METALFORMING TECHNOLOGY

11.1 Introduction

This review is organized into the following sections: 1) Presses and Press Brakes, 2) Roll Forming, 3) Shears, 4) CNC Turret Punch Presses and, 5) Forging. It is intended to be a brief overview of each area. Additional, independent study in each area is recommended to properly prepare for the certification exam.

Metalforming is a broad term used to encompass the metalworking processes of blanking, forming, stretching, shrinking, roll forming, spinning, bending, shearing, trimming, punching, drawing, stamping, extruding, upsetting, swaging, forging and casting. In many cases the workpiece is deformed into a new shape by the use of high pressure and forming dies. In other cases, the workpiece is taken beyond its fracture limits and separation occurs. The sales engineer should have a working knowledge of each of the above processes.
11.2 Glossary

**Air bending** - A press brake bending operation in which the punch and the workpiece do not bottom on the die. The sheet metal, supported by the high points of the die, wraps around the tip of the punch to form the bend.

**Adjustable stroke** - The capability of varying length of stroke on a press.

**Bend allowance** - Length of material that must be included in a flat blank to form bends of desired size.

**Bend angle** - 1. Usually, the "included" angle of the workpiece. 2. Also, the angle through which a bend is performed; that is, the supplementary angle to that formed by the two bend tangent lines or planes.

**Bend radius** - The inside radius of a bent section.

**Bending** - The straining of material, usually flat, sheet or strip metal, by moving it around a straight axis which lies in the neutral plane. Metal flow takes place within the plastic range of the metal, so that the bent part retains a permanent set after removal of the applied stress. The cross section of the bend inward from the neutral plane is in compression; the rest of the bend is in tension.

**Blank** - 1. The piece of sheet material, usually flat, produced in cutting dies and usually subjected to further press operations. 2. A piece of stock (also called a slug or multiple) from which a forging is to be made.

**Blankholder** - The part of a drawing or forming die that holds the workpiece against the draw ring to control metal flow.

**Blanking** - The operation of cutting or shearing a piece out of stock to a predetermined contour.

**Bolster plate** - A plate attached to the top of the press bed for locating and supporting the die assembly. Usually equipped with mounting provision for the lower die or die shoe.

**Bottoming bending** - A bending or coining operation on a press brake where the punch penetrates the die as far as the die and formed material will permit.

**Blow** - The force delivered by one stroke of forging equipment.

**Coining** - A closed-die squeezing operation in which all surfaces of the work are confined or restrained.

**Closed die height** - See shutheight.
**Capacity, press** - The rated force (load) that a press is designed to exert at a predetermined distance above the bottom of the stroke of the slide.

**Clutch** - A coupling mechanism used on a mechanical press to couple the flywheel to the crankshaft, either directly or through a gear train.

**Crown** - The upper part (head) of a press frame. On hydraulic presses, the crown usually contains the cylinder; on mechanical presses, the crown contains the drive mechanism.

**Connection** - A connecting member to convey motion and force from an orbiting member to a slide or lever. Also called the pitman, connecting link, or eccentric strap.

**Crosshead** - A moving member on a shear on which the upper knife is mounted.

**Cushion, die** - An accessory for a press, which provides a resistive force with motion required for some operations, such as blankholding, drawing or redrawing, maintaining uniform pressure on a workpiece, and knocking out or stripping. Normally mounted in or under the press bed.

**Deep drawing** - See drawing.

**Deflection** - The amount of the deviation from a straight line or plane when a force is applied to a press member. Generally used to specify allowable bending of bed, slide or frame at rated capacity with load of predetermined distribution. Bed deflection is calculated with the load evenly distributed over 2/3 of the nominal width of the bed between the rods.

**Die** - Generic term used to denote the entire press tooling used to cut or form material. This word is also used to denote just the female half of the press tool. The female die steel works in opposition to the punch steel.

**Die, progressive** - A die with two or more stations arranged in line for performing two or more operations on a part, one operation usually being performed at each station.

**Drawing** - In general terms, drawing describes the operations used to produce cups, cones, boxes, and shell-like parts. The sheet metal being worked wraps around the punch as it descends into the die cavity. Essentially, the metal is drawn or pulled from the edges into the cavity. Shallow drawing applies when the depth of the part is less than one-half the part radius. Deep-drawing applies when the depth of the part is deeper than one-half the part radius.

