Dynamatic®
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PRESS DRIVE APPLICATION NOTE

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INTRODUCTION

More emphasis is placed on OEM's to provide the most efficient variable speed drive systems available. Evaluating drive system efficiency and performance is time consuming and complex. Often, variable speed drive manufacturers can offer excellent technical support in matching product with application. Although several types of variable speed drive technologies may work on a particular application, one will always prevail as the best fit.

For example, the eddy current drive offers a rich set of performance characteristics not found in AC or DC drive systems. For a given horsepower, eddy current drives can produce 225 to 250% output torque on an intermittent basis. Eddy current drives inherently maintain excellent speed regulation typically 1/4 to 1/2 %. Current designs offer stationary fields which means no brushes are required to energize the coil assembly. This translates into low maintenance and a dramatic reduction in down time.
Eddy current drives are sometimes not considered energy efficient. For a constant load application, eddy current clutch efficiency is determined by the difference between the input motor RPM and the clutch rotor RPM multiplied by the output torque. The greater difference which exists between the two rotating members at constant torque, the poorer the efficiency. However, for many applications, the eddy current drive will offer optimal performance characteristics justifying a trade-off in efficiency.

PRESS DRIVES

An excellent application which exploits the eddy current drive's performance characteristics is the mechanical stamping press. Press drives supply energy to machinery used to form metal or other materials. The mechanical press must convert rotary motion of an eccentric linkage to a reciprocating motion of the slide. Typical press operations include cutting, drawing, sizing, compacting, and forging all of which demand the application of high, intermittent force.
Each operation or stroke absorbs kinetic energy from a continuously rotating flywheel. The flywheel behaves as an energy reservoir for the eccentric gear train and slide. During the working portion of the cycle, energy is transferred from the flywheel to the slide punch. At that point, the flywheel slows down and must recoup total losses prior to the next stroke.

PRIME MOVER

Electric motors have proven to be the most effective prime mover for restoring lost kinetic energy to the flywheel. The motor/drive system must instantaneously respond to the flywheel's

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energy demand. Since the actual working portion of the press cycle is relatively short, the ideal drive system should possess a high overload capacity. Insignificant energy is required during the non-working segment of the cycle. Bearing friction and windage offer negligible resistance, therefore, drive system specification criteria should emphasize peak output torque capability.

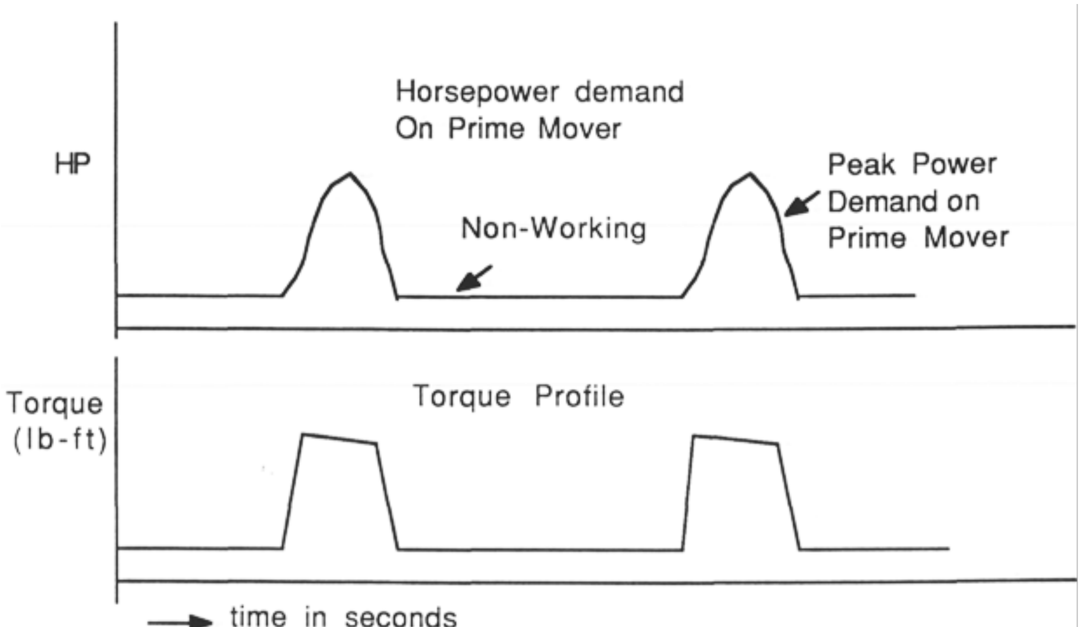

figure 1

Figure 1 represents a typical load cycle of a press drive system operating in single stroke mode. As the system free wheels during the dwell period between strokes, little energy is consumed. Also, the torque required is relatively low. Peak torque, output, however, will reach 200 to 250% of the prime mover's continuous rating.

