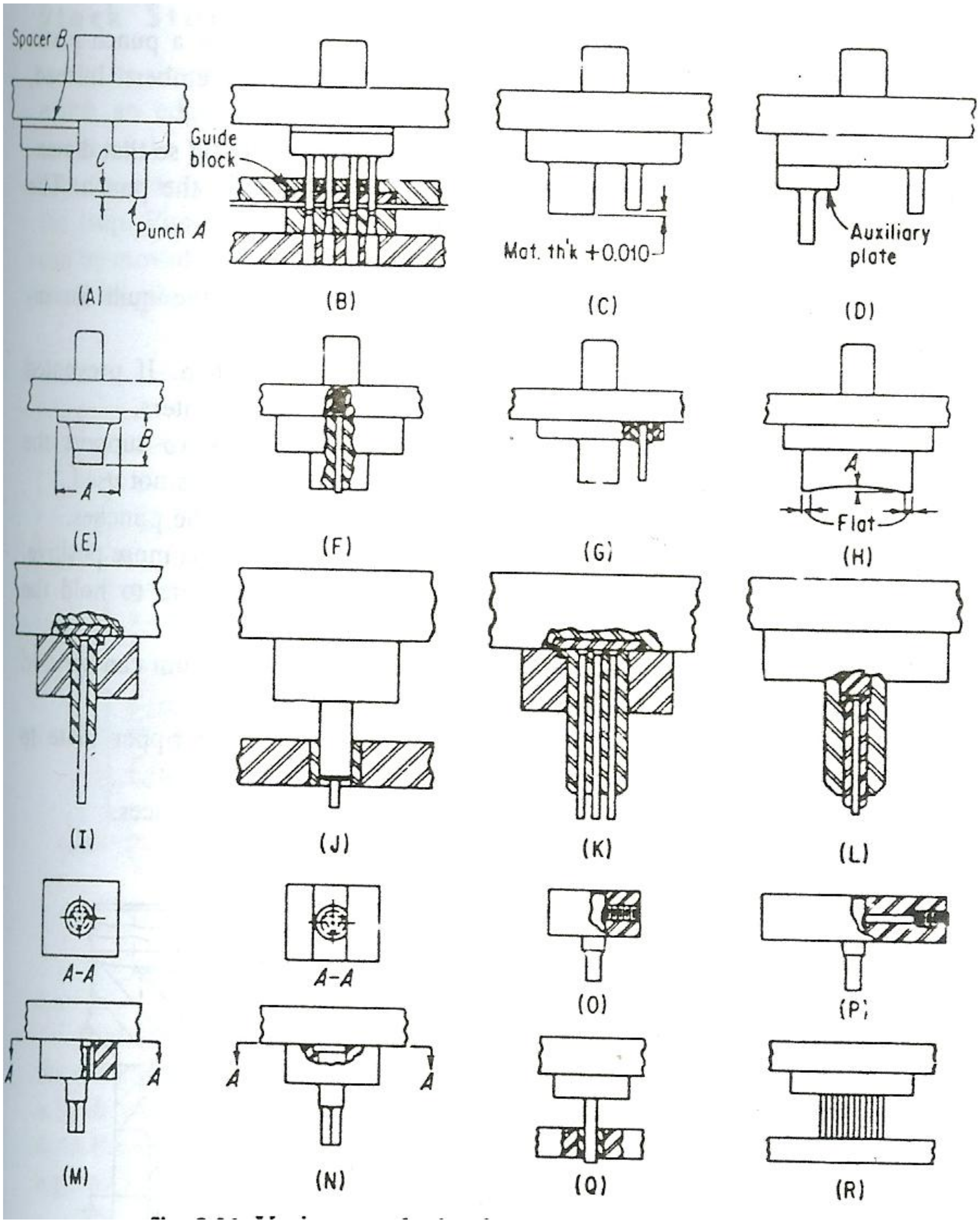
The operations of die cutting of work materials are classified as follows :

Piercing (punching). Is the operation in which a round punch (or of other contours) cuts a hole in the work material which is supported by a die having an opening corresponding exactly to the contour of the punch. The material (slug) cut from the work material is often scrap.

Blanking. Fundamentally differs from piercing only in that the part cut from the work material is usable, becoming a blank (workpiece) for subsequent pressworking or other processing.

Lancing. Combines bending and cutting along a line in the work material. It does not produce a detached slug and leaves a bent portion or tab attached to the work material.

A cut off operation achieves complete separation of the work material by cutting it along straight or curved lines.


Spacer B
C
Punch A
(A)
Guide block
(B)
Mat. th'k +0.010
(C)
Auxiliary plate
(D)
B
A
(E)
(F)
(G)
A
Flat
(H)
(I)
(J)
(K)
(L)
A-A
A-A
(O)
(P)
A
A
(M)
A
A
(N)
(Q)
(R)

Piercing die design

A complete press tool for cutting two holes in work material, at one stroke of the press, as classified and standardized by a large manufacturer as a single-station piercing die.