**Ductility** - The property that permits permanent deformation before fracture by stress in tension.

**Dwell** - A portion of the press cycle during which the movement of a member is zero or at least insignificant. Usually refers to the interval when a blankholder in a drawing operation is holding the blank while the punch is making the draw.
**Extrusion forging** - 1. Forcing metal into or through a die opening by restricting flow in other directions. 2. A part made by the operation.

**Feeds** - Various devices that move stock or workpieces to, in, or from a die.

**Flywheel** - A heavy, rotating wheel in a mechanical press, that stores kinetic energy during the non-working part of the press cycle and releases it during the working part of the cycle. This mechanical press flywheel energy must deliver enough force through the distance required to make a particular part. Flywheel energy is rated in “inch-tons.”

**Forgeability** - The relative ability of material to deform without rupture.

**Forging** - 1. The process of deforming to the desired shape by forming in presses, hammers, rolls, upsetters, and related machinery. 2. The product resulting from this deformation process.

**Forming** - In the context of this Study Guide, the term forming covers all operations required to form a flat sheet into a part. These operations include deep drawing, stretching, bending, buckling, etc.

**Guide pins** - Hardened, ground round pins or posts, which maintain alignment between punch and die during die fabrication, setup, operation, and storage.

**Impression** - A cavity machined into a forging die to produce a desired configuration in the workpiece in the forging.

**Knockout** - A mechanism for releasing workpieces from a die; also called ejector, kickout, or liftout. Crossbars, cams, springs, or air cushions are commonly used to actuate slide knockouts.

**Laser cutting** - The use of a laser beam to perform plate and sheet shape cutting operations. Normally, the beam path is programmed and servo-controlled by means of a CNC control.

**Load, press** - Amount of force exerted in a given operation.

**Moveable blade** - A shear blade having one or more cutting edges that is attached to the crosshead.

**Piercing** - The general term for cutting (shearing or punching) openings, such as holes and slots in sheet material, plate, or parts. Similar to blanking; the difference being that the slug or part produced is scrap, leaving the finished product.

**Pitman** - See connection.

**Press** - A machine having a stationary bed and a slide (ram), which has a controlled reciprocating motion toward and away from the bed surface and at a right angle to it, the slide being guided in the frame of the machine to give a definite path of motion.
**Press brake** - A form of open-frame, single-action press comparatively wide between the housings, with a bed designed for holding long, narrow forming edges or dies. It is used for bending and forming strips and plates, as well as sheets (made into boxes, panels, roof decks, etc.).

**Press, C frame** - A press having uprights or housing resembling the form of the letter C.

**Press, Gap** - See C frame press.

**Press, Double action** - A press having two independent, parallel movements by means of two slides, one slide moving within the other.

**Press, Hydraulic** - A press having a slide or slide (ram) actuated by a hydraulic cylinder and piston.

**Press, Mechanical** - A press having a slide or slides actuated by mechanical means.

**Press, Single-point** - A press with force applied to the slide through one connection.

**Press, Straight side** - A mechanical press with uprights or housings which have plain, flat sides (usually vertical) that bound or enclose the left and right sides of the die space.

**Press, Transfer** - A press having an integral mechanism for transfer and control of the workpiece.

**Press, Trimming** - A special-purpose press for shearing and trimming operations.

**Press, Triple action** - A press having three independent, parallel movements by means of three slides, two from above and one from below the die space.

**Press, Two-point** - A press with force applied to the slide through two connections.

**Press, Turret** - A multiple-station punch press via a movable tool selection turret. An upper turret holds a variety of punches and a lower turret holds the respective dies.

**Press, Laser** - A turret press which incorporates a laser cutting attachment for making cut-outs, contours and special shapes.

**Punch** - The male part of a die, as distinguished from the female part, which is called the die. The punch is usually the upper member of the complete die assembly and is mounted on the slide.

**Punching** - Die shearing of a closed contour in which the sheared out part is scrap.

**Quick Change Dies** - As the term implies, method and procedures used to reduce down time during die changeover from one component or work piece to another. Moving bolsters, universal mounting fixtures and standard upper and lower plate tooling are all procedures followed in this important effort to increase press productivity. Systems can be manual or power driven and automated.
**Rake** - The inclination of one blade with respect to the other in the shearing plane.

