HYDRAULIC PRESSES

The hydraulic press is one of the oldest of the basic machine tools. In its modern form, is well adapted to presswork ranging from coining jewelry to forging aircraft parts. Modern hydraulic presses are, in some cases, better suited to applications where the mechanical press has been traditionally more popular. [1]

Advantages of Hydraulic Presses

The mechanical press has been the first choice of many press users for years. The training of tool and die makers and manufacturing engineers in North America has been oriented toward applying mechanical presses to sheet-metal pressworking.

Modern hydraulic presses offer good performance and reliability. Widespread application of other types of hydraulic power equipment in manufacturing requires maintenance technicians who know how to service hydraulic components. New fast acting valves, electrical components, and more efficient hydraulic circuits have enhanced the performance capability of hydraulic presses.

Factors That May Favor the Use of a Hydraulic Press

Factors that may favor the use of hydraulic presses over their mechanical counterparts may include the following:

1. Depending on the application, a hydraulic press may cost less than an equivalent mechanical press.

2. In small lot production where hand feeding and single stroking occurs, production rates equal to mechanical presses are achieved.

3. Single stroking does not result in additional press wear.

4. Die shut heights variations do not change the force applied.

5. There is no tonnage curve derating factor.

6. Forming and drawing speeds can be accurately controlled throughout the stroke.

7. Hydraulic presses with double actions and or hydraulic die cushions are capable of forming and drawing operations that would not be possible in a mechanical press.

[1] R. Lown, "Hydraulic Presses in the 80's", Based on SME Technical Paper, MF82-918, The Society of Manufacturing Engineers, Dearborn Michigan, © 1982. The paper has been updated by Mr. Lown for subsequent public presentations.

Example of a Gap-Frame Hydraulic Press

Like the mechanical press, hydraulic presses deliver a controlled force to accomplish work. The style of the press frame and the hydraulic components vary depending on the intended use. Figure 1 illustrates a gap-frame or C-frame hydraulic press.

Gap Frame Hydraulic Press

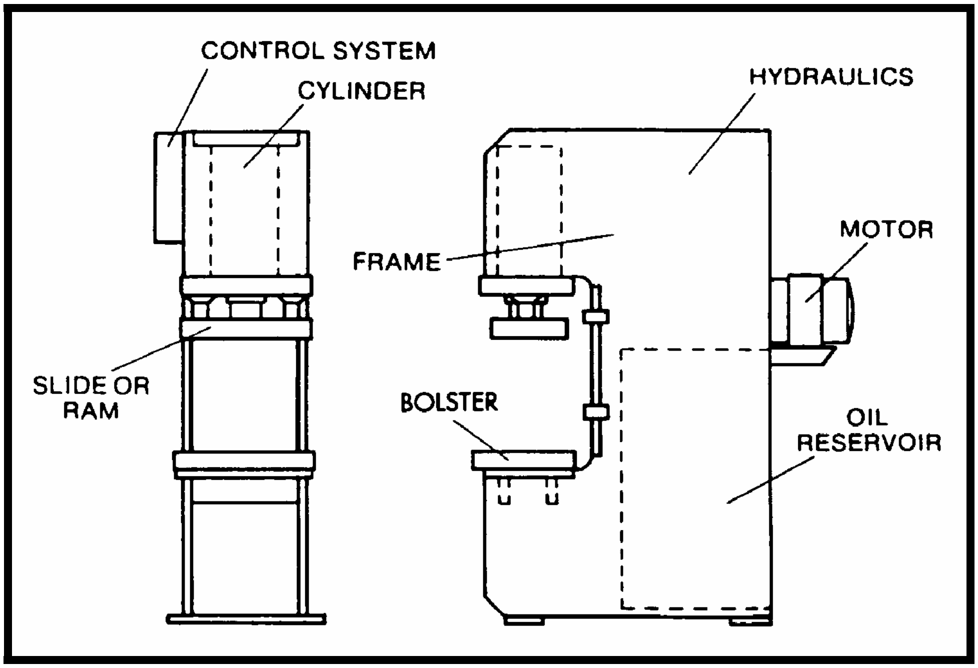

Figure 1. A typical hydraulic press featuring gap-frame construction.
Greenerd Press & Machine Company

The press shown in Figure 1 has a frame and bolster that are similar to the construction used for open back stationary (OBS) mechanical presses. The frame is of robust construction to limit both angular and total deflection. The bolster and ram provide a surface to mount tooling. The ram is actuated by a large hydraulic cylinder in the center of the upper part of the frame. Additional alignment is provided by two round guide-rods.

The motor drives a rotary pump, which draws oil out of the reservoir housed in the machine frame. The control system has electrically-actuated valves which respond to commands to advance and retract the slide or ram. A pressure regulator is either manually or automatically adjusted to apply the desired amount of force.

Unique Features of Hydraulic Presses

In most hydraulic presses, full force is available throughout the stroke. Figure 2 illustrates why the rated force capacity of a mechanical press is available only near the bottom of the stroke. The full force of a hydraulic press can be delivered at any point in the stroke. This feature is a very important characteristic of most hydraulic presses.

Deep drawing and forming applications often require large forces very high in the press stroke. Some mechanical presses do not develop enough force high enough in the downward stroke to permit severe drawing and forming applications such as inverted draw dies to be used without danger of press damage.