FLYWHEEL ENERGY

The flywheel once accelerated to full operating speed stores a significant amount of energy. Without the flywheel, the prime mover would have to be enormous in capacity and physical size. For example, to compute the main gear torque of the eccentric drive in figure 2, the following equation is used:

$$\text{Tmg} = \frac{2000Tc \times \tan x}{12}$$

Where $x = \cos^{-1}\left[\frac{b^2 + c^2 - a^2}{2bc}\right]$

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Parameters are defined and numerically represented as shown below:

a = 1/2 press stroke = 6"
b = Length of pittman = 36"
c = a + b-d = 41.5"
d = Rated Tonnage Distance = 0.5"
T = Rated Tonnage of Press = 150 Ton
Tmg = Total Main Gear Torque
2000 = conversion factor, 2000 lbs/ton

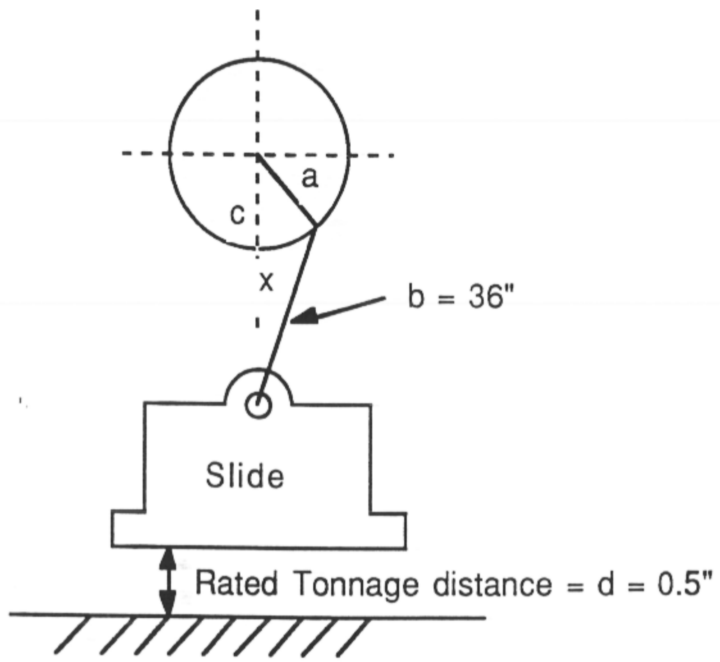

Figure 2

For a 150 ton press with a 0.5" rated tonnage distance, the torque at the main gear becomes:

$$x = \cos^{-1}\left[\frac{(36)^2 + (41.5)^2 - (6)^2}{2 \times (36) \times (41.5)}\right] = 3.55$$

$$Tmg = \frac{2000 \times (150) \times (41.5) \times \tan(3.55)}{12} = 64{,}355\ lb\ ft$$

This is the minimum torque necessary to generate 150 tons of pressure at 0.5" above BDC or Bottom Dead Center. The motor requirement would be 1500 HP, 1800 RPM to provide this torque without a flywheel.

Stored kinetic energy in the flywheel is used to supply the torque. The prime mover brings the flywheel up to a high energy level over a long time; then the pittman link must deliver a large portion of the energy through the crank to the ram in a brief period of time. The flywheel

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stores and delivers energy by changing its RPM. Typically, the flywheel is designed to deliver 10 to 15% of its stored energy to the ram when it is engaged within the work cycle. The equation to determine energy in the flywheel is:

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

If the press operates at 30 SPM, or 360 RPM at the flywheel, and a 15% slow down occurs and the estimated flywheel inertia is 10,800 lb-ft^2, the energy is :

$$E = 1.7 \times 10{,}800\ lb\ ft^2 \times \left(\frac{360}{100}\right)^2 = 237{,}945\ ft\ lb$$

$$\Delta E = 237{,}945\ ft\ lb - (1.7)\times(10{,}800\ lb\ ft^2)\times\left(\frac{(360)\times(1-\ .15)}{100}\right)^2$$

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

This is the energy which must be restored to the flywheel by the prime mover. The motor/drive system must restore the lost energy from the flywheel within the non-working portion of the press cycle. Figure 2 illustrates the press with a 12" stroke (two times the crank radius), it would be 0.5" above BDC when the crank was 25 degrees above BCD. Dividing 360 into 25 provides a 7% work period. The following expression permits us to calculate the required energy to accelerate the flywheel:

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

f = The cycle frequency or SPM of the press, in this instance 30.

t = Working time = $(.07)\times \left[\frac{60}{f}\right]$ for 7% cycle time

$$\frac{60}{f} - t = \frac{60}{f} - (.07)\times\frac{60}{f} = .93 \times \frac{60}{f}$$

$$HP = \frac{66.029\ lb\ ft}{.93 \times \frac{60}{30} \times 550} = 64.54\ or\ 65$$

This is the demanded HP over the 7% period the press is doing work. Since eddy current drives provide 250% intermittent overload capacity, the mechanical unit would be sized to:

$\frac{65}{(2.50)}$ = 26 plus 10% to account for friction and gear loss

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or $26 \times 1.1 = 28.6$ round up to **30 HP.**

A variable frequency and/or a DC drive can generally provide only 150% overload and therefore drive size would be:

$\frac{65}{(1.5)} = 43.33$ again add about 6% for frictional and gear losses or about **50 HP.**

That's right, a whopping 20 HP difference! Because the eddy current drive can generate 250% or almost 100% greater peak output capacity than equivalent AC or DC drives, the user benefits from having to supply a much smaller and far less expensive drive system! The question comes to mind, "How does the eddy current drive produce 250% intermittent output?". The answer is the eddy current coupling can transmit up to the peak torque of the AC induction motor. Since AC induction motors have a breakdown torque of 250%, as shown in figure 2b, the eddy current drive can transmit this torque to the load.

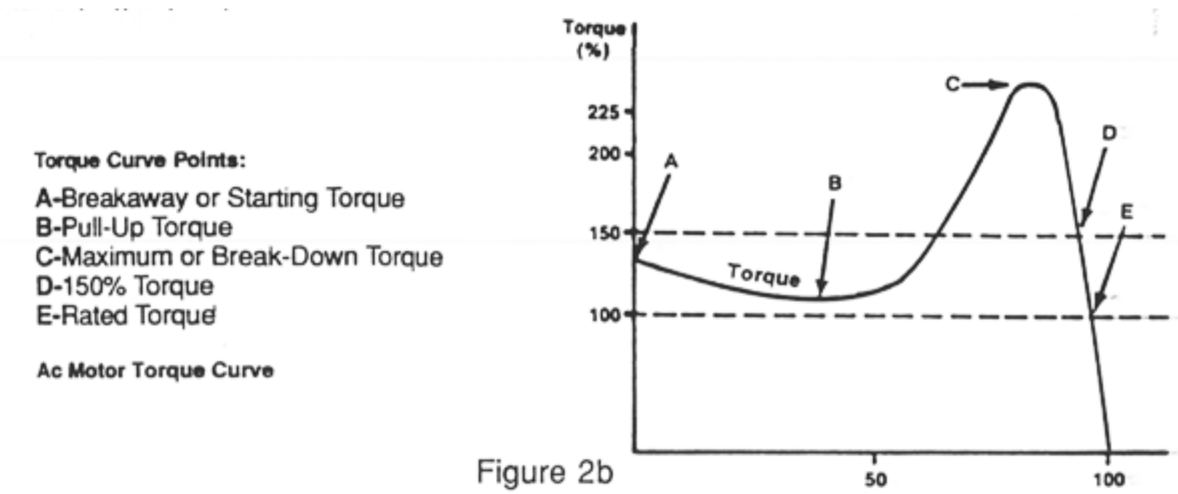

Figure 2b

Also, the rotating members within the eddy current clutch all contribute kinetic energy during external load disturbances. The motor rotor, drum, and output rotor are all in continuous motion during operation. In AC drive systems, only the motor rotor is in continuous rotating motion which can offer a mere fraction of the kinetic energy the eddy current system can produce.

NON-WORKING CYCLE

Referring back to figure 1, we determined the peak output HP requirement. Next, the non-working portion of the HP demand is calculated. First, determine the torque requirement:

$T = \frac{(W \times \mu \times r)}{eff}$ where r = radius of the flywheel's hub

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W = weight of the flywheel
μ = coefficient of friction = .1
eff = efficiency of gear system (.85)

The inertia of the flywheel is estimated at 10,800 lb-ft^2, and, the weight is estimated at 2000 Lbs. Next the radius of the flywheel's inner hub is defined as one half the diameter of the support shaft. Assuming the shaft supporting the flywheel is directly coupled to the eccentric linkage, which in this instance is 6", the torque is;

$$T = \frac{(2000 \times .1) \times \frac{6}{2\times 12}}{.85} = 58.82\ lb\ ft$$

Next, the reflected torque back to the eddy current is 58.82 Ib-ft divided by the belt ratio as shown below in figure 3:

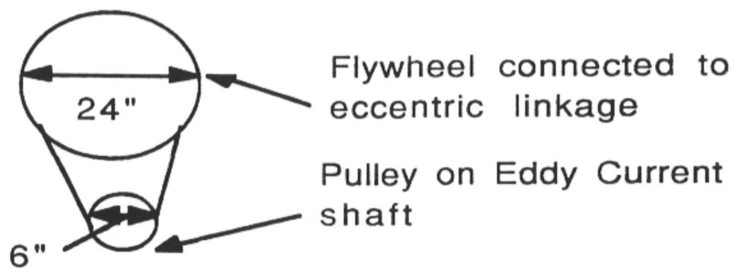

Figure 3

Finally, the running HP during the non-working portion of the cycle can be determined by:

$$HP = \frac{T \times S}{5252}$$

$$HP = \frac{(58.82 \times 74)\times(4 \times 360)}{5252} = 4\ HP$$

Insignificant! Only 4 HP is required to overcome windage and friction during the non-working portion of the cycle or 93% of the presses operating time!

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ENERGY SAVINGS

Most OEM's, retrofitters, and users will want to know how much energy is utilized by the process during the entire operating period. The key word is the "process". Motors and variable speed drives do not demand a significant amount of energy; the machine or process does. The variable speed drive system is nothing more than the medium upon which energy is passed through or converted from electrical input to mechanical output. The clear objective is to select the most cost effective system and not dwell on small energy consumption differences. Getting back to the original example, the total amount of energy consumed by the machine in an eight hour period would be;

Total Power = Peak HP X Working Period X eight Hr + Non Peak HP X Non working X eight Hr

The peak HP was determined at 65 and demanded for a brief 7% of the cycle time. Only 4 HP was demanded for the remaining 93% of the cycle. Therefore, using the total power equation shown above, the total power demanded by the process in Kwhr is:

Total Power = 49.355 KwHr

This figure is nothing more than the raw power required to do the demanded work and does not account for drive system losses. We must add to this figure the energy consumed by the adjustable frequency drive.

For the variable frequency drive, system efficiency consists of a 97% inverter and a 50 HP motor rated at 94.5% with a 95% power factor. Combining motor efficiency, displacement power factor, and drive efficiency, a figure of system merit is established at; .97 X .945 X .95 = .87; approximately. Next, the total daily cost to operate the press with a variable frequency drive based on a 7.50¢/KwHr charge would be;

$$Total\ Cost = \frac{49.355\ KwHr \times 7.50¢}{.87}$$

Total cost to operate VFD system is **$4.25 per day**

The eddy current drive is less efficient at this speed range. Eddy current drive losses are proportional to slip speed. In this instance, the motor input is four pole running constantly at 1750 RPM while the output is running at 1440 RPM. System efficiency isr based on a 30 HP motor at 94.5 % while the clutch is around 83% for this particular speed. Unlike the inverter, eddy current does not commutate from a constant voltage bus, it's simply an induction motor running across line. The displacement power factor is not better than .85, therefore, system figure of merit is computed as; .945 X .83 X .85 or .67 would be a good estimation.

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Total system figure of merit is 67% with the cost to operate the system being:

$$Total\ Cost = \frac{49.355\ KwHr \times 7.50¢}{.67}$$

Total cost to operate EC system is **$5.55 per day**

A difference of $1.30 per day to operate an eddy current drive vs a VFD is Insignificant compared to the high upfront costs of purchasing and installing a VFD.

CONCLUSION

From the analysis, it becomes obvious the press drive or prime mover should be selected based on peak output requirements. Many press manufactures might present their opposition to eddy current regarding its poor efficiency. However, during the working portion of the cycle, a high energy level is required which the prime mover must deliver independent of drive system type. Energy savings is of no concern during this portion of the cycle. The remaining 93% or the non-working portion of the cycle demands so little power, any energy savings would be insignificant. The user or OEM could not realistically expect a payback for two reasons:

1.) The flywheel's energy is directly proportional to the square of its speed. This means the press can't be realistically operated much below 75% of top speed. The eddy current is only inefficient at speeds below 80% of motor input speed.
2.) Horsepower is torque times speed divided by a constant. Even if the press was operating below 50% of top speed, the torque requirement to keep the flywheel moving is so low, virtually little to no energy savings can be realized.

The Bottom line is if you are a press manufacturer, press owner, or system integrator, stay with eddy current! You will lower your purchase costs, benefit from the higher reliability, and be less burdened with having to mount and wire a complex AC drive system.