**Shearing** - The parting of material resulting when one blade forces the material past an opposing blade.

**Shutheight** - The distance from the top of the bed or bolster to the bottom of the slide of a vertical press, with stroke down. (See "Closed die height")

**Slide** - The main reciprocating member of a press, guided in the press frame, to which the punch or upper die is fastened, sometimes called the ram. The inner slide of a double-action press is called the plunger or punch-holder slide; the outer slide of a double-action press is called the blankholder slide; the third slide of a triple-action press is called the lower slide; and the slide of a hydraulic press is often called the platen.

**Slide Forming** - A press process for the production of complex bends and shapes similar to production from a progressive die, but with much less force than that used in normal press operations. The phrase “Four Slide Operation” is often used to describe this forming procedure.

**Spinning, Metal** - Spinning is a process somewhat similar to turning and is used in circular, high strength, thin wall applications, such as: nose cones, missiles case, pressure vessels and disc brakes using a manual or CNC machine similar in configuration to a horizontal or vertical lathe.

**Springback** - Tendency of material (metal) to return to its original shape after a forming operation.

**Stamping** - In its broadest interpretation, the term stamping encompasses all pressworking operations on sheet metal. In its narrowest sense, stamping is the production of shallow indentations in sheet metal.

**Stripping** - The removal of sheet metal from the punch or die after piercing or blanking is complete. The addition of a punch vent hole can also aid in the stripping process.

**Stroke** - The distance between the terminal points of the reciprocating motion of a press slide.

**Swage (swedge)** - Reducing or changing the cross-sectional area of the stock, usually by revolving the work between rapid impact blows (forging).

**Tie rod** - Steel rods, threaded at both ends for nuts, used to prestress straight-side press frames. They are also used to reduce deflection in gap-frame presses.

**Tonnage** - See Capacity, press.

**Tripping mechanism** - Any auxiliary mechanism, manually, mechanically, or automatically operated, which engages and disengages the clutch for starting and stopping the press.
**Upsetting** - Working metal in such a manner that the cross-sectional area of a portion or all of the stock is increased.
11.3 Presses & Press Brakes

Presses are categorized based on the following: 1) source of power, 2) number of slides, 3) type of frame and construction, 4) type of drive, 5) application and, 6) capacity in tons. There are four basic power sources for presses, they are manual, mechanical, hydraulic and pneumatic. Each has their own market and application positioning.

Selection of a press will require a complete application study of the workpiece, process and press specifications. Presses are most often manufactured to match an application. Therefore, selection is critical. When selecting a press, be prepared to discuss 1) machine size (bed area, slide stroke and frame), 2) force (amount, location, direction and time), 3) energy, 4) speed, 5) part size and geometry, 6) number of workpieces, 7) production rate, 8) accuracy and finish, 9) equipment costs and more!

MECHANICAL PRESSES

Mechanical presses have been the backbone of the press industry. They are powered mechanically through the kinetic energy stored in a flywheel. An electric motor is used to restoring energy to the flywheel, thus keeping the flywheel at operational speed. Any number of designs is used to transfer the energy from the flywheel to the slide (gears, cranks, eccentrics or levers).

1. Construction and Frame Design

Two basic frame designs are used in mechanical presses. The Gap-frame press and the Straight-sided press are different in concept and application. The Gap-frame rating is in the 1 to 300 ton range while the inherent strength of the straight-sided press allows ratings over 2000 tons.

Frames are constructed of cast iron, cast steel, steel weldments or bolted steel. The gap-frame construction is subject to more frame deflection than the straight-sided frame because of its "C" shape, but has some advantages such as lower cost and easier access for some applications.
### Gap
1. More deflection
2. Lower cost
3. Three-sided access (parts & dies)
4. Lower height
5. Capacity: 1 to 300 ton
6. Poor off-center loading
7. Poor for progressive dies

### Straight-Sided
1. Less deflection
2. Higher cost
3. Two-sided access (parts & dies)
4. Taller height
5. Capacity: 50 to 2000+ tons
6. Better off-center loading
7. Better for progressive dies

The straight-sided press with its double column construction will not exhibit angular deflection when the die is closed. On workpieces where angular deflection cannot be tolerated, the straight-sided press should be specified. Straight-sided presses can incorporate pre-stressed tie-rods to improve rigidity and reduce press frame deflections. Gap-frame presses are available in 1) open-back inclinable-OBI, 2) adjustable-bed stationary-ABS, 3) open-back stationary-OBS and, 4) bench press configurations. Refer to additional texts on press construction to illustrate each design, understand its application benefits and learn the nomenclature.

