Press Applications:

When metalformers consider the horsepower required, the installation costs and life-cycle expectancy, eddy-current drives will outperform VFDs in metal-stamping/forming press applications.

Eddy Current vs. Variable Frequency Drives

BY DAVID STRONER

Eddy-current and variable-frequency drives (VFDs) have been employed to provide variable-speed control for presses for many years. Mechanical presses, which use flywheels to store energy, are segregated by several standards; here we'll focus on speed, rating, flywheel energy and main motor requirements.

Generally, we specify three speed ranges for presses: slow (0 to 20 strokes/min.); medium (20 to 40 strokes/min.); and fast (40 strokes/min.) and faster.

When discussing ratings, we say "this press is rated at ½ in. off bottom stroke," which means that the press is designed to perform work at its full rated tonnage from ½ in. before bottom through bottom dead center (BDC).

The rating of a variable-speed press will allow for full flywheel energy to be developed at mean speed. Consider a machine that runs at 20 to 40 strokes/min.—the mean speed is 30 strokes/min., which is where you will likely find the full flywheel energy developed. You will have an overabundance of energy as speed continues to rise from 30 to 40 strokes/min., but the energy available from 30 to 20 strokes/min. will suffer greatly. The energy available is a function of the square of the velocity of the flywheel.

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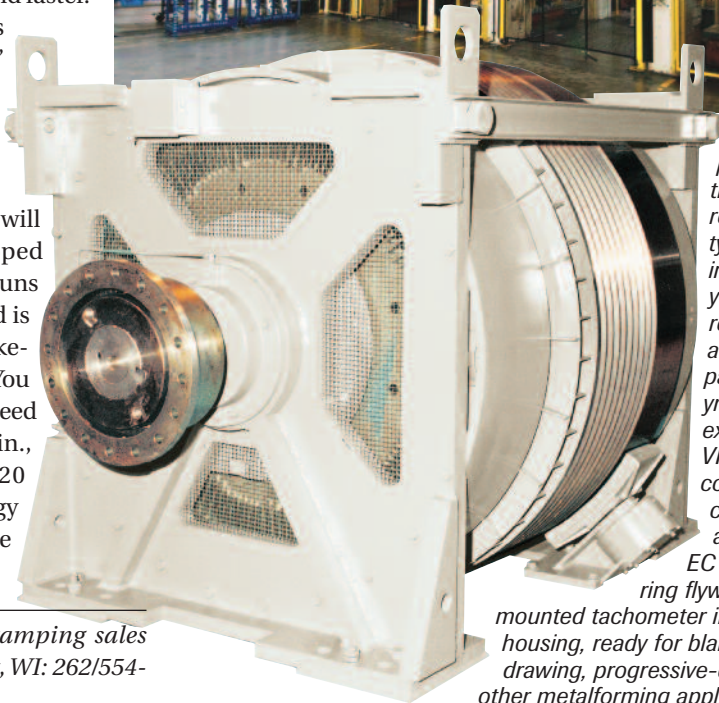
In stamping-press applications, eddy-current (EC) drives typically run well in excess of 20 years before requiring major attention, compared to the 7-10 yr. average life expectancy of a VFD. Shown is a combination air-cooled adjustable-speed EC drive, brake, belt ring flywheel and shaft-mounted tachometer in a common housing, ready for blanking, deep drawing, progressive-die stamping and other metalforming applications.

Flywheel Energy and Main Motor Requirements

Flywheel energy is based on the rating of the press, and the size of the main motor relates to the amount of energy that must be put back into the flywheel and the amount of time during which that energy must be replaced.

There is a dependent relationship between the permissible speed reduction of the flywheel and the type of driving motor used. Manufacturers select from three different types of motors and flywheel-speed reduction options: 3 to 5 percent slip and a 10-percent speed reduction (fast press); 5 to 8 percent and 15-percent speed reduction (medium-speed press); and 8 to l3 percent slip, 20-percent speed reduction (slow press).

The flywheel provides energy during the working part of the press stroke. When performing work, its speed of rotation is reduced with a subsequent loss of energy. The motor must restore this lost energy to the flywheel.

The energy available in the flywheel varies directly as the square of the speed of the wheel. A flywheel rotating at 100 RPM only has 25 percent of the energy of the same-size wheel rotating at 200 RPM.

