HIGH SPEED PRESSES AND DIE OPERATIONS

The press speed in strokes per minute (SPM) defining high-speed operations has no absolute definition. Generally, high-speed operation involves press speeds of 300 SPM or greater. Machine size and part configurations are factors. Speeds at which the inertia and vibration of moving machine and die parts becomes an important consideration is one definition of high-speed operation. The upper end of the speed range for small high volume parts can exceed 2,000 SPM or more.

Gap frame presses find use for some high-speed work. However, the more costly precision high-speed straightside presses provide better alignment. Multiple slide forming machines are a separate class of machine widely used for high-speed presswork.

Common factors in presses designed for high-speed operation include compact robust construction. Special attention to the close fit and lubrication of all bearing surfaces is required.

Typical Applications
Coil stock fed progressive dies are widely used in high-speed presses. Here, a number of basic die operations occur sequentially. In this way, one or more parts per stroke. The peak force required in each station occurs at different points during the stroke. Some unbalanced loading is probable. Excellent alignment of both the press and die is critical to quality work and low maintenance costs.

These processes produce a variety of products ranging from razor blades and tiny electrical connectors, to motor laminations and beverage container lids. The multiple slide-forming machines are especially versatile. It produces products ranging from surgical needles to assembled worm gear hose clamps.

Rigid Press Frames
When analyzing high-speed success factors, the press and die a single system. Maintaining low deflection of press components under load is always a goal of good press design. Press frames and ram guiding systems designed for low deflection provide good alignment for the die. The benefit to the stamper is reduced die and press maintenance costs as well as consistent part quality.

Ram Tipping

1 D. Smith, “Die Design Handbook”, Section 20, Tools for Multiple Slide Forming Machines, The Society of Manufacturing Engineers, Dearborn, Michigan, © 1990. This chapter was contributed by Larry Crainich, President of Design Standards Corporation, Charlestown, New Hampshire. Many innovative uses of both conventional four slide forming machines and rotary multislide machines are shown.
The layout and timing of progressive die stations in the strip layout is essential. The location of the various stations often results in instantaneous ram tipping as the die closes. The potential for instantaneous misalignment due to ram tipping is eliminated in the process design. Often, offsetting die placement in the press will correct or minimize the problem. A perfect load balance, at any instant in time, in progressive die operations is desirable, but difficult to realize in practice. Operating the tool in a stiff machine having low deflection is highly beneficial to tooling life and quality.

**Dynamic Balance and Inertial Factors**

To avoid vibration, high-speed press crankshafts often have counterweights to provide dynamic balance. The counterweights, attached to the crankshaft, function much like those used in automotive engines. When the stroke is short compared to the crankshaft diameter, the shaft has eccentrics to actuate the pitmans. Comparatively large diameter eccentric shafts maximize rigidity. High-speed presses are typically single end drive machines. A very rigid eccentric shaft is especially important in two point presses to minimize any angular misalignment due to twist.

Some high-speed presses dynamically balance the reciprocating mass of the slide and upper die. A mass having the same moment of inertia as the slide and upper die, but driven on the opposite direction provides dynamic balancing.

The upper die weight should be minimized. One-way of doing this is using aluminum alloy die shoes rather than steel or cast iron. While aluminum is more costly, it is easier to machine. Compared to steel, aluminum has the advantage of higher heat conductivity and greater vibration damping capacity. Greater thermal expansion and a much lower modulus of elasticity are disadvantages.

**Inertia and Temperature Effects**

The actual shut height in the die space may vary significantly with changes of press speed. This results from the mass of the slide stretching the press pitman(s) and other machine components as the slide approached bottom dead center. The actual work may be done with the mass of the slide with the pitman(s) going into tensile load near bottom. This effect can be observed and a good setup made with conventional lead checks provided the machine is brought up to full operating speed.

Temperature changes cause most metals and alloys to change dimensions. The effect of machine temperature changes from friction as well as the environment in which the machine is located can cause changes in the actual shut height in the diespace. This factor is not usually monitored at all by a shut height indicator. Where the actual shut height is very important in very precise stamping, stop blocks equipped with strain gages can both serve as a physical slide-bottoming stop and measure the amount of force loading on each block.
Figure 1. Strain gauged setup or stop blocks used for critical pressworking applications. These “kiss” blocks are carefully calibrated and have NIST traceability. Toledo Transducers, Inc.

For critical work in any size press at any speed, changes in the machine speed in strokes per minute (SPM) of temperature changes will cause the shut height to vary slightly during operation. These effects can be minimized through careful control of the machine speed and designing the press with oil heaters to maintain constant temperature of the lubricating oil. Some press builders use oil chillers for this purpose, but this approach is not recommended because warm oil is less apt to have moisture contamination problems than cold oil.

Figure 1 illustrates a pair of strain gauged kiss or bottoming blocks. Four strain gages are installed in each of the round holes. The strain gage signals are brought out through rugged armored cable and connected to a readout device that measures the actual force or applier to each block. These blocks serve several valuable functions to the diesetter and/or operator.