### 2. Slides
The slide is the moving member of the press, which holds the upper half of the die (sometimes called the punch). A press can have more than one slide, each with the same or separate actuators. The slide moves up and down the machine frame on guideways, which must be very accurate in order to guarantee parallelism and rigidity. In order to offset the weight of the slide a counterbalance is employed. These are normally air cylinders with surge tanks. Each slide is connected or suspended at one or more points where the power is applied to the slide, thus the terminology "single-point", "two-point" or "four-point" press. The more connections, the more balanced and aligned a slide will be during operation. A four-point press is highly recommended where alignment and accuracy are critical, whereas a single-point press would be best in lower volume, less accurate and evenly loaded (square work surface). Individual slides also can have multiple, independent, parallel movements. A "double-action" slide actually has two independent slides, one inside of the other. A common application for a double-action slide would be for one the outer (blankholding) slide to hold the outer edges of a blank while the inner (punch) slide performed a drawing operation. Triple-action slides utilize a third slide actuated upward from inside the bed for additional complex forming capabilities.

### 3. Die Cushions
Another use of air pressure on the press is for die cushioning. The die cushion is normally located in the bed, beneath the lower die and bolster plate. Applications with flat blanks use the pressure of the die cushion for drawing operations. They are also used as workpiece liftouts and in assisting die removal. Die cushions can also be hydropneumatically operated.
4. Lubrication
In the metalforming process workpiece lubrication plays several important roles. It will 1) reduce the friction between the die and the workpiece, 2) keep the die and workpiece separated, 3) cool the work surface and prevents rust, 4) allows even deformation and reduces stresses, 5) reduces die wear and, 6) reduces force requirements. Lubricant selection and application techniques are part of the tooling process.

5. Vibration & Noise
Metalforming presses are vibration and noise intensive machines. Installations should be evaluated for maximum vibration and noise reduction. Using spring steels, cork, felt, rubber, plastics, high-density fiberglass, or air-mount systems can assist vibration dampening. The benefits of using vibration isolation mounts under the press are: 1) vibration reduction, 2) noise reduction and 3) press leveling.

6. Clutches & Brakes
Clutches and brakes are a required feature on a mechanical press. The clutch engages the flywheel to the motor shaft, either directly or through a gear train, to provide timing and control of the periodic, reciprocating movement of the press slide. The purpose of the brake is to stop the slide, and other components, after the clutch is disengaged. Several clutch and brake designs depend on the type of press and its application. However, these units act as a safety device as well as machine power components. For instance, a quill on a clutch and brake unit on a stamping press will keep the flywheel in place if the crankshaft breaks.

HYDRAULIC PRESSES
Hydraulic presses have hydraulic cylinders that provide the power to the press slide. This motor-driven hydraulic pump system is contrasted to the flywheel used on the mechanical press. The popularity of hydraulic presses is gaining because of the additional flexibility offered by hydraulics. The machine is no longer a fixed cycle, fixed force, fixed stroke machine like the mechanical press. They have fewer moving parts, are smaller in size and are quieter than a comparable mechanical press. One of the biggest advantages is that the force exerted by the slide and the speed of the slide can be changed to best suit changing applications. This capability results from a hydraulic press being able to provide full tonnage anywhere on the down stroke compared to a mechanical press, which reaches rated capacity at the bottom of its stroke. Maximum slide force is normally needed just above the bottom of stroke. Hydraulic presses can change this maximum force height and force intensity. Also, if the slide is slowed just before contacting the part the die life is extended. Depending on required stroke height, hydraulic presses may be slower than mechanical presses. Hydraulic presses are found performing a broad range of metalforming and blanking operations. Deep drawing operations are well suited to the force capabilities of the hydraulic press.
Construction and Frame Design
Frame designs include the straight-side, C-frame (OBI & OBS), open-back stationary (OBS) and column type. Special purpose frame designs are also available. The hydraulic press can be oriented either vertically or horizontally. The use of die cushions, counterbalances and safety controls are similar to those used on mechanical presses. The use of Programmable Logic Controllers (PLC) on hydraulic presses is increasing. The PLC can allow many settings to be programmed via a keyboard which include: forming or blanking pressure, stroke length, dwell time, pull-out pressure and other variables including event sequencing.