Hydraulic Presses Have Full Force through the Stroke

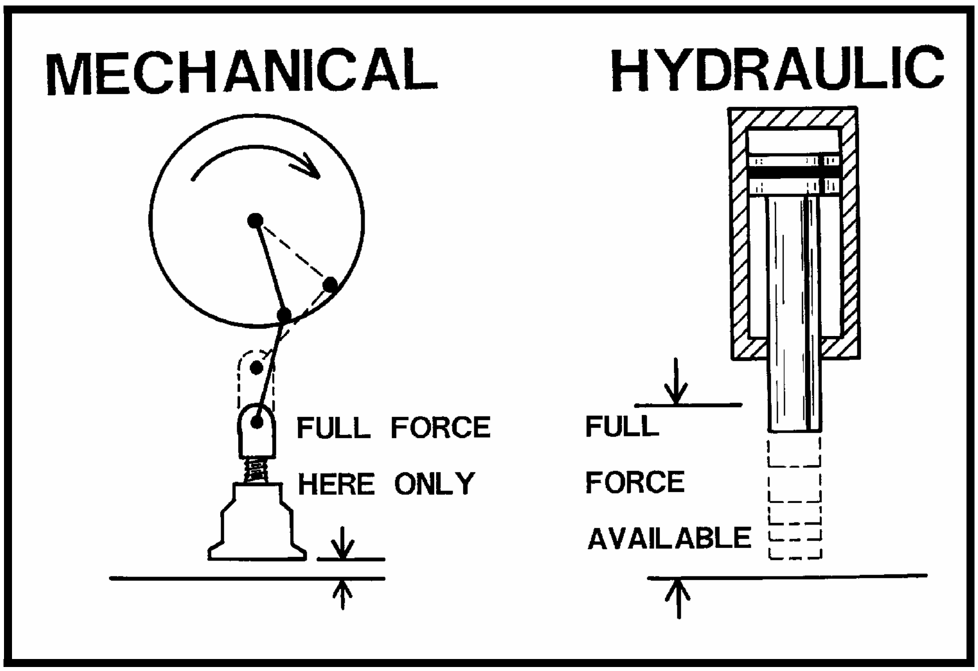

Figure 2. The rated capacity of a mechanical press is available only at the bottom of the stroke. The full force of a simple hydraulic press can be delivered at any point in the stroke.

Another advantage is that the stroke may be adjusted by the user to match the requirements of the job. Only enough stroke length to provide part clearance is required. Limiting the actual stroke will permit faster cycling rates and also reduce energy consumption.

The desired pre-set hydraulic pressure provides a fixed working force. When changing dies, different shut heights do not require fine shut height adjustment. Different tool heights or varying thicknesses of material have no effect on the proper application of force.

The availability of full machine force at any point in the stroke is very useful in deep drawing applications. High force and energy requirements usually are needed throughout the stroke. The ram speed can also be adjusted to a constant value that is best for the material requirements.

Built-in Overload Protection

The force that a hydraulic press can exert is limited to the pressure applied to the total piston area. The applied pressure is generally limited by one or more relief valves.

A mechanical press usually can exert several times the rated maximum force in the event of an accidental overload. This extreme overload often results in severe press and die damage. Mechanical presses can become stuck on bottom due to large overloads, such as part ejection failures or diesetting errors.

Hydraulic presses may incorporate tooling safety features. The full force can be set to occur only at die closure. Should a foreign object be encountered high in the stroke, the ram can be programmed to retract quickly to avoid tooling damage.

Lubrication

Hydraulic presses have very few moving parts. Those parts that do move, operate in a flood of pressurized oil, which serves as a built-in lubrication system. Should leakage occur, it is usually caused by the failure of an easily repairable part such as the ram packing, or a loose fitting.

Hydraulic presses having guide rods or gibbing, may require a different lubricant than the hydraulic fluid. The same type of metered or recirculating lubrication systems used on mechanical presses are used in such cases.

Large Force Capacity

Mechanical presses with high force capacities are physically much larger than their hydraulic counterparts. Few mechanical presses have been built with force capacities of 6.000 tons (53.376 mN) or more. Higher tonnages or more compact construction is practical in hydraulic presses. Hydraulic presses for cold forging are built up to 50,000 tons (445 MN) or greater force capacity. Some hydraulic fluid cell presses have force capacities over 150,000 tons (1,334 mN).

Figure 3 illustrates how two pistons having different diameters both deliver 75 tons (667 kN) of force. The force developed by a hydraulic piston is the product of the area of the piston times the applied pressure.

Force Depends on Hydraulic Pressure and Piston Area

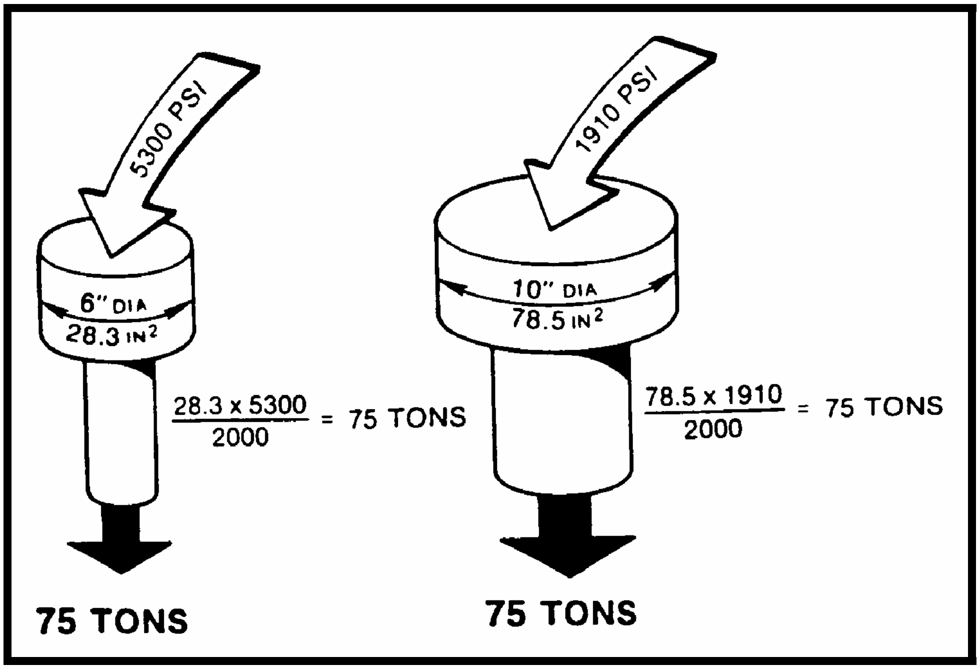

Figure 3. Two pistons having different diameters both deliver 75 tons (667 kN) of force by applying different pressures to each piston.

Figure 3 shows that, 75 tons (667 kN) of force can be achieved by applying 5,300 psi (36,538 kPa) to a 6-inch (152.4 mm) diameter piston. The same 75 tons (667 kN) of force is achieved by applying 1,910 (13,168 kPa) to a 10-inch (254 mm) diameter piston.