The pressure or force required to perform the operation, and the distance through which this force must be exerted impact the energy requirement of the flywheel. For example, consider an ironing operation that requires 40 tons of press force over a distance of 18 in. The required flywheel energy is 40 x 18, or 720 in.-tons. A shallow draw operation might require an average pressure of 500 tons thru 2 in. of press stroke; required flywheel energy would be 1000 in.-tons.

Power Required to Accelerate the Flywheel to Operational Speed

The prime mover brings the flywheel up to a high energy level over a period of time. Then, the pitman link must deliver a large portion of the energy through the crank to the ram in a period of time. The flywheel stores and

Comparing Eddy-Current Drives and VFDs for Press Applications		
Considerations	**VFD**	**Eddy Current**
Cable Length	**50 ft.** Manufacturers recommend no more than 50 ft. from the VFD output to motor termination, due to inductance and EMI.	**500 ft.** Recommended length up to 500 ft. (transmitting only DC voltage) before requiring an increase in wire size.
External Cooling	**Forced-air HVAC or water cooling** Switching losses in VFDs creates heat that must be mitigated through external cooling methods.	**Ambient air** Switching losses equal less than 0.1 percent of total system power.
Harmonic Mitigation	**Input isolation transformer** Limits current to drive and mitigates harmonic interference to peripheral equipment.	**Input isolation transformer** Small input isolation transformer (on board) included in all controls.
	Input line reactor Noise mitigation on input side of drive.	**None required**
	Output harmonic filters To reduce the amplitude of fixed frequency currents, prevent them from entering the rest of the system.	**None required**
Installation Cabling	**Factory recommended** Special consideration must be given to the proper installation and operation of the overall system that comprises the VFD, the motor it controls and the cable that connects them. The way in which VFD-based systems are constructed and operated will have an impact on the longevity and reliability of all components of the system, as well as nearby systems.	**None required** No specialty cable requirements, national electrical code standards apply.
System Grounding	**Factory recommended** Complex grounding system due to pulse width modulation	**None required** No specialty grounding requirements, national electrical code standards apply.
Requirements for Inverter Duty Motor	**Factory recommended** Pulse-width modulation can cause voltage transients well above the rated voltage of the motor, which can lead to premature failure of the insulation system.	**None required** Standard Class F insulated, Design B motors
Brand Flexibility	**Factory recommended** Motor manufacturers limit warranty to select pretested VFDs.	**Nonexclusive** Systems are compatible with all motor manufacturers.
Bearing Protection	**Applicable** "Shaft currents" which flow as a result of shaft-to-frame electrical potentials.	**None required** Due to absence of shaft currents
Motor Heating	**Oversizing Motors** The ability of a motor to cool itself effectively is reduced as the motor slows. Oversizing the motor or providing external forced-air ventilation may be required with extended operation at low speeds and high loads.	**None required** Standard TEFC or ODP motors suffice
Dynamic Braking	**Factory recommended** Dynamic braking is required to control the bus voltage on the drive. Bus voltage needs to be dissipated to avoid resultant nuisance tripping.	**None required** Eddy-current drives can dissipate energy without compromising its internal electronics.

delivers energy by changing its RPM. Typically, the flywheel is designed to deliver 10 to 20 percent of its stored energy to the ram when engaged within the work cycle.

To determine flywheel energy:

$$E \text{ (ft. lb.)} = 1.7 \times Wk^2 \times \left(\frac{N}{100}\right)^2$$

If the press operates at 30 strokes/min., or 360 RPM at the flywheel, a 15-percent slowdown occurs and estimated flywheel inertia is 10,800 lb-ft.[2] The energy is:

$$E = 1.7 \times wk^2 \times \left(\frac{360}{100}\right)^2 = 237{,}945 \text{ ft. lb.}$$

$$\Delta E = 237{,}935 \text{ ft. lb.} - (1.7)$$
$$\times (10{,}800 \text{ lb. ft.}^2)$$
$$\times \left(\frac{(360) \times (1 - 0.15)}{100}\right)^2$$

$$\Delta E = 66{,}029 \text{ ft. lb.}$$

The motor/drive system must restore the lost energy from the flywheel within the nonworking portion of the press cycle. The figure illustrates a press with a 12-in. stroke (two times