MULTIPLE PRESS OPERATIONS

There are a number of ways to increase productivity on a press. This is especially true when high part volumes and multiple operations are required. The first technique is to use progressive dies. The progressive die has several stations, each with a sequential operation. The part stock is usually continuous and is fed through the press. Pilot pins are used to locate the stock in each station prior to the stamping operation. As it advances to the next station in the die, the press slide is actuated and another operation performed. Progressive dies can be used on single-slide presses.

Transfer dies, used on transfer presses, are another popular way to increase productivity. This process is similar to a progressive die except that in this case individual part blanks are fed through the machine. Each station of the transfer die performs its operation. In this setup the special press, called a transfer press, must have the ability to shuttle or transfer the blanks from one station to the next. The transfer mechanisms used vary with the application but are normally a single-axis, lift-and-carry or robotics to transfer parts. Roller conveyors or dial indexing tables are used to feed the blanks into the press. Automotive and appliance manufacturers are good customers for transfer presses because of the high part volumes. These presses reduce labor, floor space, energy and maintenance costs.

Four-slide presses are also used for multiple operations on the same press. In this scheme individual slides, with their own die set, perform an operation. These presses are more limited in force per slide but can perform more complex forming operations than progressive dies.

PRESS TOOLING

The majority of machine tool metalcutting operations use standardized tooling. The picture is much different in the world of metalforming. Each workpiece has its own set of dies custom machined to match the shape of the workpiece. A die set consists of the upper die (punch) the lower die and the guide pins. Taking into consideration the
clearance required between the punch and die, it is actually the punch that controls the size of the hole and the die that controls the size of the blank in a punching operation. Guide pins are used to align the dies and utilize bushings or ball bearings for consistent operation and alignment. Die sets are normally machined from steel, cast iron and cast steel to one of three precision standards (commercial, precision and superprecision). Die sets fall into two general categories, either forming dies or cutting dies (blanking and punching). Progressive and transfer dies are special multiple-station dies for high volume production.

**DEEP DRAWING**

In general terms, drawing describes the operations used to produce cups, cones, boxes, and shell-like parts. The sheet metal being worked wraps around the punch as it descends into the die cavity. Essentially, the metal is drawn or pulled from the edges into the cavity. Shallow drawing applies when the depth of the part is less than one-half the part radius. Deep-drawing applies when the depth of the part is deeper than one-half the part radius. Application considerations include: 1) press speed, 2) radii on the punch and dies and 3) slide velocity which must be maximized in mid-stroke.

**PRESS LOADING AND UNLOADING**

The stock materials fed into presses are often awkward to handle manually due to their size or configuration (e.g., coil stock). These applications require special loading and unloading equipment for blanks, workpieces, and strip or coil stock. Loading equipment for blanks and workpieces can take the form of 1) lift and transfer, 2) robot arm and, 3) chute, push, follow and dial feeds. Equipment used for coil and strip stock includes: 1) mechanical slide feed, hitch-type, air and hydraulic slide feeds and, 2) single and double roll feed. Today, popular applications of roll feeds include electronic, digitally controlled, independent roll feeds. This allows rapid feed-length and speed adjustments of almost any length or width of coil stock. Coil stock may require a straightener to flatten the stock (remove the coil curvature, in the direction of the winding, which is known as coil set) prior to the forming operation. Adjustable feed length controls can be incorporated for accurate feeding. These systems range from simple mechanical to computer-servo driven control.

Unloading of the press is of equal importance to loading. These are 1) gravity and air ejection, 2) kickers, lifters and shuttles, 3) mechanical hands and 4) robots. On smaller workpieces, which are coil fed the coil can be rewound. Typically however, residual coil is run through a scrap cutter.

In a punching operation, the part must first be removed from the punching members before it can be unloaded. After the forming operation, the part may have adhered to either the punch (male member of the die set) or the die (female member of the die set) due to forming pressures and/or an oil-film seal. Several options may be employed to
minimize this condition. In maximum force conditions, a mechanical stripper (either movable or fixed) or knockout (also called a liftout) device can be used to strip the stock from the tools. A knockout is normally used to push or lift parts from die cavities. Strippers and knockouts are designed into the tooling setup and come in many configurations.

To aid in breaking an oil-film seal an integral kicker (shedder) pin can be used in a die. An additional design technique is the use of a vent hole in the punch (male member of the die set) to assist in breaking the vacuum caused by the oil-film seal.