1. Striking the blocks helps take variability out of the true press shut height or diespace due to press ram inertia.

2. A change in temperature, which may change shut height, is indicated by a change on the force or compression to the gauged blocks.

3. The actual compression of the stop blocks accurately indicates very slight changes in shut height—an aid in maintaining constant shut height under varying speeds and other conditions.
Clutch and Brake Systems

Electronic die protection is useful as both a process protection and control tool in high-speed work. Human reaction time is slow. The operator's attention will wander.

Electronic misfeed detection built into the die is widely used to avoid or limit mishit damage. A tonnage monitor wired to stop the press in the event an overload is also a desirable process protection feature even though it requires a bad hit.

To assure minimum tooling damage, the stopping time of the press must be less than one revolution. If an air actuated clutch and brake is used, it should be designed for rapid actuation and stopping.

Hydraulically actuated clutches and brakes are available that have very short actuation and release times. If needed for tooling protection, the added cost is a worthwhile investment.

Limitations on the Use of Tonnage Monitors

Advertising claims that tonnage monitors are useful to gather meaningful SPC data and detect dull tooling tend to be somewhat overstated. Except for the case of simple blanking operations, one must be able to track changes in key portions of the waveform signature in order to detect load changes related to the dulling of a cutting station. Often, a forming load that occurs at bottom dead center of the press stroke creates the peak load. This will mask any change in tool dulling. The run will stop for quality complaints of excessive burr height defect long before the tonnage monitor indicates a change in peak reading.  

Snap Through Related Problems

Some high-speed work, especially lamination blanking operations, results in a sudden release of energy as the punches break through the stock. This energy is stored in the press and die as strains or deflection.

Presses for this class of work should be designed with massive members relative to the size of the machine to provide good stiffness, or conversely, as little deflection as possible for the press force rating. One way that the press user can limit deflection is to specify the press bed to be no longer than necessary.

Snap through excites a vibration or oscillation in the press. While steel has the greatest stiffness per unit volume of the materials used to build presses, cast iron and iron alloys provide superior vibration damping. A heavy cast iron frame is a desirable feature that contributes to damping press vibration.

High Speed Press Bearings
The ram guiding and rotating shaft bearings are critical to maintaining machine alignment in high-speed presswork. Working loads, shock and inertial forces must not result in significant machine misalignment. High-speed presses use both ball or roller and plain hydrostatic bearings.

Hardened steel ball and roller bearings can operate with very little clearance. Their application in pressworking is most familiar in the ball bearing guide pins used to align dies. Some press builders favor rollers for flat bearings such as slide gibbing, although some slide alignment systems make use of round guideposts. One design makes use of the press tie rods to assist in guiding the slide with recirculating ball bearings.

Ball and roller bearings provide good alignment and long service life if properly lubricated and offset loading does not occur. No machine is infinitely rigid. Ram tipping under normal operation may result in high-localized loads and accelerated wear. Ball and roller bearings are not adjustable to take up wear.

Maintenance costs involving bearing replacement can be very high. Rebuilding a press where extensive replacement of hardened ball, roller and the hardened surfaces on which they run is required is often uneconomical and the press scrapped.

Hydrostatic and Hydrodynamic Bearings
The plain bearings used in larger presses depending on a film of oil to avoid metal-to-metal contact. Moving bearing surfaces supplied with filtered oil under pressure develop both hydrostatic and hydrodynamic oil film lubrication. The metal surfaces meet each other. Many critical high-speed bearings use this lubrication method. The automobile engine is a familiar example of plain bearings used in a very demanding application.

Plain bearings have advantages in high-speed presses. Like the automobile engine, clean filtered oil under pressure supplied to each bearing. Essentially zero wear occurs because of the film of oil. Plain bearings will withstand substantial shock loads without metal-to-metal contact occurring. Another advantage over ball or roller bearings is that eventual press rebuilding costs are much lower.

Example of a Modern High Speed Press
Figure 1 illustrates many key features of a modern high-speed straightside press. The massive one-piece frame (1) is of cast iron alloy construction. The mass and damping capacity of the frame is important to reduce the overall press vibration level.

A combination hydraulic clutch and spring applied brake (2) provides rapid engagement and stopping. Achieving a reduced stopping angle at high speeds is a necessity if electronic tooling protection is to be effective. An automatic flywheel brake speeds up power lockout to permit rapid access for work in the die area.
Figure 1. Cut away view showing key features of a modern high-speed press. *The Minster Machine Co.*

Hydraulic preload applied to the slide adjusting screws removes all clearance. This feature (3) eliminates thread play and wears during operation. A hydraulic cylinder at each connection supplies pressure for hydraulic slide lockup.
The hydraulic system (4) lifts the slide to a fixed open position to provide access to the die for inspection, troubleshooting and threading of stock. The hydraulic system returns the slide to the original shut height position against fixed mechanical stops.