There is no set rule on the best peak operating pressure for a press design. Obviously, higher pressures permit the use of more compact cylinders and smaller volumes of fluid. However, the pumps, valves, seals, and piping are more costly because they must be designed to operate at higher pressure.

Advantages of Adjustable Force

The force of a hydraulic press can be programmed in the same way that the movements of the press are preset. In simple presses, the relief valve system that functions to provide overload protection may also serve to set the pressure adjustment. This allows the press to be set to exert a maximum force of less than press capacity.

Usually there is a practical lower limit, typically about 20% of press capacity. At extremely low percentages of force capacity, a stick-slip phenomena known as *stiction* in the cylinder rod and piston packing can cause jerky erratic action.

Programmable controllers are a feature of many modern hydraulic presses. The correct pressure together with ram travel and other parameters is stored in memory by job number and automatically preset by the diesetter. For deep drawing operations, the blankholder or hydraulic die cushion force can be varied through the press cycle for best results.

Light Duty Press with a Large Bed Area

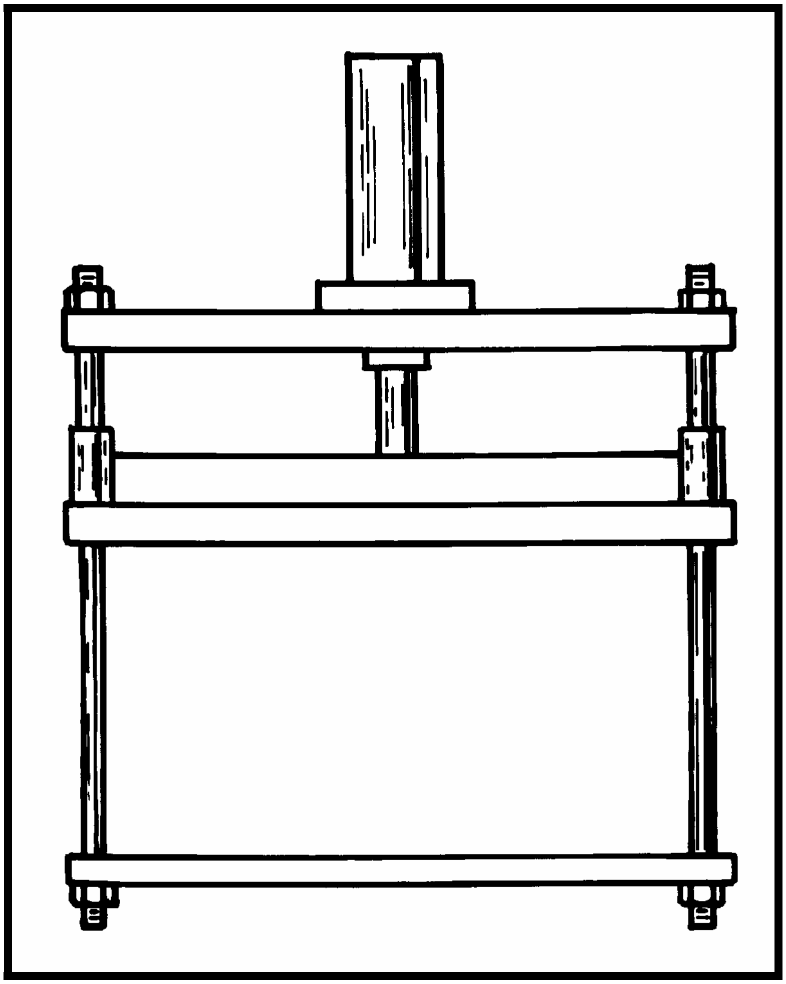

Figure 4. Cutting soft materials and laminating work may require a low force capacity machine with a large bed area such as the one illustrated in this simplified drawing.

Press Construction Depends on the Type of Work Performed

The bed size, stroke length, speed, and tonnage of a hydraulic press are not necessarily interdependent. Press construction depends upon the amount of total force required and the size of dies to be used.

Figure 4 illustrates a large bed size press having low force capacity. Note the small cylinder size. Some uses for these presses include cutting and pressing soft materials such as fabric, and in wood or plastic laminating applications.

High Force Press With Small Bed Area

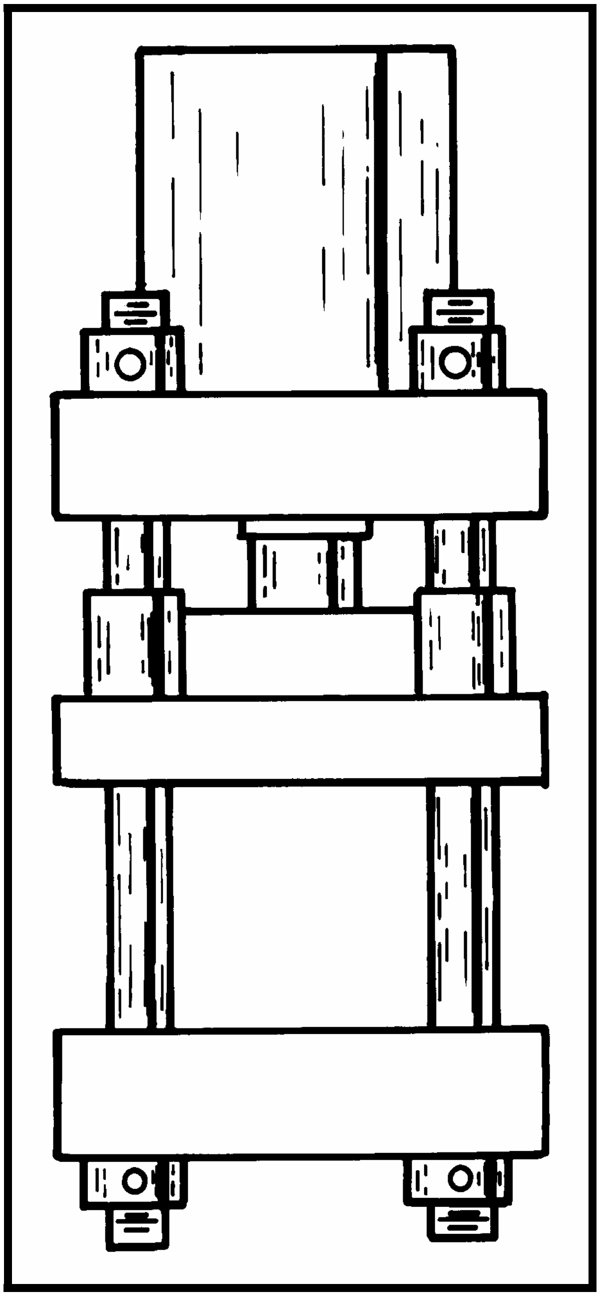

Figure 5. Heavy work such as coining and cold-forging requires a compact machine capable of delivering high forces over a small bed area.