**BLANKING OR PUNCHING FORCES**

The progression of a punch force cycle is as follows:
1. The first point of impact (a measurable force) for a punch is with the hold-down and stripper units.
2. Next, the force increases dramatically as the punch begins penetration of the stock. The distance a punch will compress the material before fracture occurs is called “punch penetration.”
3. As the punch experiences breakthrough there is a reversal of forces. This reversal of stresses is called “snap-through” and causes extreme shock on the tooling (punch) and machine. This condition is increased when using hard stock such as stainless, high-carbon steel and alloy steels. This is also the point of greatest tool wear and possible fracture. With these very hard materials, a press capacity may be selected based on snap-through calculations.
4. As the punch withdraws from the die it must once again overcome the hold-down and stripper forces similar to number 1 above.

Punches wear about three times as fast as dies because the punch must penetrate the material and then be stripped out of it. Other wear factors, in addition to snap-through are:

1. hole size & configuration
2. punch and die clearance
3. type of stripping
4. tool alignment
5. punch material and hardness
6. type & thickness of material being punched
7. punching speed
8. type of lubrication being used.

Utilizing good tooling design can actually reduce press tonnage. Two techniques are common:
1. Using a stepped punch will reduce the force requirements, improve die life and reduce press maintenance. A rule of thumb is to maintain a stepping height slightly greater than the punch penetration depth. The machine tool sales engineer should study the various types and design parameters of press dies.

2. Providing a shear angle equal to the metal thickness on the punch or die face could reduce the force requirements by one third to one half.

PRESS BRAKES

Press brakes are a special type of press that use the process of bending to form straight bends in flat stock. The press normally features a long narrow bed and ram with maximum width between side housings. Since press brakes are a basic metalforming machine tool they can be found in both manual and powered configurations. Produced in mechanical, hydraulic or hybrid versions they can generally handle sheet metal less than 10 gage (0.141”). In some limited applications, press brakes are also used for punching, dimpling, countersinking and embossing.

Press brake tooling usually consists of a 90 degree forming die, however, specialized dies of diverse shape and application are also popular on press brakes. Some of the typical specialized dies are gooseneck, hemming, offset, seaming, radius and channel-forming dies. Specialized brakes are frequently used for special applications such as a pan-and-box brake, which easily handles the complexities of fabricating a four-sided box. Factors to consider when specifying a press brake include 1) tonnage, 2) speed, 3) accuracy, 4) stroke length, 5) controllability and, 6) tooling.

NOTES
11.4 Roll Forming

Roll forming is another metalforming process that uses bending to produce the workpiece. Sheet, strip or coiled stock can be formed into unique shapes by being fed between stations of upper and lower roll tooling that gradually shape the workpiece. The workpiece assumes the shape of the rollers through bending, one stage at a time until finished. The individual stations are normally mounted on a common baseplate. Roll forming machine types are identified by spindle support, station configuration and drive system.

The rolls are the tooling on a roll forming machine. How the rolls are supported on a spindle determines if it is an inboard or outboard machine. Inboard machines support the roll spindle on one end as opposed to outboard machines, which support the spindle on both sides. Inboard machines feature easier roll changing but are used in lighter bending applications. The station configuration can be 1) single-duty, 2) conventional or standard, 3) side-by-side, 4) double-high, 5) rafted or, 6) double-head machines. The machine drive can be one of five types which are 1) chain, 2) spur gear, 3) worm gear, 4) square gearing or, 5) universal drive. When specifying a machine, the factors to consider include load capacity, section size, section type, and roll changeover. Roll form tooling and processing is an art unto itself. Careful consideration must be given to the part geometry required. Application engineers will evaluate the part symmetry, cross section depth, bend radii, blind corners, leg length, section width, part length and notched or punched hole requirements in determining roll tool and machine parameters.

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11.5 Shears

Straight line cutting of metal sheets is called shearing. It is called shearing because of the metalforming process that takes place during the shearing process. Shears use two opposing knife blades that act on the metal sheet like a pair of scissors on paper. The knife blades enter the sheet stock, pressure grows until the material's tensile strength is exceeded and a fracture or tear occurs. This fracture occurs along a shear plane and the angle, clearance and condition of the blades determine the resulting appearance of the sheared edge. Edge condition is important on many applications where burrs and deformation must be limited or non-existent. Shearing operations can be performed on all types of materials with hardness up to Rc30. Some machines will handle sheets sizes up 240” wide. Reference tables are available from manufacturers that list materials, stock thickness and required shear strengths.

