Dynamatic®
DRIVE SOURCE INTERNATIONAL, INC.

EFFICIENCY, LIFE CYCLE COST AND THE EDDY CURRENT DRIVE

Introduction

There is great emphasis on efficiency in the world today and the manufacturers and users of adjustable speed drives are certainly not exempt from this concern. Determining the best drive for a particular application can be a time consuming process which should include not only evaluation of performance and acquisition cost but also the cost of ownership. In a great many applications, the Eddy Current drive is one of the strongest contenders but it is sometimes discarded without a thorough investigation into all of the elements which make up the total cost of ownership.

Life Cycle Cost

The life cycle cost of a piece of equipment is defined as the sum of all costs associated with that equipment from the day it is purchased throughout its entire operating life. To the engineer specifying drives, costs of items such as spare parts inventory, maintenance personnel training and downtime may not seem as important as acquisition costs and efficiency. However, "the name of the game is profits", and selecting a drive which performs well and has the lowest cycle cost, will present the opportunity for increased profitability.

Major items to be considered when evaluating life cycle cost are:

1. Acquisition costs
2. Installation costs
3. Operating costs
4. Downtime costs
5. Maintenance and repair costs

Each drive candidate should be evaluated on all the items included in the life cycle cost. The drive with the lowest life cycle cost which meets the performance requirements should then be selected for purchase.

Eddy Current Drive Characteristics

The Eddy Current drive is the simplest of all electrical adjustable speed drives. It is a rugged industrial drive which has been proven in the past 60 years by thousands of units in nearly every industry. The prime mover is an AC induction motor, the work horse of industry today. The Eddy Current clutch consists of two rotating members, a drum operating at constant speed connected to the shaft of the induction motor and an output member which couples the torque produced by the motor to the load at a controlled adjustable speed. There is no direct mechanical connection between the drum and the output member eliminating friction and mechanical wear. Torque is transmitted through an electromagnetic field between the two rotating members. The excitation to the field is provided by a low power solid state controller which typically requires approximately 1/2% of the drive's rated power. The controller is basically a simple regulator and a phase controlled rectifier which provides excellent speed regulation and stability in a low cost, easy to maintain module. The typical operating characteristics for Eddy Current drives are:

1. 30 to 1 speed range at constant torque
2. Intermittent torque equal to 250% of rated torque
3. Speed regulation of -0.5% of maximum speed, no load to full load
4. +0.05% per °C of maximum speed
5. Ability to deliver rated torque at stall conditions
6. No need for line isolation
7. No harmonic distortion to power lines

$ ″œ° Ł¹ŁŁł ı #& ł ¹

The acquisition cost of the drive system is generally the easiest to identify. The specifying engineer must be certain, however, to include the cost of all components of the drive system.

The Eddy Current drive has an advantage in that only two power conversion items, the motor and the clutch, are required to handle the full power. In general, the motor starter can be connected directly to the plant power distribution system that is appropriate for its HP rating. Drives with full power solid state conversion units generally require a full rated isolation transformer because they frequently require isolation to minimize the effects of harmonic distortion on the power system. The controller for the Eddy Current drive is a low power unit which may be connected to any 115/230/460 single phase power source. Because Eddy Current drive systems are inherently simple and require fewer full power handling components, they frequently have significantly lower acquisition costs.

In some applications such as stamping presses, adjustable frequency drive systems are typically oversized and require NEMA-D design AC motors to insure sufficient torque is available. Additionally, dynamic braking is frequently required to absorb the regenerative power from the flywheel. All this adds significant cost and also decreases operating efficiency. Also, care must be taken to insure that the AC or DC motor can withstand the overhung load requirements of stamping press applications. The acquisition cost of an eddy current drive system can typically be 20% less than that of DC or AF drive systems.

Installation Costs

Because each drive type has different system components: foundations, wiring and cooling costs may also vary. DC and AFD controllers are generally packaged in large NEMA I convection or forced air cooled enclosures which are susceptible to contamination. DC and AF controllers and their associated transformers require additional floor space and installation labor. Often it is necessary to locate the conversion units remotely due to floor space limitations and even at times in their own specially constructed "clean room". Eddy Current controllers, on the other hand, are small and can be located adjacent to the drive to minimize inter-connect wiring. When the environment dictates, they are easily packaged in totally enclosed NEMA 12 cabinets.

Operating Costs

The cost of electric power is an important item to consider when evaluating the operating costs of various types of drives. The efficiency at each point in the operating profile must be considered for each drive type. Table 1 shows the efficiency relationship for typical 100 HP, DC, AFD and Eddy Current drive systems for a typical speed range of 70 to 100%. Even though the Adjustable Frequency drive system has the highest average efficiency, the calculated annual savings is not nearly as great as most users are lead to believe.

Annual Savings Comparison

1. HP Rating: 100
2. .746: Constant for KW per HP
3. Operating Hrs./Year 12 hrs./day x 260 days/yr. = 3120
4. Operating load: 85%
5. KW Rate/Hr.: Assume rate fee is $0.6 per KW hour
6. % Efficiency Difference: AF system average efficiency - EC system
   average efficiency = 86.65 - 78.57 = 8.1%

Calculation: 100 x.746 x 3120 x .85 x.06 x.081 = $960.00

If, as in the case of stamping press applications, the AF drive controller is oversized and a NEMA-D design motor is used, the average efficiency of the AF system is reduced to approximately 81.5% which reduces the annual savings to approximately 1/3 the savings show above.