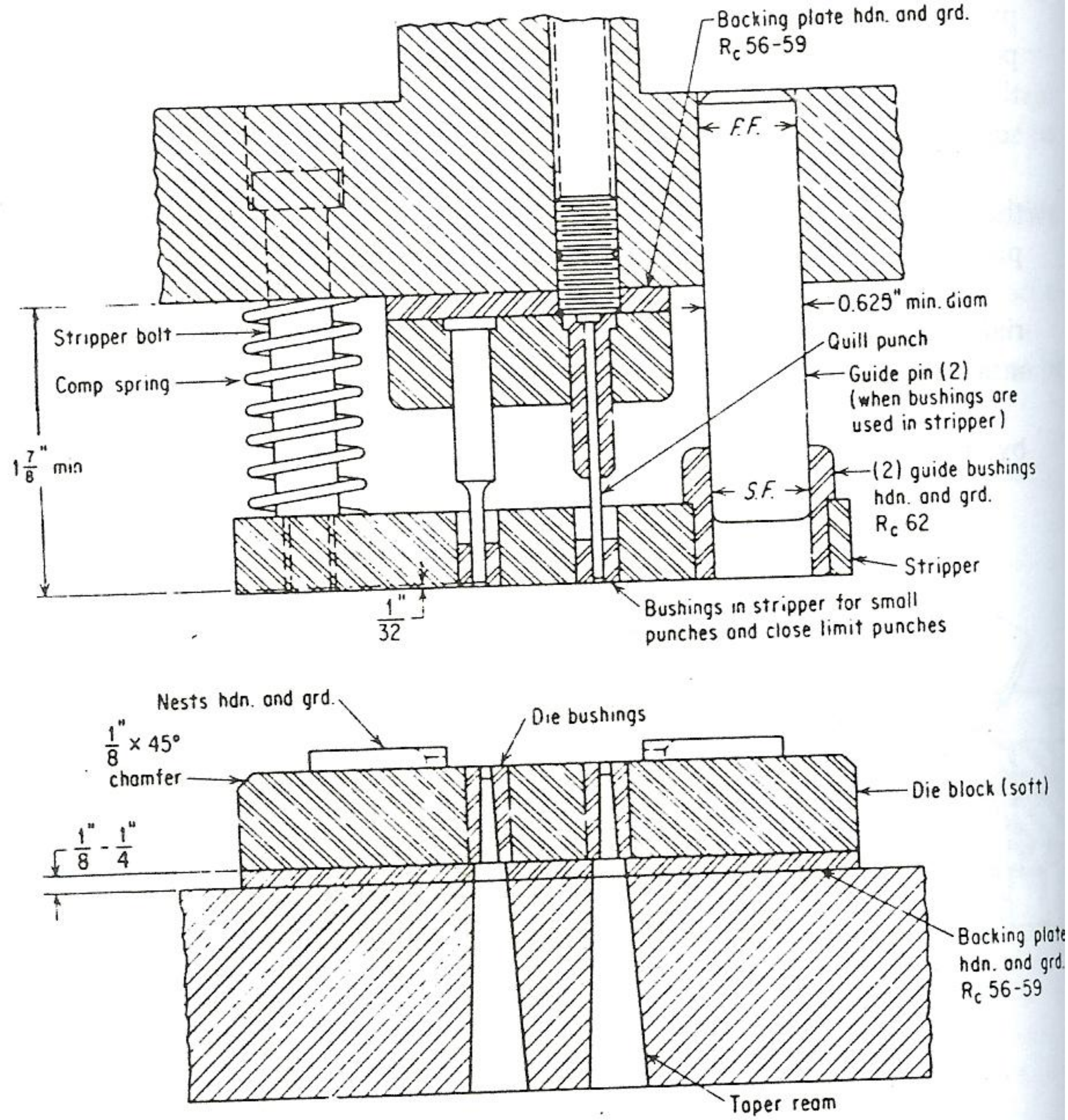
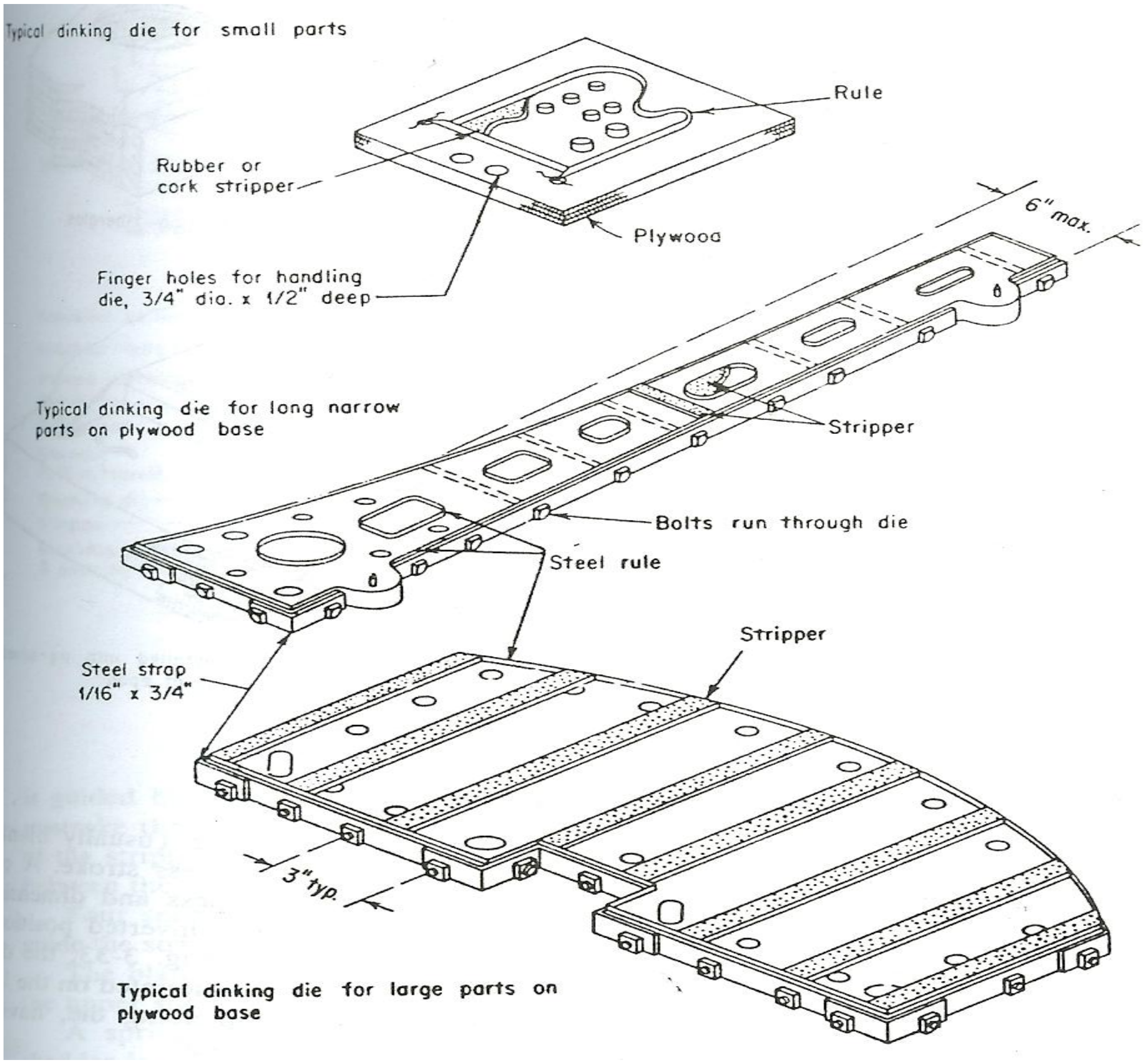