Guide Lines for Press Selection

Figures 4 and 5 illustrate how bed size does not directly relate to press force capacity. Both if these illustrations show presses that use the tie rods for ram guiding which is suitable for jobs that do not produce lateral or side loads. Hydraulic presses are available in many types of construction which is also true of mechanical presses. There are many factors to consider when deciding between a hydraulic and mechanical press. These include stroke length, actual force requirements, and the required production rate.

Long Stroke Lengths Can be an Advantage

Since the stroke length can be fully adjustable, long stroke lengths provide for ease of setup and flexibility of application. The full stroke may be used to open the press up for the installation of dies. In production, the stroke length can be set as short as possible to provide for stock feeding and part ejection while maximizing stroking rates.

Hydraulic Press Speeds

Most press users are accustomed to describing press speeds in terms of strokes per minute. Speed is easily determined with a mechanical press. It is always part of the machine specifications.

The number of strokes per minute made by a hydraulic press are determined by calculating a separate time for each phase of the ram stroke. First, the rapid advance time is calculated. Next the pressing time or work stroke is determined. If a dwell is used that time is also added. Finally the return stroke time is added to determine the total cycle time. The hydraulic valve reaction delay time is also a factor that should be included for an accurate total time calculation.

These factors are calculated in order to determine theoretical production rates when evaluating a new process. In the case of jobs that are in operation, measuring the cycle rate with a stopwatch is sufficient.

Most hydraulic presses are not considered high speed machines. In the automatic mode, however, hydraulic presses operate in the 20 to 100 stroke per minute range or higher. These speeds normally are sufficient for hand fed work. The resulting production rate speeds are comparable to that of mechanical OBI and OBS presses used single stroking applications. Here, there is no additional clutch and brake wear to consider in the case of the hydraulic machine.

Force Requirements

When choosing between a mechanical or hydraulic press for an application a number of items should be considered. The force required to do the same job is equal for each type of press. The same engineering formulas are used.

There is always a possibility that an existing job operated in a mechanical press requires 20 to 30 % more force than the rated machine capacity. The overloading problem may go unnoticed, although excessive machine wear will result. If the job is placed in a hydraulic press of the same rated capacity, there will not be enough force to do the job. Always make an accurate determination of true operating forces to avoid this problem.

Press that Uses the Tie Rod for Ram Guiding

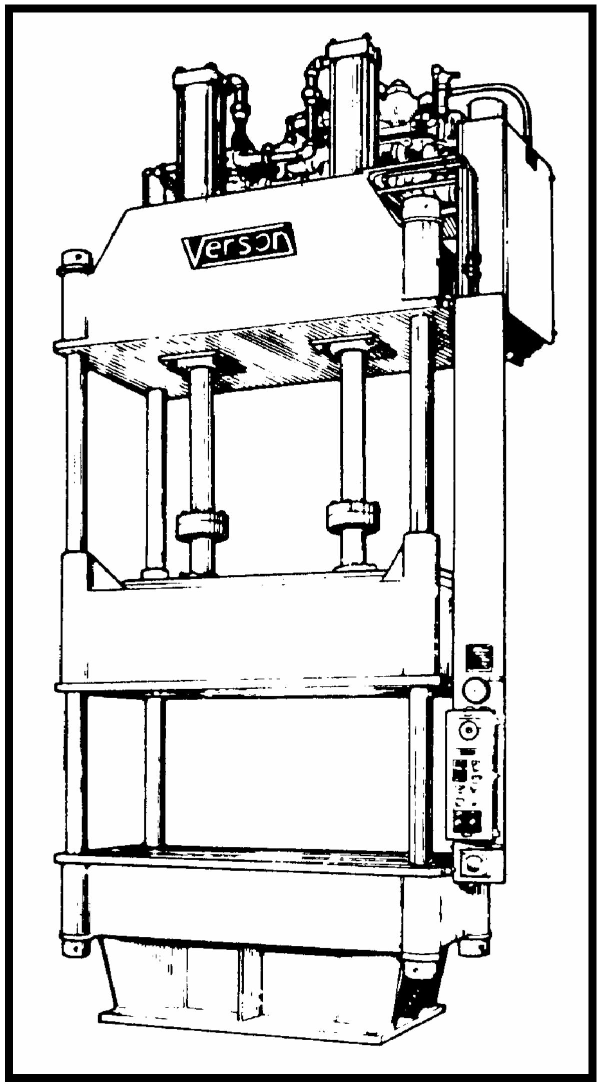

Figure 6. A two cylinder four post hydraulic press: note that the hydraulic reservoir, pump and controls are located on top of the machine. A machine of this type is suited for light to medium duty work that does not involve lateral (side) loads. *Verson Corporation*

Machine Speed

The forming speed and impact at bottom of stroke may produce different results in mechanical presses than their hydraulic counterparts. Each material and operation to form it has a optimal forming rate. For example, drop hammers and some mechanical presses seem to do a better job on soft jewelry pieces and jobs where coining is required. In some cases, a sharper coined impression may be obtained at a rapid forming rate.

In deep drawing, controllable hydraulic press velocity and full force throughout the stroke may produce different results. Often parts that cannot be formed on a mechanical press with existing tooling can be formed in a hydraulic press that has controllable force throughout the press stroke and variable blankholder pressure as a function of the ram position in the press stroke.

The Type of Press Frame

Like the mechanical press, open gap-frame machines provide easy access from three sides. Four-column presses such as the machine shown in Figure 6 insure even pressure distribution provided that there is little or no off-center loading.

