6.2.5 ADJUSTABLE-SPEED BELT DRIVES

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Mechanical adjustable-speed drives for pump applications are generally of the compound adjustable-pitch-sheave and rubber-belt variety, as illustrated in Figures 1 and 2. The integrated drive package converts constant input speed to an output that is steplessly variable within a certain range. The drive packages are usually driven by constant-speed ac induction motors and usually contains built-in gear reducers to obtain low output speeds.

Drive packages may be mounted horizontally, vertically, or on a 450 angle and are available in standard open or totally enclosed designs. Some of the possible mounting arrangements are illustrated by Figure 3. Speed ranges of 10:1 to 2:1 can be obtained with most units. A typical distribution of available output speeds is 4550 to 1.4 rpm, including drives with and without reducer gearing. Increaser gearing (offered as an integrally mounted package) provides speeds to 16,000 rpm.

Alternating-current induction-drive motors used with mechanical adjustable-speed drives usually operate at a speed of 1750 or 1160 rpm. The electric design characteristics of these motors comply with the standards if the National Electrical Manufacturers Association (NEMA). The NENIA design B motor with normal torque and normal slip characteristics is standard. NENIA design C (high torque low starting current) and NEMA design D (high torque, high slip) motors may be used when their specific characteristics are dictated by the application.

The mechanical mounting characteristics of the drive motors for mechanical adjustable-speed drives vary from one manufacturer to another. Motors of round body, footless, NEMA C-face construction are commonly used. Sometimes standard foot-mounted motors are supplied as an option in conjunction with a scoop support by some manufacturers or as standard practice by others until others may supply mechanically special partial motor frames with their drives.

For a given power rating, many manufacturers will supply drive motors with increased service-factor power. This increased power of the drive motor compensates for and overcomes the inherent mechanical losses of the drive. This in turn causes full-rated power to

FIGURE 1 Pump application utilizing typical mechanical adjustable-speed belt drives (Reliance Electric)

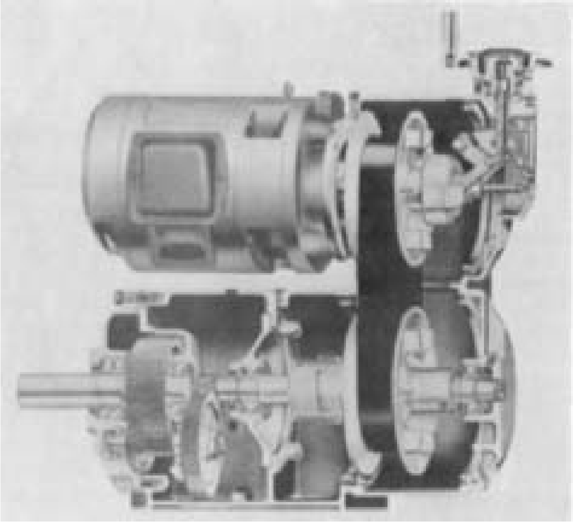

FIGURE 2 Cutaway view of typical mechanical adjustable-speed drive (Reliance Electric)

be developed at the output shaft of the mechanical adjustable-speed drive. Drive output power ratings are more fully discussed under “Rating Basis.”

The input speed of the mechanical adjustable-speed drive is typically 1750 or 1160 rpm, as defined by the speed of the drive motor. The output speed of the internal adjustable-speed belt section goes above and below the drive motor speed. A maximum speed of 4200 rpm or greater is not uncommon for fractional and small-integral power drives. The need for stages of output gearing to obtain final output speeds that are usable for pump or other applications is therefore readily apparent.

FIGURE 3 Mechanical adjustable-speed drive mounting and special enclosures

Parallel-shaft or right-angle-shaft reducer gearing, at the option of the design engineer or user, may be incorporated as an integral part of the mechanical adjustable-speed drive package. Generally speaking, gear reduction is required when drive maximum output speed must be lower than 1750 rpm or drive minimum output speed lower than 583 rpm.

The American Gear Manufacturers Association (AGMA) does not define standards for reducers used in adjustable-speed applications. However, most all drive manufacturers produce reducers for these drives in accordance with accepted AGMA standards for constant-speed reducers.

Where infinite, or stepless, adjustment over a specific finite speed range is necessary, stepless mechanical adjustable-speed drives are generally most economical for standard pump application requirements. Initial costs are usually lower than for comparable electric or hydraulic systems, and the mechanical systems are easier to operate and maintain.

Reliability and accuracy of speed control are advantages of the mechanical adjustable-speed belt delve package. Construction details, size, and mounting dimensions are not standardized and vary with the manufacturer but all employ dual adjustable-pitch sheaves mounted on parallel shafts at a fixed center distance and a special wide-section rubber V belt to provide a compact assembly. Most of the designs utilize spring-loaded sheaves for control of belt tension.

A high degree of control and flexibility in application is offered by mechanical adjustable-speed belt drive power packages. Capacities range from fractional to 100 hp (75 kW), with maximum speed ratios of 10:1 in the fractional power sizes, decreasing to 6:1 at 30 hp (22 kW) and 3: 1 in the largest sizes. Multiple-belt drive arrangements are usually required for capacities over 50 hp (37 kW). Again, depending on capacity, speeds ranging from a maximum of 16,000 to a minimum of 1.4 rpm are possible, although most of the standard units are within the 2 to 5000 rpm range.