Two large diameter hydrostatically guided pistons (5) provide slide alignment. Pressurized oil is supplied to these bearings as well as the large wrist pin bearings. In addition, four hydrodynamic guide posts (6) are provided between the bed and slide at the material pass line level.

Motorized shut height adjustment (7) is a standard feature. A mechanically driven shut height indicator is provided to assist in making accurate shut height settings.

The press drive motor (8) is equipped with an eddy current variable speed drive. The motor is totally enclosed and fan cooled.

The press feet (9) can be factory equipped with integral press shock mounts. The press is designed to accept an integral lift type sound enclosure (10) that is both mechanically and electrically interlocked. A counterweight (11) on the eccentric shaft provides dynamic balance.

The combination of an inherently vibration damping one-piece frame, shock mounts and acoustical enclose greatly reduce sound and vibration levels in the area. Other equipment may include quick die change bolster rollers and die clamps. 3 4

**High Speed Progressive Die Operations**

A high volume application for high-speed presswork is the production of electrical motor and transformer laminations. Most electrical steels contain a high percentage of silicon in order to minimize energy losses. In addition, a hard oxide layer is present on the material, which acts as an electrical insulator. High silicon lamination steels are very abrasive. High volume production requires precision tungsten carbide tooling and accurate press alignment.

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3 D. Hemmelgarn, “Flexibility in the Stamping Room”, The Minster Machine Company, Minster, Ohio. The application of state of the art controls and pressroom auxiliary equipment to press operations is covered in this paper

4 D. Hemmelgarn and D. Schoch, “Tuning your System to Increase Productivity”, The Minster Machine Company, Minster, Ohio. Detailed information on the application of high speed presses is given in this tutorial. The solutions to enable the use of stepped punch breakthrough while keeping ram tipping within specifications is covered in detail. A patented method for measuring vibration severity as a process control tool is also described. This paper is highly recommended as a source of information on successful high speed press operation.
A Combined Rotor and Stator Lamination Die

Figure 2 illustrates a progressive die to stamp a rotor lamination 2.813-inch (71.45 mm) in diameter and a mating stator lamination 4.875-inch (123.82 mm) in diameter.

In the first station, a number of holes are punched. These include two pilot holes, the center hole with an alignment notch, the electrical winding holes in the rotor and an alignment notch for the stator. In station two, the rotor is blanked from the strip. The conductor holes for the stator are punched in the next station.

Example of a High Speed Press Motor Lamination Die
Figure 2. Carbide progressive die used to produce one electrical motor rotor and stator lamination per stroke. A plan view (A) is shown. A sectional view of the first three stations (B) illustrates important construction features. Harig Mfg. Corp.

Station four is an idle station where only pilots engage the strip. This station insures good alignment and provides for more robust die construction. Finally, the stator lamination is blanked from the strip in the last stage.

The two blanking punches have a carbide ring fastened to a steel body. All punches and cutting edges are solid or inserted carbide. Hardened steel retainers and hardened steel backing plates are used to hold and support all dies and punches.

A tunnel or fixed stripper is used to strip the punches from the stock. This type of construction is less costly than a spring-loaded stripper. The use of fixed strippers is satisfactory if stock control or punch alignment is not a problem. However, a precision-guided movable spring loaded stripper is often preferred for this type of die.

Dies That Produce Multiple Parts Per Hit
Dies that produce more than one part per hit have many advantages over a single or one out die. These include:

1. Higher productivity
2. Production of symmetrically opposite or complimentary parts at the same time
3. Balancing die loading to avoid ram tipping or lateral thrust
4. Improved material utilization, especially in the case of round blanks or parts

Example of a Five Out Progressive Die
The progressive die illustrated in Figure 3 produces five spark plug seat gaskets per stroke. The strip pattern illustrated has alternate rows of three and two gaskets across a strip of 0.020 in. (0.51-mm) thick AISI-SAE 1008 sheet steel 5.75 in. (146 mm) wide.

The strip advances 1.25 in. (31.8 mm) per stroke. The sectional view illustrates key features of good die design. An idle station between each operation allows space for robust die section construction. Most stations have a spring loaded pressure pad attached to the upper die shoe for accurate stock control.

In station one, the blanks are cut from the strip except for a small tab on each side attaching them to the carrier skeleton. Station two draws the blanks into cups and a bead formed around them in station three. The flat bottoms are punched out of the cups in station four. Finally, the curved portion of the cup bottoms are flanged into straight tubes in station five.
A curling operation is performed in station six which is closed tightly together in station seven. Finally, parts are cut off and dropped through the lower die shoe in station eight. All the punches and the die inserts are backed up by a 0.375 in. (9.52-mm) thick hardened and ground steel plate. Spring loaded lifters push the part out of the die cavities. The stock guide rails are spring loaded to hold the strip up when it is advanced to the next station.

**A Good Design for an Automotive Component Die**

![Figure 3. A progressive die, which produces five complete spark plug seat gaskets per stroke. AC Spark Plug Division, General Motors Corp.](image)

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