Some two piston presses similar to the design shown in Figure 6 feature a system of linear position transducers and servo valves to vary the force to each piston in order to maintain the ram level with the bed. How well such a system works depends on the accuracy of the position sensors and reaction speed of the servo valving. If snap through energy release is involved, the servo system may not be able to react quickly enough to prevent ram tipping that may be harmful to the press, tooling and process.

Straight side presses such as that illustrated in Figure 7 are much better able to withstand off-center loading and snap through energy release than the type shown in Figure 6. Quality features to look for in a press designed for severe work when ram tipping is to be minimized are a single piston design together with a large ram or slide with long guiding and eight point gibbing. However, loading should be carefully balanced and cutting dies timed to minimize snap through shock to the best extent possible in any pressworking operation.

Accessories

Most hydraulic press builders offer many control options and accessories. These include:

1. A distance reversal limit switch which is preset for the depth of ram stroke for automatic return to the top of stroke position.

2. A pressure reversal switch which is set for the highest force delivered before the ram returns automatically to the top of stroke.

3. Automatic or continuous cycling controls which are used in conjunction with automatic feeding equipment.

4. Dwell timers which are adjustable, and are set to open the press after a pre-set dwell period.

5. Ejection cylinders or knockouts which can be actuated at a preset position, time, or pressure.

6. Rotary index tables and other work positioning devices often powered by the press hydraulic system.

7. Hydraulic die cushions which have the advantage of taking up less space than air cushions while offering controllable programmable resistance throughout their travel.

Press with Heavy Columns and Excellent Ram Guiding

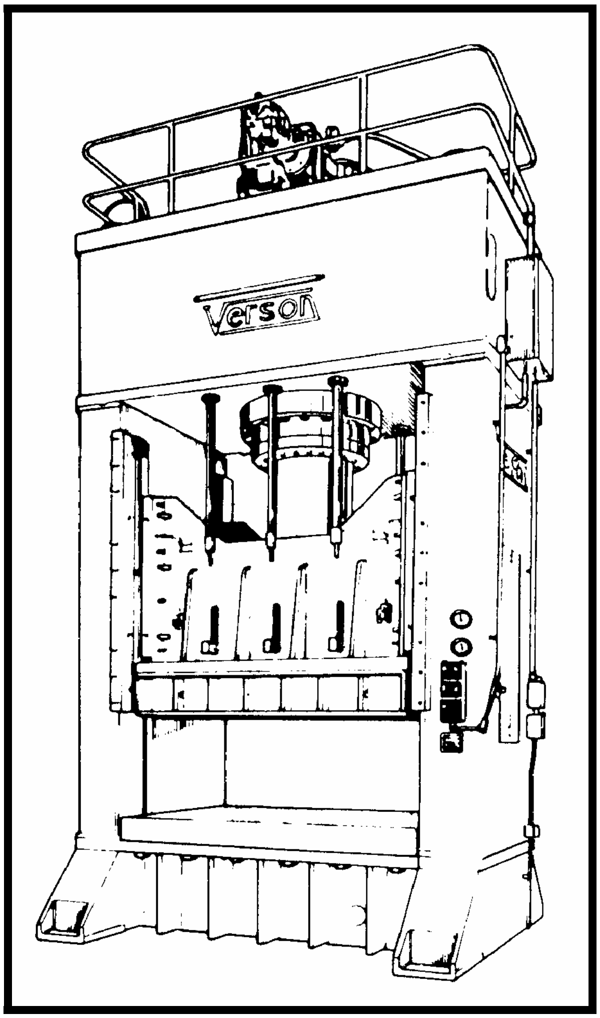

Figure 7. A straight side hydraulic press is designed for applications requiring close alignment. *Verson Corporation.*

Press Quality

Since the applications for hydraulic presses ranges all the way from simple hand pumped maintenance presses, to machines having very high force capacities, types of construction and desirable features varies accordingly.

Here are just a few design and construction questions that will provide a basis for comparison of one machine with another.

Frame: Compare the weight if possible. Try to determine the character of the frame construction. If a weldment, look at the plate thicknesses, extent of ribbing, and stress relieving.

Cylinder and slide construction: The cylinder size, type of construction used, and availability of service parts are important. Also determine how well the ram travel is guided.

Maximum System Pressure: The pressure at which the press delivers full tonnage is important. The most common range for industrial presses is from 1000 psi (6,894 kPa) to 3000 psi (20,682 kPa). Some machines operate at substantially higher pressures. Higher pressures may accelerate wear. Make sure that replacement parts are readily available.

Horsepower: The duration, length, and speed of the pressing stroke are the major factors that determine the required horsepower.

Speed: Take the time to calculate the speed based on the operations you intend to perform. There are wide variations in hydraulic press speeds.

Hydraulic Press Limitations

The fastest hydraulic press is slower than a mechanical press designed for high-speed operation. For example, the high speeds together with short stroke and feed progressions used for electrical terminal production favor the use of mechanical presses.

Stroke Depth Control

While hydraulic presses are available with an reasonably accurate built-in method of stopping the down stroke, generally stop or bottoming blocks must be provided in the tooling. Under production conditions, stroke depth typically can be controlled to within 0.020-inch (0.51 mm), even though readout devices with higher resolution may be provided on the machine.

Hydraulic presses are often provided with controls to reverse the machine at a pre-set pressure. This feature used in conjunction with stop or bottoming blocks in the die, can result in excellent part uniformity.

Shock after Breakthrough in Blanking

Problems with snap-through energy release are common to both mechanical and hydraulic presses. Damage to the hydraulic press structure may result. Severe snap-through shock can damage lines, fittings, valves, and the press electrical controls.

Presses that are robustly constructed have lower deflection and are preferred for heavy blanking applications. Snap through energy release is directly proportional to the amount of machine deflection at the moment of breakthrough when blanking.

Arresting Snap-Through Energy

Some hydraulic press manufacturers build snap-through arresting devices into hydraulic presses used for heavy blanking applications. Hydraulic damping cylinders on each corner of the machine arrests snap through energy. Hydraulic snap-through arrestors are also available as add-on devices for retrofitting to existing mechanical and hydraulic presses.