Slide

Rated tonnage distance = d = 0.5"
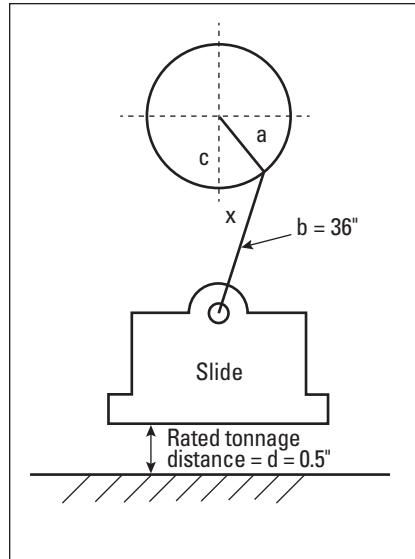
the crank radius); it would be 0.5 in. above BDC with the crank 25 deg. above BDC. Dividing 360 into 25 provides a 7-percent work period.

Parameters:
a = half of press stroke = 6 in.
b = Length of pitman = 36 in.
c = a + b-d = 41.5 in.

d = Rated tonnage distance = 0.5 in.
T = Rated press tonnage = 150 tons
T_{mg} = Total main gear torque
2000 = conversion factor, 2000 lb./ton

To calculate the required energy to accelerate the flywheel:

$$HP = \frac{\Delta E}{\left[\frac{(60 - t) \times 550}{f}\right]}$$

f = The cycle frequency or strokes/min. of the press (30 in this example).

$$t = \text{Working time} = (.07) \times \left[\frac{60}{f}\right]$$

for 7-percent cycle time

$$\frac{60}{f} - t = \frac{60}{f} - (0.07) \times \frac{60}{f} = 0.93 \times \frac{60}{f}$$

$$HP = \frac{66{,}029 \text{ lb. ft.}}{0.93 \times \frac{60}{30} \times 550} = 64.54 \text{ or } 65$$

This represents the demanded horsepower over the 7-percent working period of the press. Since eddy-current drives provide 250-percent inter-

mittent overload capacity, the mechanical unit would be sized to:

65/2.50 = 26 hp, plus 10 percent to account for friction and gear losses, or 26 x 1.1 = 28.6 (round up to 30 hp).

A VFD and/or DC drive typically can provide only 150-percent overload, so drive size would be:

65/1.50 = 43.33 hp (about 50 hp when accounting for frictional and gear losses.

That's right, a 20-hp difference, because eddy-current drives can generate 250 percent, or nearly double the peak output capacity, of equivalent AC or DC drives.

Heat and Longevity of AC Motors

At full speed and load, an AC motor will slip by an amount roughly equal to 3 percent of its synchronous speed, depending on the motor design. This slip represents energy loss in the rotor and converts directly to heat inside the motor, which must be dissipated. This makes AC motors relatively limited in terms of full-torque thermal speed range. A standard induction motor cannot produce full torque over more than a two-to-one speed range without overheating, if subjected to continuous duty. Even with substantial modification, the motor cannot run continuously at full torque at very low speeds due to the thermal losses in the rotor caused by slip.

Special inverter duty motors are subject to serious longevity concerns when subjected to continuous full-torque demands. Heat is the enemy of the VFD when used in a variable-speed press application.

However, in eddy-current drive applications, the AC motor runs at near synchronous speed, optimizing life expectancy due to the inherent heat-dissipating design capabilities of the motor. Eddy-current drives typically run well in excess of 20 years before requiring major attention, compared to the 7-10 yr. average life expectancy of a VFD.

Common Stamping Press Applications

Many stampers run their presses in progressive and transfer applications, loading the press and not stopping it until production is complete. This continuous mode of operation demands that the press drive run under high load conditions at all times; such demand on the press drive is augmented by the energy that must be restored to the flywheel in slower-speed operation when the flywheel-energy demands may already be compromised by the work being done in the press. That's where eddy-current drives find a home.

Eddy-current drive controls are simple, inexpensive, easy to maintain and readily available in time-proven successful design configurations. It is common for analog controls to run for 30 to 40 years before they require service. Their availability and cost effectiveness makes them highly desirable when compared to typical VFD controls. **MF**