Input power factor also plays an important role in determination of total power cost. Power companies charge for the energy consumed as well as the rate at which it is consumed (demand charge). A common formula for billed demand is shown below:

Measured demand x 0.85
Billed demand = Power Factor

Where 0.85 is the "standard" power factor, measured demand is the monthly average of the highest weekly 15 minute interval demand readings and power factor is the average power factor for the month. Table 1 shows typical speed-power factor relationships for Eddy Current drives and drives using solid state power conversion. Note that the EC system has a positive effect on the "billed demand" equation. Power factor correction capacitors can be added ahead of the EC system if additional correction is desired but it is not recommended to do so for solid state conversion type systems.

Downtime Costs

One of the primary objectives of any plant is to minimize downtime and maximize the availability of the machinery to perform its intended function. It is often difficult to assign a cost to machine downtime. However, these costs are real and must not be ignored. One must consider the following items in determining the appropriate costs per hour of downtime for a particular situation.

1. Loss of profit on un-produced product

2. Operator idle time
3. Overhead cost adjustments
4. Maintenance and repair costs - both preventative and corrective

Downtime cost can easily run from several hundred to several thousands of dollars per hour. Considering the inherent simplicity and increased reliability of the eddy current drive, thousands or even tens of thousands of dollars can be realized from reduced down time annually.

Maintenance and Repair Costs

Maintenance and repair costs are major contributors to the cost of downtime. In order to properly evaluate these costs, the following items must be considered for each drive type.

1. Cost of spare parts inventory
2. Skill level of repairmen
3. Equipment needed for repair
4. Complexity of drive components
5. Ease of trouble shooting and repair

Simplicity is obviously the key to minimize costs in these areas. The Eddy Current drive can readily be serviced by normal plant maintenance personnel using basic trouble shooting techniques and equipment. Maintenance requirements consists of simple bearing lubrication. The controller, which typically consists of a single printed circuit board, requires no maintenance. Since one controller can operate drives from 1/4 to 200 horsepower, spare parts inventory costs are kept to an absolute minimum.

Another area to consider is the cost of replacement parts 5 or 10 years after the system is installed. With the rapid changes in solid state electronics, AF, DC and to some extent EC controllers are obsolete approximately 4-5 years after introduction. Unfortunately, this occurs at a time when these controllers are increasingly more susceptible to printed circuit board failures.

Since many users expect a drive system to last 10 to 15 years, repair boards for vintage AF and DC systems can easily cost three times what they cost just a few years earlier and may be unavailable for quick delivery at any cost. This frequently leads to the user replacing the entire controller much sooner than anticipated an adding thousands of unexpected dollars to the life-cycle costs.

Since the eddy current controller consists of a single printed circuit board, if replacement parts become unavailable, an entire control can be replaced for approximately five hundred dollars for drive systems up to 200 horsepower.

Summary

When selecting an adjustable speed drive, it is necessary to select a drive which will perform the intended function at the lowest life cycle cost. This minimization of total cost coupled with careful attention to maintaining high operating speeds will certainly result in the opportunity to generate increased profitability for the user. The Eddy Current drive with its inherent simplicity, ruggedness and performance features is a strong candidate for the lowest life cycle cost.

Table 1

System Efficiency and Power Factors for an Operating Speed Range of 70 to 100%
Eddy Current Drive System Consisting of a 100 HP High Efficiency AC Motor Integrally Mounted to an Eddy Current Clutch and a Model 4050 Controller

Percent Speed	Percent Motor Efficiency	Percent Clutch Efficiency (1)	Percent System Efficiency	Power Factor
70	95.0	67.5	64.1	.90
80	95.0	77.7	73.8	.90
90	95.0	87.8	83.4	.90
100	95.0	97.9	93.0	.90

Average Efficiency = 78.57% (1) Includes Controller Losses

DC Drive System Consisting of a 100 HP DC Motor Controller and an Isolation Transformer

Percent Speed	Percent Motor Efficiency	Percent Controller Efficiency	Percent Transformer Efficiency	Percent System Efficiency	Power Factor
70	87.0	93.0	96.5	78.1	.65
80	87.5	93.0	96.5	78.5	.73
90	87.5	93.5	96.5	78.9	.81
100	87.0	94.5	96.5	79.8	.88

Average Efficiency = 78.33%

Adjustable Frequency Drive System Consisting of a 100 HP High Efficiency Motor, an AFD Controller and an Isolation Transformer

Percent Speed	Percent Motor Efficiency	Percent Controller Efficiency	Percent Transformer Efficiency	Percent System Efficiency	Power Factor
70	89.0	95.0	96.5	81.5	.95
80	90.0	95.5	96.5	82.9	.95
90	92.0	95.0	96.5	84.3	.95
100	93.9	95.0	96.5	86.0	.95

Average Efficiency = 83.67%

(1) Motor efficiency is adjusted to reflect the additional losses in an AC motor operating on adjustable frequency PWM sine wave.