Hydraulic dampers are effective snap-through arresting devices on both mechanical and hydraulic presses. While the dampers are an effective solution, they add to equipment cost, may require time-consuming adjustment for different jobs and increase energy consumption. Snap-through energy control should be achieved through good die timing wherever possible.

Modern Developments in Hydraulic Presses

As hydraulic presses continue to improve, there is no doubt that they will play an increasingly significant role in industrial production. Hydraulic presses are already in far more widespread use in Europe than in North America.

Response Time and Precise Control

Hydraulic press speeds have increased over the last few years. Hydraulic component manufacturers have developed new valves with higher flow capacities, faster response time, and precise flow control capability. But unless a radically different hydraulic circuit design is developed, it is unrealistic to predict that hydraulic press speeds will overtake the mechanical press.

Feeders and Auxiliary Equipment

With the exception of high speed operations, mechanical press crankshaft-driven feeders are seldom specified for new installations. Today, hydraulic presses use the same roll feeders, and other auxiliary equipment designed for mechanical presses.

Actuation is by one or more microprocessor-based programmable controllers. Important features of such systems are easy programming and multiple job memory capability.

Programming the Press

Modern control systems permit the press sequence to be programmed for each job. Based on job memory parameters the correct pressure, stroke length, speed and dwell time, retraction force can be set-up quickly.

Safety, Human Engineering and Ergonomics

Important improvements on all types of presses is continuing to increase the comfort and safety of the operator. Better illumination, quieter machines, comfortable work positions, semi unattended operation, and provisions for simplified machine adjustments, all add to operator comfort and increased productivity.

Hydraulic presses are increasingly specified for production applications where mechanical presses were once used almost exclusively. The proper selection and use of the machine can be enhanced by a greater understanding of the characteristics of a hydraulic press. The manufacturing engineer should view the press as only one part of a total system which includes tooling, part feeding, personal protection, and part unloading equipment.

Programmable Hydraulic Blankholder Force Control

Hydraulic die cushions are used on both mechanical and hydraulic presses. They have several advantages when compared to an air cushion. These include:

1. Much larger forces can be obtained in the same press bed space.

2. Timed cushion lock-down or return delay: this feature is used to avoid deforming the part as the press opens.

3. The ability to control the instantaneous cushion pressure with a servo valve. This feature can be used to optimize the blankholder force as a deep drawing operation is in progress.

By controlling the hydraulic die cushion pressure with a servo valve, optimization of blankholder force can be achieved. Typically the pressure of air-actuated die cushions increases 10% or more between initial contact to the end of travel. A pressure increase of up to 40% is typical for self-contained nitrogen cylinders and some manifold systems. Metal movement on the blankholder may be severely retarded at the end of the forming cycle by this pressure increase. The result may be failure due to fractures. A programmable hydraulic die cushion can optimize blankholder forces through the forming sequence.

For example, the following sequence may be best for producing automotive quarter panels:

1. A high blankholder pressure is maintained upon initial punch contact with the blank. This will allow the metal to be impressed with the main character features of the draw punch, lessening the chance of lateral slippage. If slippage occurs a defect known as a *draw line* where the initial character line impression will be visible.

2. Next, the blankholder force is then reduced to allow metal to be drawn into the die cavity.

3. Then the exact pressure to allow metal flow without objectionable wrinkling is maintained until the punch nears the end of travel.

4. Near the end the draw punch travel, the blankholder force is increased in order to prevent metal movement. This may be required to obtain plane strain stretching of the side-walls in order to reduce springback and stiffen the part.

Hydraulic Control of a Mechanical Press Blankholder

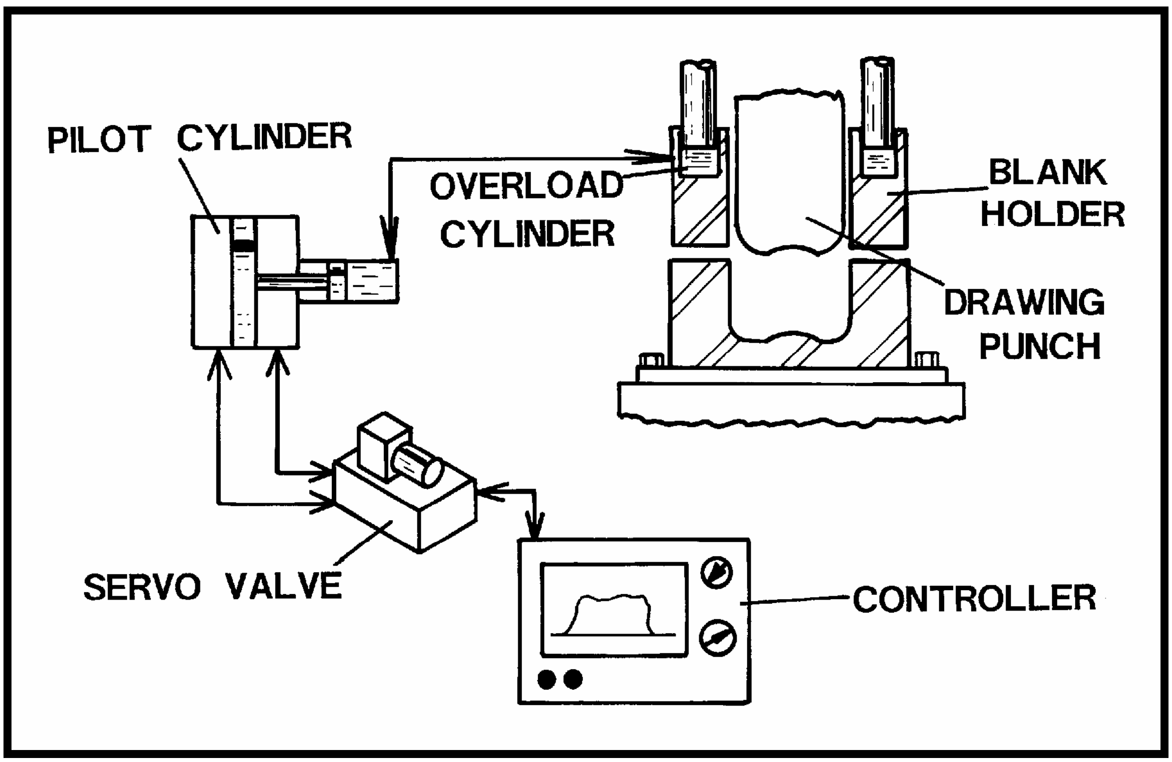

Figure 8. A blankholder force control system employing hydraulic overload cylinders in conjunction with a programmable servo control system. *The Ohio State University Engineering Research Center for Net Shape Mfg.* (ref. 3)

Hydraulic Control of Mechanical Press Blankholders [2]

Figure 8 is a simplified illustration of a method of combining the function of hydraulic overload cylinders and blankholder force control. The hydraulic overload cylinders at the press blankholder connection typically provide up to 1.000-inch (25,4 mm) of travel in the event of an overload.