Shear construction is normally of steel (welded or bolted) or ductile iron castings. The basic components include a housing, table, lower knife blade, crosshead with upper knife blade and holdown beam. The crosshead is the main powered component. It holds the upper knife blade and proceeds down against the lower knife blade. Crossheads are either driven by manual, mechanical, hydraulic or, pneumatic means. The common types of shears are 1) gapless shears, 2) gap shears, 3) alligator or pivot shears, 4) ironworkers, 5) cutoff machines, 6) CNC shears and 7) rotary shears. Each type of shear should be studied for its application and benefits. Refer to the "Reference Books and Suggested Reading" section at the end of Volume II.
11.6 CNC Turret Punch Presses

Punch presses use the principle of shear to punch holes in sheet materials. These punching operations can also include nibbling, notching, perforating, piercing, slotting, pointing, forming and marking. CNC positioning controls and a multiple-punch turret allow fully automated operation with versatility and accuracy. In addition, some CNC punch presses can be equipped with accessories that allow plasma and laser cutting operations.

Punch press construction is generally a steel weldment frame in either a C-frame or bridge-frame configuration. The punch and die are located in a revolving turret, above and below the work and the workpiece is moved in an X and Y plane by servo control until positioned directly under the selected turret tool. The punch can be actuated by either mechanical or hydraulic power.

When selecting a CNC Turret punch press the factors to be considered are:
1. table size, load capacity and work envelope.
2. strokes per minute.
3. table positioning speed.
4. workpiece clamping.
5. turret capacity and speed.
6. punch force.
7. punch drive type.
8. tooling requirements.
9. accessories available (plasma, laser, etc.).
10. workpiece loading and unloading.

Tool changers for special tooling applications are being used on some CNC punch presses. These may be needed for large tools not able to fit in the turret. The CNC Turret punch press will increase productivity in short to medium runs but is also frequently used in both prototype and long production runs. It has the ability to optimize the punching operations through computer control and allows contour shapes through either punching or the use of plasma or laser attachments.

Workpiece loading and unloading is handled either manually or automatically. Since workpieces are large and usually not very rigid, automatic systems are a productive addition. Different builders use various designs and each should be analyzed based on the advantages to the customer. Another important consideration is the machine's ability to reposition the workpiece while on the machine. This allows punching to be done on one section of a large workpiece then repositioned to another section for remaining operations. This saves the time of multiple manual setups.
11.7 Forging

Forging is one of the oldest forms of metalworking. Probably best typified in the blacksmith heating metal parts and delivering sharp blows to produce the desired shape. Forging has some distinct advantages over other types of metalworking. Looking at the forging process we discover that the workpiece is first heated above its re-crystallization temperature. At this temperature, any impact forming that takes place on the workpiece will also change its crystalline structure or grain flow. In other words, the grain of the metal will flow with the form of the part. This allows for increased strength, ductility and resistance to impact and fatigue.

Forging equipment can perform upsetting, extruding, deep-piercing, splitting and bending operations. However, the most common forms of forging are upsetting and extruding. Upsetting uses dies and repeated blows to rearrange existing material into a new shape (decrease cross-section in one area which forces increase of cross-section in another area). Extruding forces metal into, or through, a die opening by restricting its flow in other directions.

Forging is performed on both ferrous and non-ferrous materials with excellent results. Traditional ferrous materials include carbon and alloy steels, tool, maraging and stainless steels. Non-ferrous materials include aluminum (and alloys), copper alloys, magnesium alloys, beryllium, titanium alloys, super alloys and refractory materials. Typical parts produced by forging include 1) aircraft engine parts, 2) crankshafts, 3) turbine rotors and parts, 4) nuclear components, 5) oil field parts, 6) ordnance components, 7) pump and compressor parts and, 8) mill rolls and spindles.

Forging, as a process, can be accomplished on a number of different machines. Machines are normally classified based on their principle of operation as indicated below.

| Energy-restricted: | Deformation is caused by the kinetic energy of the hammer ram. |
| Stroke restricted: | Deformation is determined by the length of the stroke and the force available in the stroke travel. |
| Force restricted:  | Deformation is determined by the maximum force rating of the press. |

A listing of the more common machines used in the forging process and the principle of operation that they employ is provided below. In addition to the common machines listed below, other specialized forging machines are hot formers, forging rolls, wedge rolling machines, radial forging machines and ring rolling machines.
Hammers:

<table>
<thead>
<tr>
<th>Hammers</th>
<th>Principle of Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravity drop hammers</td>
<td>Energy Restricted</td>
</tr>
<tr>
<td>Power drop hammers</td>
<td>&quot;</td>
</tr>
<tr>
<td>Die forger hammers</td>
<td>&quot;</td>
</tr>
<tr>
<td>Counterblow hammers</td>
<td>&quot;</td>
</tr>
<tr>
<td>Open die forging hammers</td>
<td>&quot;</td>
</tr>
<tr>
<td>High energy rate forming</td>
<td>Energy-restricted</td>
</tr>
<tr>
<td>machines (HERF)</td>
<td>Load-restricted</td>
</tr>
</tbody>
</table>

Type of Machine               

<table>
<thead>
<tr>
<th>Machine Name</th>
<th>Principle of Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical presses</td>
<td>Stroke-restricted</td>
</tr>
<tr>
<td>Hydraulic presses</td>
<td>Force-restricted</td>
</tr>
<tr>
<td>Screw presses</td>
<td>Energy-restricted</td>
</tr>
</tbody>
</table>

Type of Machine               

<table>
<thead>
<tr>
<th>Machine Name</th>
<th>Principle of Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal upsetters or</td>
<td>Energy-restricted</td>
</tr>
<tr>
<td>Heading machines</td>
<td></td>
</tr>
</tbody>
</table>

In selecting the proper equipment the factors to be considered are:

1. force and energy capabilities as these relate directly to the ability to forge any given part (force versus energy diagrams are available from the machine builder).
2. rate of deformation of the workpiece.
3. shape and definition of the workpiece.
4. heat transfer rate to the dies.

Hammers and presses deliver different deformation rates, an important factor to successful forging of a given workpiece. Additional information on forging applications can be found by reading materials listed in the "Reference Books and Suggested Reading" section found at the end of Volume II.
11.8 Review Questions

These review questions are provided for study purposes only and are not on the CMTSE certification exam. Correctly answering these questions does not guarantee a passing exam grade.

1. The best machine for deep drawing is the:
   1. hydraulic press.
   2. mechanical press.
   3. shear.
   4. roll forming machine.

2. Which one of the following parts is not considered part of the die?
   1. Punch
   2. Slide
   3. Stripper
   4. Guidepin

3. A triple-action vertical press has one slide that comes upward from the bed. What direction(s) do the other two slides come from in the press?
   1. Rear and top
   2. Top and bottom
   3. Both from the top
   4. Rear and backside

4. Forged-steel parts have an advantage over cast-steel parts because they:
   1. have better heat-treating capability.
   2. have better grain flow.
   3. are less expensive to machine.
   4. have not been heated above the re-crystallization point.

5. The term OBI stands for:
   1. outboard blanking insert.
   2. open-back inclinable.
   3. open-bed indexing.
   4. outboard bolster incline.

6. On a shear press the term "rake" refers to:
   1. inclination of one blade with respect to the other.
   2. the part of the feed mechanism that grips and pulls the workpiece.
   3. blades that have multiple cutting edges.
   4. a shearing tool whose cutting edge makes a complete revolution about a fixed axis.
7. The purpose of a material straightener is to:
   1. “iron” the edge bow.
   2. re-set material width.
   3. eliminate the coil set.
   4. adjust material camber.

8. Which of the following would not be found as a feature or accessory on a CNC Turret punch press?
   1. Inclinable table
   2. Laser cutting
   3. Plasma Arc cutting
   4. Automatic load/unload system

9. Flywheel energy on a mechanical press is rated in:
   1. revolutions per minute.
   2. feet per minute.
   3. pounds per revolution.
   4. inch-tons.

10. The procedure in which a flat strip of metal is passed through a series of rolls and is sequentially shaped is called:
    1. roll driving.
    2. blanking.
    3. roll forming.
    4. deep drawing.

11. Pilot pins provide which essential function to the stamping die process?
    1. Accurately position the stock before stamping
    2. Punch vent holes in the material to assist in stripping
    3. Prevent shearing
    4. Push or lift stock from the die cavity

12. The main drive motor on a mechanical press serves which of the following primary purposes?
    1. Adjusts the press speed
    2. Minimizes the forming load
    3. Restores energy to the flywheel
    4. Provides power for the knockout mechanism
ANSWERS TO REVIEW QUESTIONS

1. (1)
2. (2)
3. (3)
4. (2)
5. (2)
6. (1)
7. (3)
8. (1)
9. (4)
10. (3)
11. (1)
12. (3)