Fig. 3-27. Typical single-station die for piercing two holes.

Blanking die design.

Cutting-rule dies. Instead of a conventional female die, the sharp edges of steel rule form the cutting blades of the dies. The rule, bent to the contour of the blank outline, is used principally for blanking cork, paper and similar nonmetallic fibrous material, although the economical blanking of aluminum stock up to 0,4 in.



BENDING, FORMING AND DRAWING DIES

Bending dies

Bending is uniform straining of material, usually flat sheet or strip metal, around a straight axis which lies in the neutral plane and normal to the lengthwise direction of the sheet or strip. Metal flow takes place within the plastic range of the metal, so that the bend retains a permanent set after removal of the applied stress. The inner surface of a bend is in compression; the outer surface is in tension. A pure bending action does not reproduce the exact shape of the punch and die in the metal; such a reproduction is one of forming.

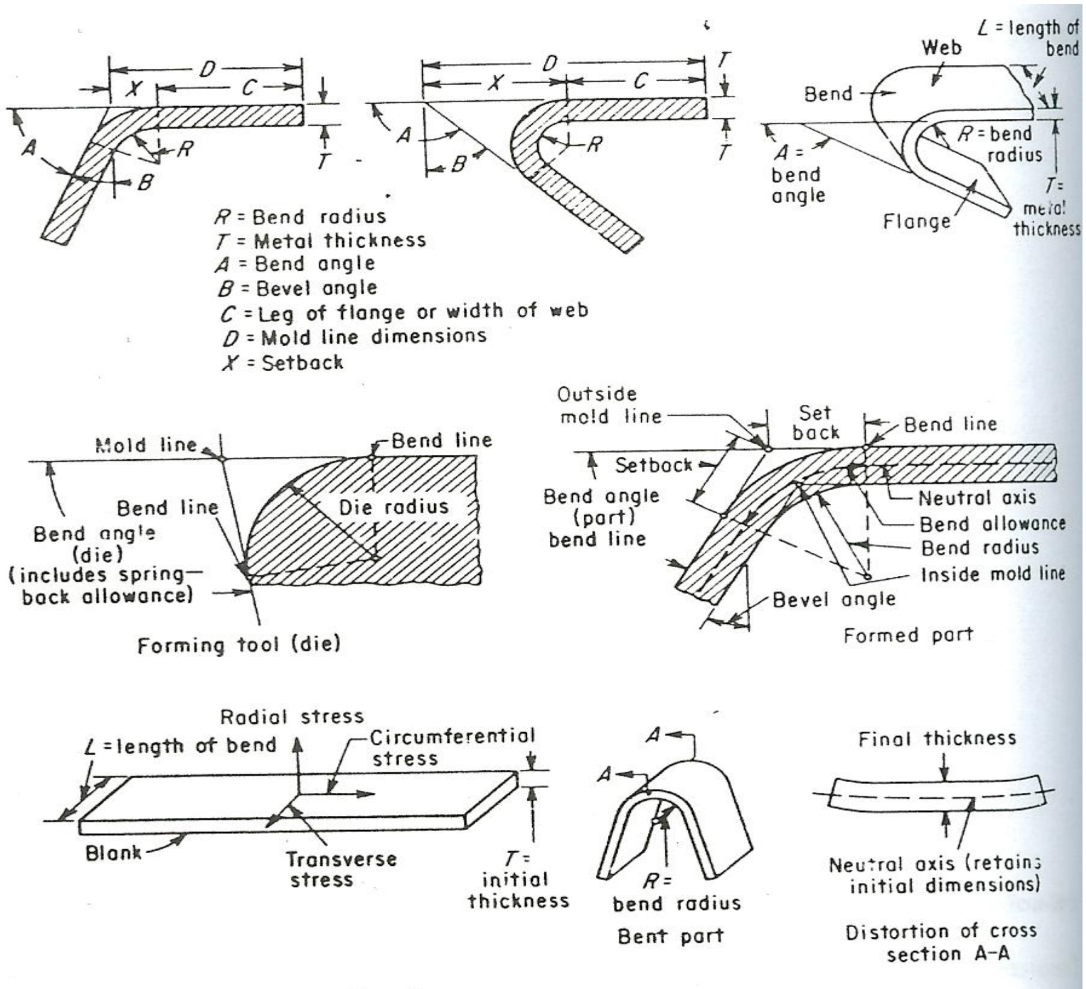
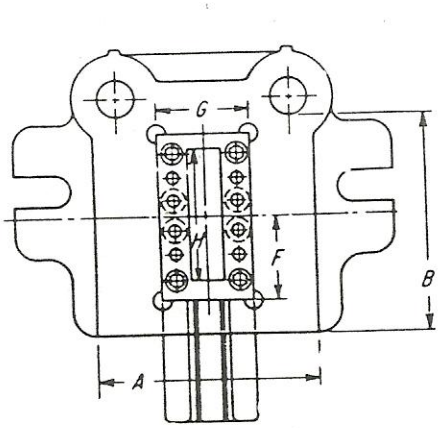