The pressure source for each overload cylinder is a pilot cylinder or pressure intensifier. Air or oil under pressure is metered to the pilot cylinder or intensifier by a servo valve.

The servo valve is actuated by a programmable controller that varies the blankholder force throughout the forming cycle, using pre-programmed instructions for the part being produced. This system is less flexible that the programmable hydraulic die cushion due the short cylinder travel available. However, in four point presses, it can relieve or increase the pressure on a critical corner during the stroke to eliminate a fracture, or draw an area more tightly to stiffen the part.

Both the hydraulic die cushion and blankholder force control system have a long history of use in pressworking. The advent of the modern programmable electronic controller has made these blankholder force control systems much more flexible and simplified their use.

Hydraulic Forming Machines and Dies

An advantage of forming processes in which hydraulic pressure acts on one side of the workpiece is that only one half of the die is needed. Simple dies may use rubber pads or cast shapes alone as a forming medium to transmit pressure.

The Guerin process uses a thick rubber pad contained within the ram of the press. The die is placed on the lower press platten or bed. This process has long been used to form short runs of parts from thin soft materials such as aluminum.

Specialized dies use oil or water under pressure to act directly on the workpiece. Uses include forming metal into female cavities and bulging special shapes in tubing and deep drawn parts. The tooling costs are generally low and complicated shapes can be produced. Housekeeping problems, may be a concern, especially where oil is used.

[2] M. Ahmetoglu and T. Altan, "Improving Quality in Stamping by Controlling Blankholder Force and Pressure", The Ohio State University Engineering Research Center for Net Shape Manufacturing, presented at FMA/SME Presstech Conference, Rosemont (Chicago), Illinois, October 1994. This conference paper discusses some stamping failure modes and how blankholder force control is used to improve the process. A number of innovative blankholder force control methods are described and illustrated.

There are several processes that apply hydraulic pressure to the workpiece through a flexible rubber bladder or membrane. These systems combine many of the advantages of direct fluid application without the mess associated with applying the working fluid directly to the part. [3]

The Wheelon Process

The Verson Corporation Wheelon forming process uses a method of applying direct hydraulic pressure to the rubber forming pad. The blanks are placed over simple male dies, similar to those used in the Guerin process. Figure 9 illustrates a Wheelon hydraulic forming machine. The blanks and dies are moved into the press frame on a carrier, and forming pressure is applied by hydraulically inflating a rubber bladder mounted in the immobile roof of the press.

A Wheelon Hydraulic Forming Machine

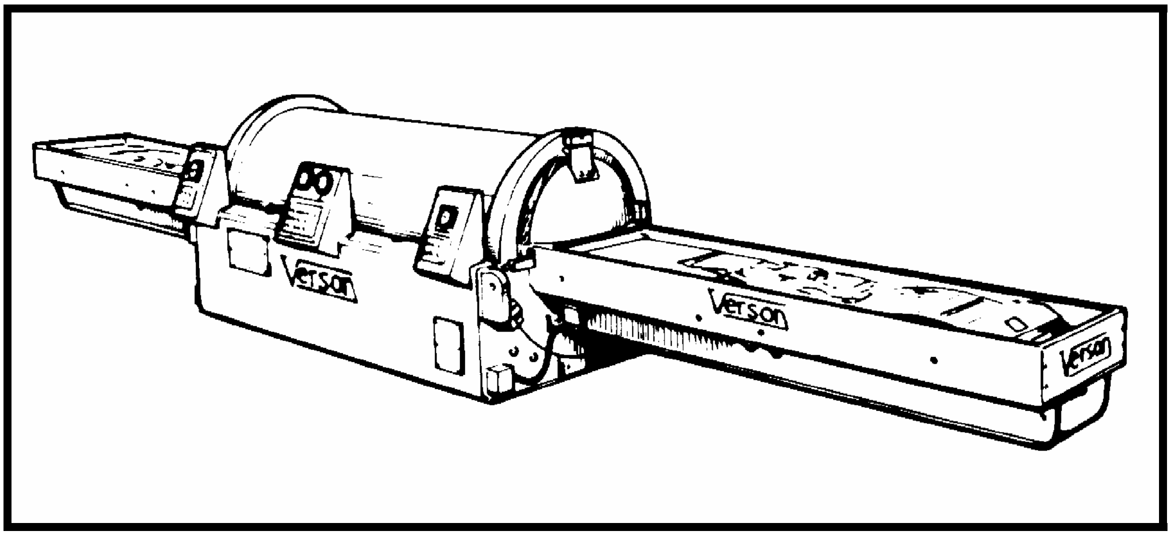

Figure 9. The Verson Corporation Wheelon hydraulic forming machine.
The Verson Corporation

Figure 10 shows a cross section of the press frame with a die and blank in place. The rubber bladder is shown in the released and the forming positions. This method is limited in depths of draw to about the same as the Guerin rubber pad forming process but, with pressures of 6,000 to 10,000 psi (41.4 to 68.9 MPa) available, practically all wrinkling is eliminated.

[3] D. Smith, ***"Die Design Handbook",*** Section 14, Rubber-Pad and Hydraulic-Action Dies, The Society of Manufacturing Engineers, Dearborn, Michigan, © 1990.