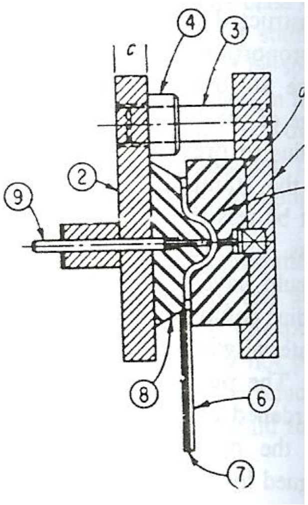
Fig. 4-1. Bending terms.

Forming dies

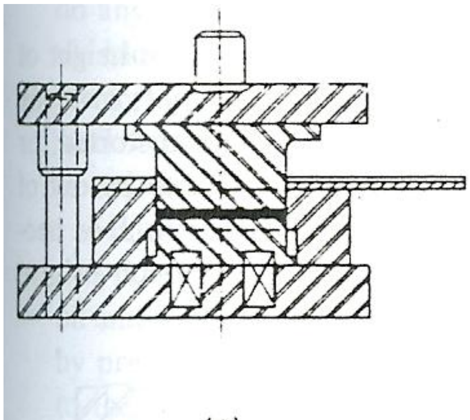
Forming dies, often considered in the same class with bending dies, are classified as tools that form or bend the blank along a curved axis instead of straight axis. There is very little stretching or compressing of the material. The internal movement or the plastic flow of the material is localized and has little or no effect on the total area or thickness of the material. The operations classified as forming are embossing, curling, beading, twisting, and hole flanging

Solid form dies

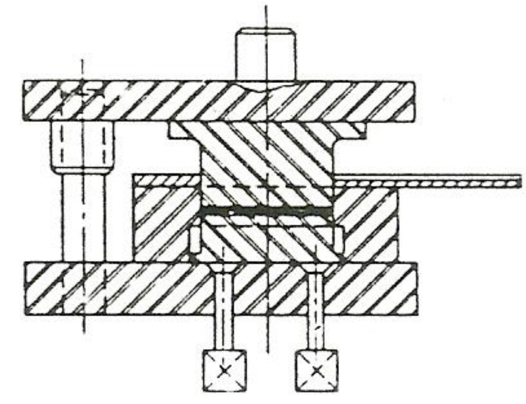




Forming dies with pressure pads



(A)



(B)

Drawing dies

Drawing is a process of changing a flat, precut metal blank into a hollow vessel without excessive wrinkling, thinning or fracturing. The various form produced may be cylindrical or box-shaped with straight or tapered sides or a combination of straight, tapered or curved sides. The size of the part may vary from ¼ in. diameter or smaller, to aircraft or automotive parts large enough to require the use of mechanical handling equipment.

Single action dies

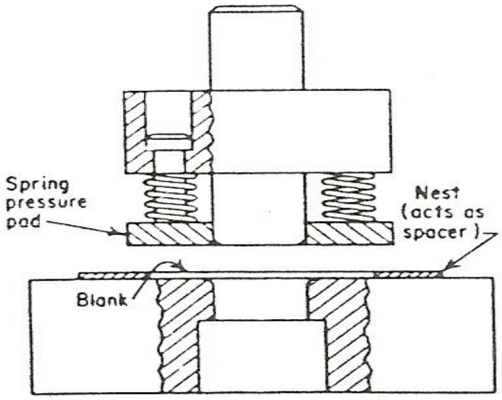


Fig. 4-34. Draw die with spring pressure pad.

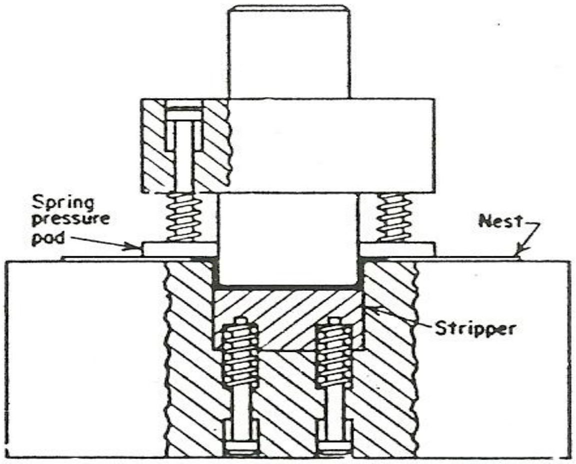
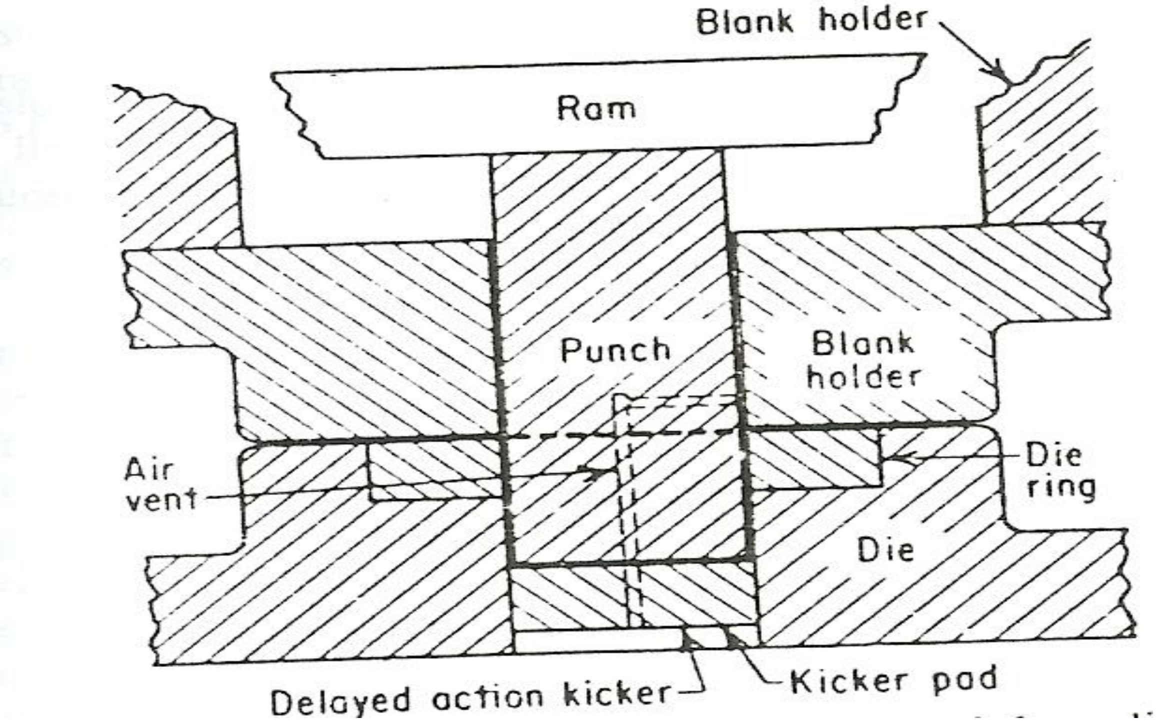
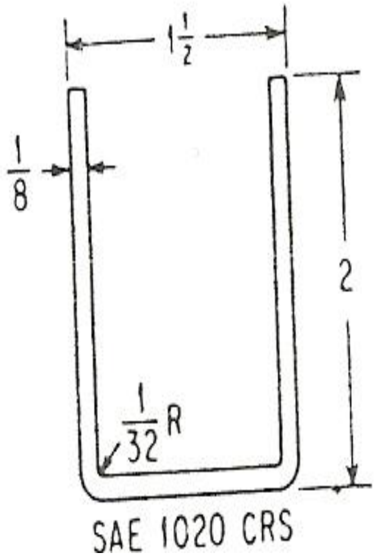


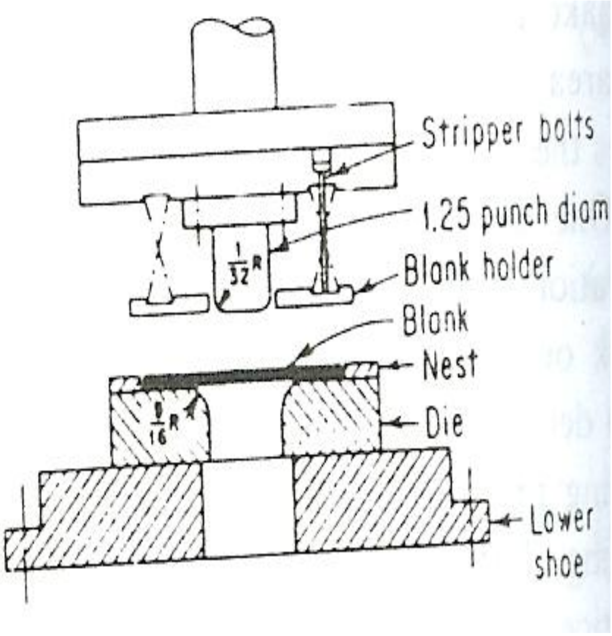
Fig. 4-35. A draw die with spring pressure pad and stripper.

Double action dies



Evolution of a draw die





INJECTION MOLDS AND EXTRUSION MOLDS

Classification of injection molds

A critical evaluation of a large number of injection molds for part fulfilling a variety of applications results in the identification of certain classes and groups thet differ from each other in the construction in some basic manner. a basic requirement of any mold that is intended for use on an automatic injection molding machine is that the molded parts be automatically ejected from the mold without the necessity for secondary operations.