Sequence of the Wheelon Process

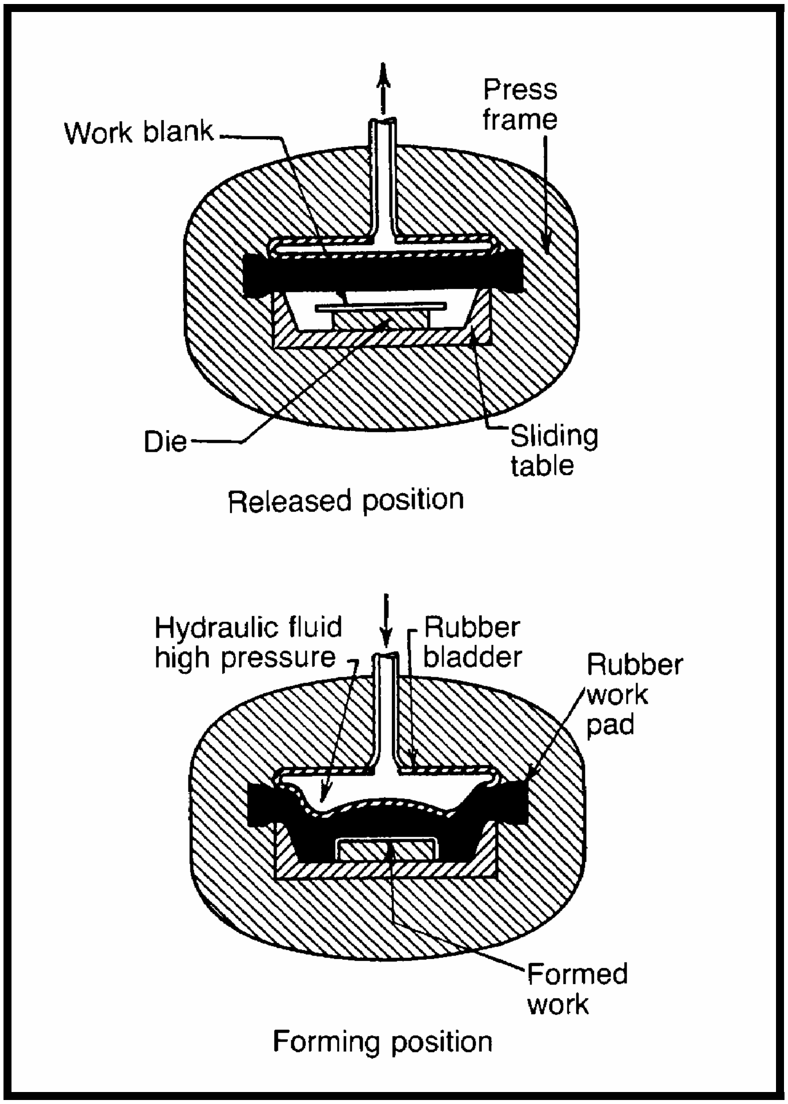

Figure 10. The Wheelon forming process sequence of operation.
The Verson Corporation

Hydraulic Forming in Conventional Presses

The SAAB fluid-form method, illustrated in Figure 11 uses a flexible diaphragm punch which assumes the shape of the die. The punch serves as a blankholder. The diaphragm is soft, and behaves much like a fluid due to the high pressures used.

In this process, the punch and blankholder of the conventional draw-die press are replaced by a steel cylinder which contains hydraulic fluid. The pressure is developed by the telescoping piston upon press closure.

The lower die used for the SAAB fluid-form method is of conventional construction. Air escape holes are provided for the air enclosed in the die cavity.

The SAAB Fluid-form Method

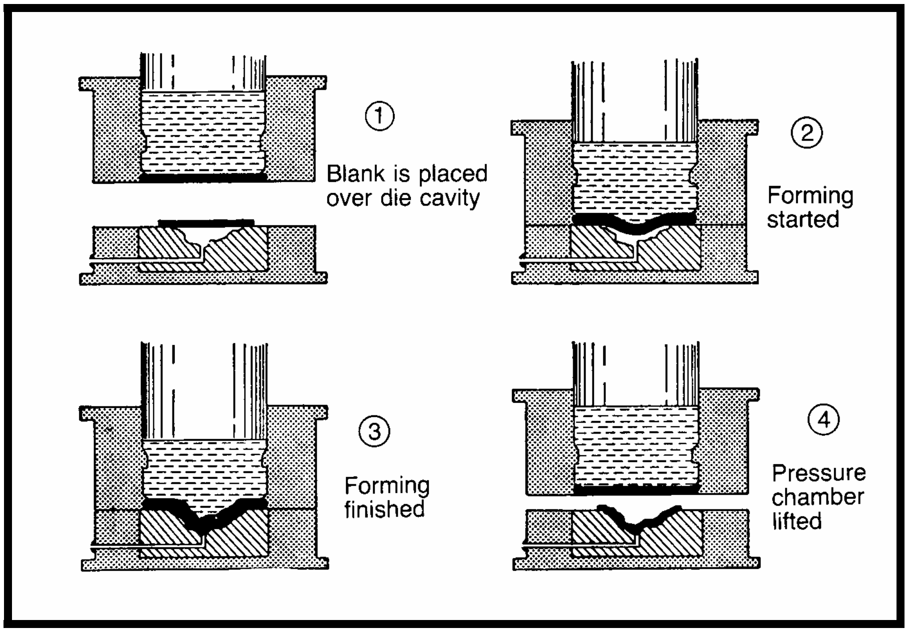

Figure 11. Stages of the SAAB fluid-form method of pressworking. (ref. 3)
SAAB Fluid Form Division, McMahon & Co., Inc.

The process can be adapted to a conventional single or double-action press by the installation of a fluid-form unit. The hydraulic unit is removable, permitting the press to be used for conventional presswork.

The fluid-form unit consists of two main parts, the punch or press chamber and the die holder. The die holder consists of a steel cylinder containing a telescoping piston which is sealed against the cylinder wall by a rubber or bronze packing and is retained in its upper position by a spring. The lower end of the cylinder is closed by a rubber diaphragm which is retained by an annular slot in the cylinder wall. The size of the unit (diameter of the diaphragm) depends primarily on the available press forces. Presses between 100 and 3,000 tons (890 kN to 26.7 MN) or more are suitable for the process.

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