From a practical standpoint, a classification of injection molds should be based on the main design features and manner of operation. These include:

- The type of gating and means of degating
- The type of ejection used for the molded parts
- The presence or absence of external or internal undercuts on the parts to be molded.
- The manner in which the part is released from the mold

Effect of draft on the design of an injection mold

For functional reasons, the draft that must sometimes be employed in an injection mold appears contrary to that required for easy part removal. The requirements in this example is to produce a slip together protective coil case consisting of two identical halves of which four are produced simultaneously in one mold

Fig. 1.4/1

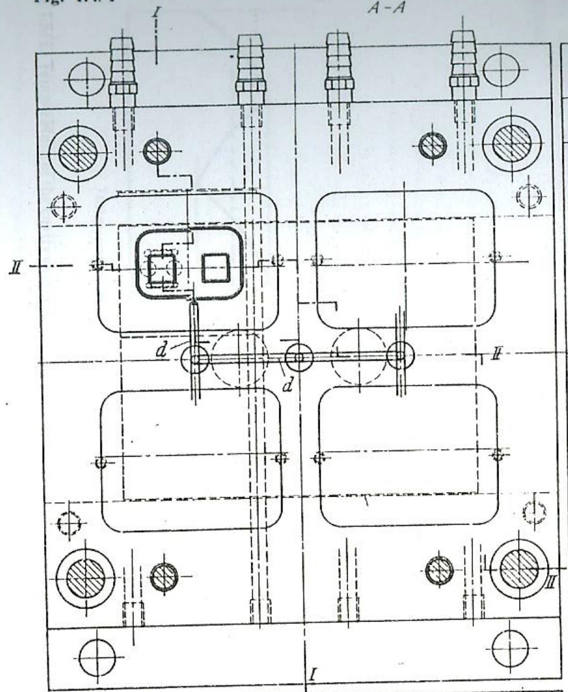


Fig. 1.4/2

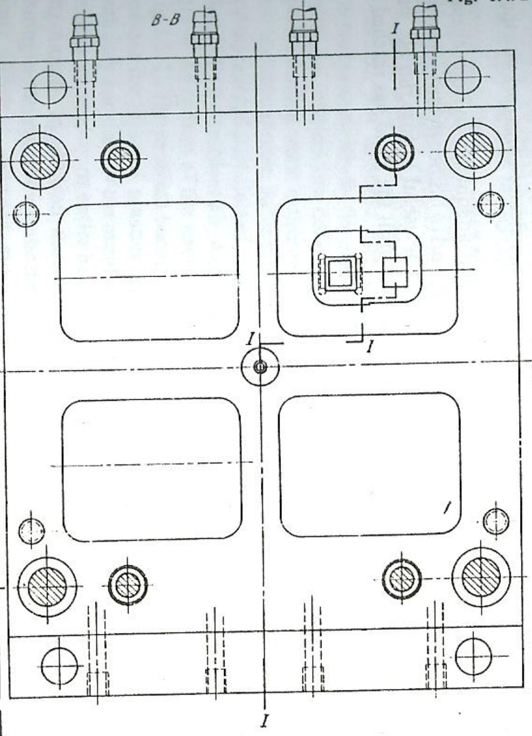
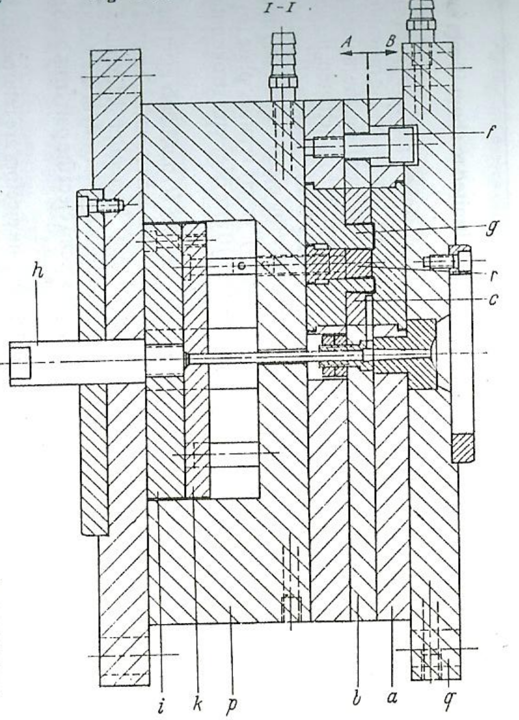


Fig. 1.4/3



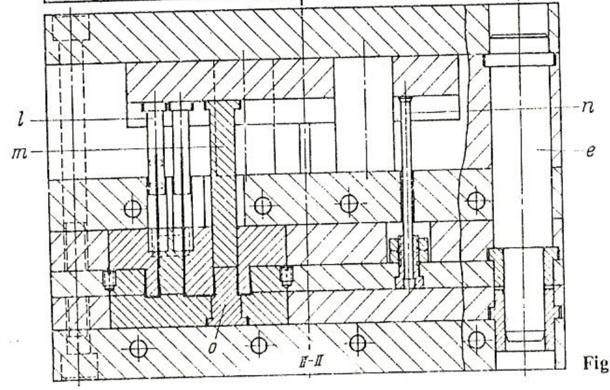


Fig. 1.4/4

Example 1

Figs. 1.4/1 to 1.4/4. Four-cavity mold for coil case.
(*a, b*) Insert retainer plates, (*c*) stationary-side inserts, (*d*) runners, (*e*) guide pins, (*f*) stop bolts, (*g*) cores, (*h*) ejector rod, (*i, k*) ejector plate, (*l*) blade ejector, (*m*) ejector cores, (*n*) ejector pins, (*o*) cores; (*p, q*) cooling plates.

Four cavity injection mold for production of ABS cases

Fig. 1.5/24

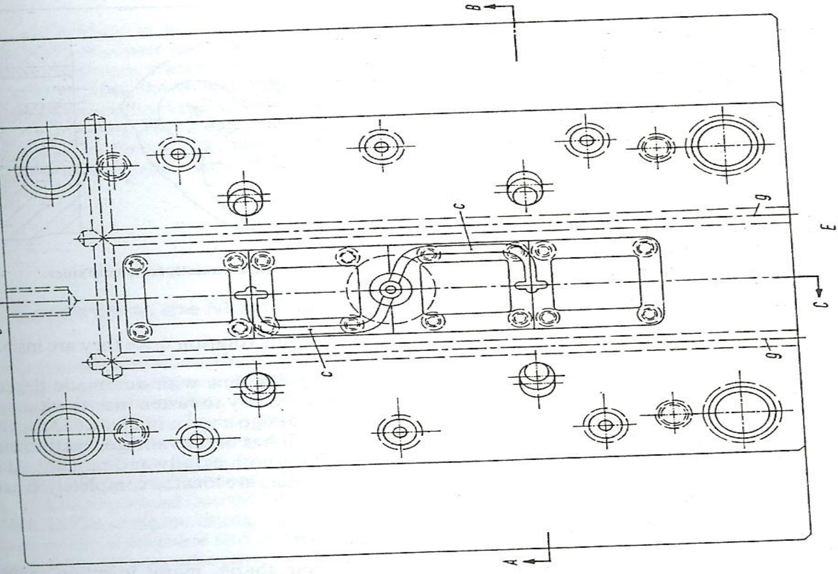
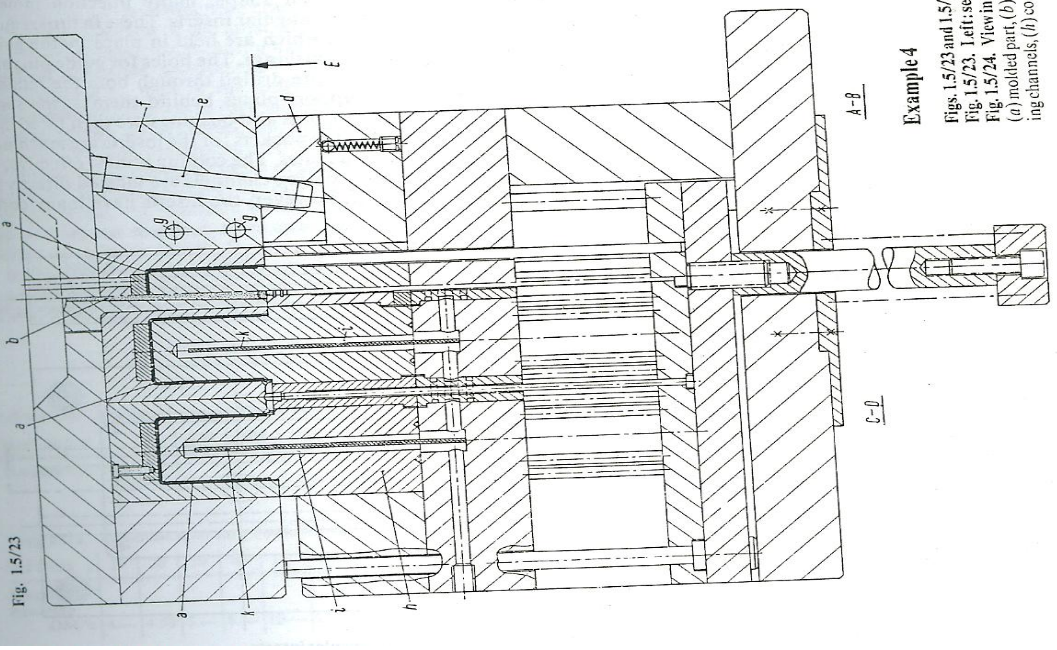


Fig. 1.5/23



Example 4

Figs. 1.5/23 and 1.5/24. Four-cavity injection mold for ABS case, designed using standard mold components.
Fig. 1.5/23. Left: section C–D, right: A–B.
Fig. 1.5/24. View in direction of E.
(*a*) molded part, (*b*) sprue, (*c*) runner, (*d*) sliding plate, (*e*) cam pin, (*f*) stationary side cavity retainer plate, (*g*) cooling channels, (*h*) cores, (*i*) cooling channels, (*k*) baffles.

Runner system and gating

Sizing of sprues and runners

Sprues, runners and gates fulfill the function of conveying the plastics melt from the nozzle of the injection unit to the individual cavities.

Sprue

The sprue may be considered the continuation in the mold of the channel in the nozzle. Single cavity molds where the sprue leads directly to the molded part are said to have direct sprue gating. The sprue should have $1{,}5^{o}$ of draft. Greater draft may simplify removal from the sprue bushing, but with a longer sprue results in a greater diameter and thus longer cooling time. The nozzle orifice should be about 0,5 mm smaller in diameter than the smallest opening in the sprue bushing so that there is no undercut at the end of the sprue to hinder removal.

Runners

In multiple cavity molds, the plastic melt must flow to the individual cavities through runners in the mold parting line. The same basic rules that apply to the sprue apply also to the cross section of this runners. An additional factor that must be considered is that the cross section is also a function of the length of the runner, since it may be assumed that the pressure lost in a runner increase at least proportionally with the length. Because the sprue and runner system represent lost material and lost plasticating capacity, the runners should be designed to be as short as possible and with the smallest possible section.

Self degating injection molds for flat parts

Fig. 2.2/4
I–I

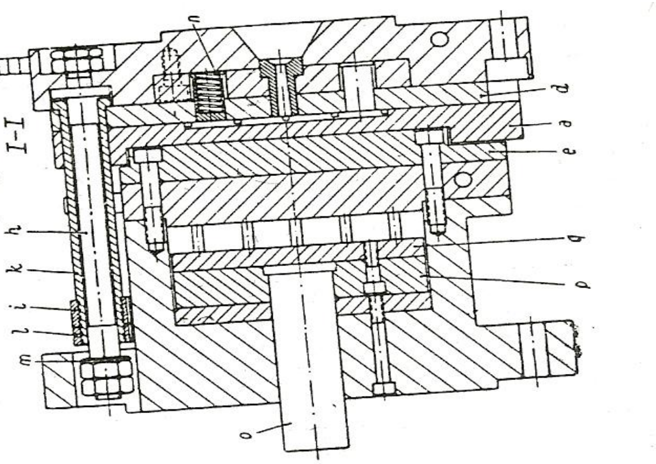


Fig. 2.2/3
B-B

Fig. 2.2/2
A-A

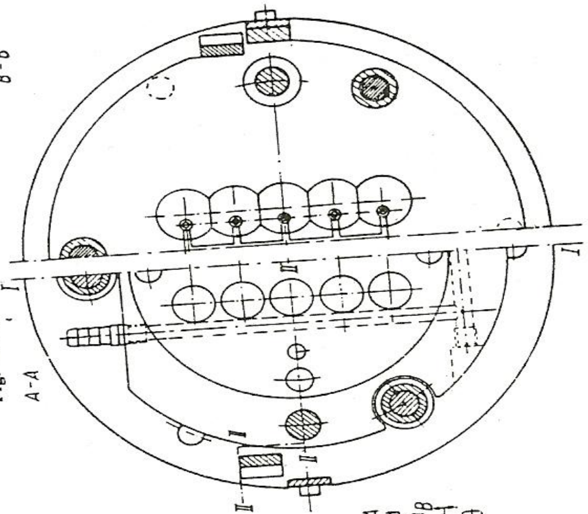
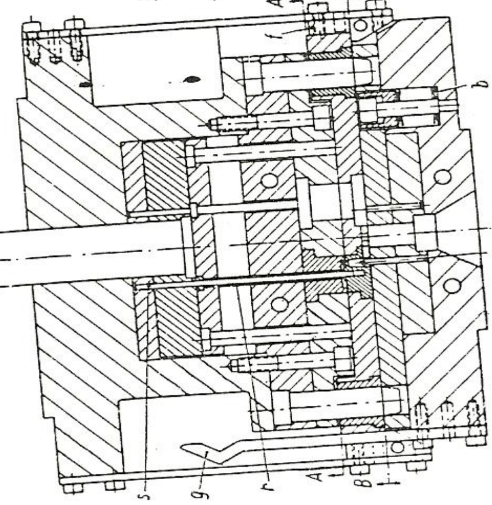


Fig. 2.2/1
II–I



Extrusion dies

Impact extrusion, as known as cold extrusion or cold forging, is closely allied to coining, sizing and forging operation. The operation are generally performed in hydraulic or metal presses. The press applies sufficient pressure to cause plastic flow of the workpiece material (metal) and to form the metal to a desired shape. A metal slug is placed in a stationary die cavity into which a punch is driven by the press action. The metal is extruded upward around the punch, downward through an orifice, or in any direction to fill the cavity between the punch and die. The shape of the finished part is determined by the shape of the punch and the die.

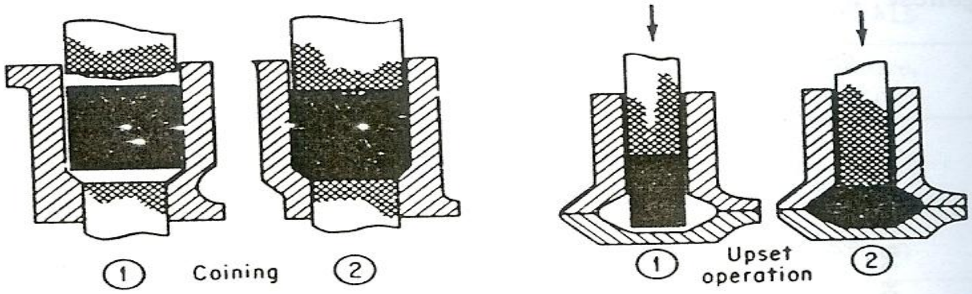


Fig. 4-56. Slug coining and upsetting. (*Courtesy American Machinist.*)

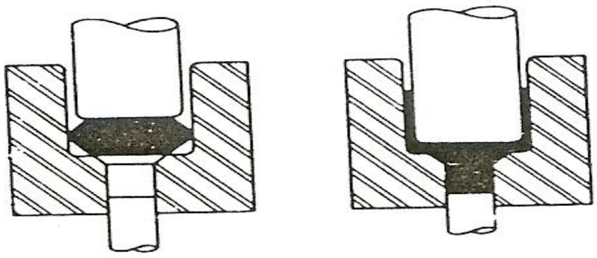


Fig. 4-57. Profiled slugs. (*Courtesy American Machinist.*)

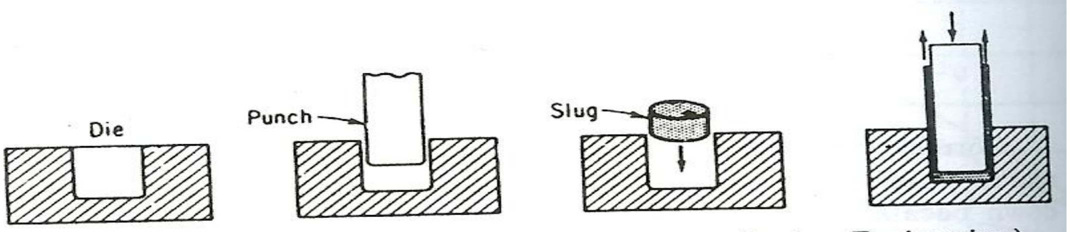


Fig. 4-58. Backward extrusion. (*Courtesy Design Engineering.*)