OPERATING PRINCIPLE

In Figure 4, the upper disk assembly is the input assembly driven directly by the shaft of the ac induction motor at a constant speed. This constant-speed disk assembly has one stationary disk member on the *left* and one movable, or sliding, disk member on the *right*. The sliding member is mechanically attached to a positive shifting linkage arrangement consisting of a thrust hearing, bearing housing, and shifting yoke. This linkage is actuated by a control hand-wheel or some other speed-changing device.

In the same view, the lower disk assembly is the output assembly, whose speed is adjustable. In this adjustable-speed disk assembly, the sliding member is next to the spring cartridge on the *left* and the stationary member is on the *right*. Note that this arrangement is just the opposite of that for the upper, or constant-speed, disk assembly. This adjustable-speed output shaft of the drive. A flexible, wide-section, rubber V belt connects the two disk assemblies.

Assuming the minimum speed belt position as a starting point, the positive shifting linkage or the sliding member of the constant-speed disk assembly is moved to the left toward the fixed member. This positive change forces the wide-section V belt to a larger diameter in the constant-speed disk assembly. Simultaneously, the belt forces the sliding member on the adjustable-speed disk assembly against its spring so the belt assumes a smaller running, or pitch, diameter in this disk assembly. The speed of the output shaft increases in stepless increments, whereas the drive motor speed remains constant. Reversing the previous procedures reduces the output shaft speed.

When the V belt is at this maximum diameter in the constant-speed disk assembly, it is at a minimum diameter in the adjustable-speed disk assembly and the output shaft speed is at maximum. Conversely, when the V belt is at its minimum diameter in the constant-speed disk assembly, it is at a maximum diameter in the adjustable speed disk assembly and the output shaft speed is at minimum.

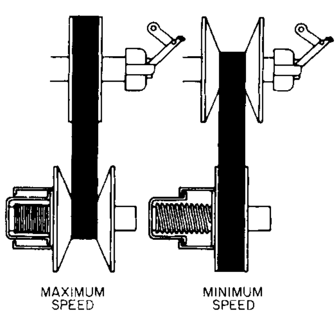

FIGURE 4 Functional diagram for a mechanical adjustable-speed drive belt section (Reliance Electric)

Because one member of each disk assembly is fixed on its shaft, the V belt must move axially as well as along the inclined surface of the disk to assume different diameters and cause the speed to change. Centrifugal force makes this composite movement of the belt effortless when the drive is in operation, but the speed setting of the drive must never be changed while the drive is not operating and motionless. If speed-setting change is attempted while the drive is motionless, destructive, crushing forces are imposed on the belt. These same forces may also damage the positive shifting linkage of the otherwise rugged mechanical adjustable-speed drive.

OTHER BELT DRIVES

Other drives of the mechanical adjustable-speed type, such as the single adjustable-motor-sheave or pulley and the wood block or metal-chain-belt type transmission, are only mentioned briefly here because of their rather limited application as pump drives.

The motor sheave, or pulley, illustrated in Figure 5, is a simple, single, adjustable-pitch device mounted on a motor shaft. It drives by way of a standard or wide-section V belt to a companion fixed-diameter, flat-face pulley, or V sheave. Driving and driven shafts are parallel but must be arranged so their center distance is adjustable; this is generally accomplished by means of a sliding motor base. The entire base assembly is usually operated as an open belt drive.

The wood-block or metal-chain belt transmission uses the original mechanical adjustable-speed belt drive operating principle. This drive utilizes a special wide-section wood-block belt or laminated-metal-chain belt driven by two pairs of positively controlled variable-pitch sheaves. Movement of the sheave flanges is synchronized by a positive linkage arrangement.

The transmission-type drive is generally thought of as a low-speed, high-torque device that can withstand severe overload and abuse for long periods of time.

RATING BASIS

The mechanical adjustable-speed drive package is usually rated as a constant-torque, variable-power device. The power rating is based upon the capacity of the whole unit at maximum speed setting. When operating at any output speed below this maximum, the power capacity is reduced in direct proportion.

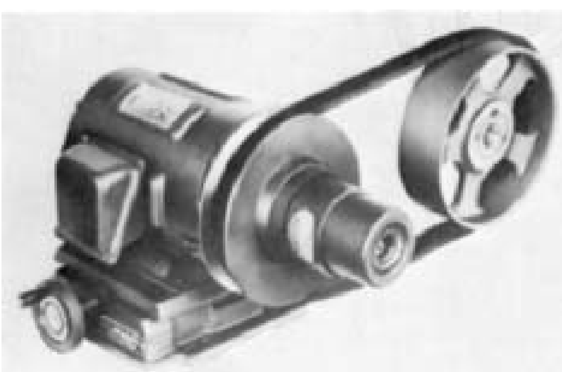

FIGURE 5 Typical motor pulley belt drive with adjustable center distance between driving and driven shafts (Reliance Electric)

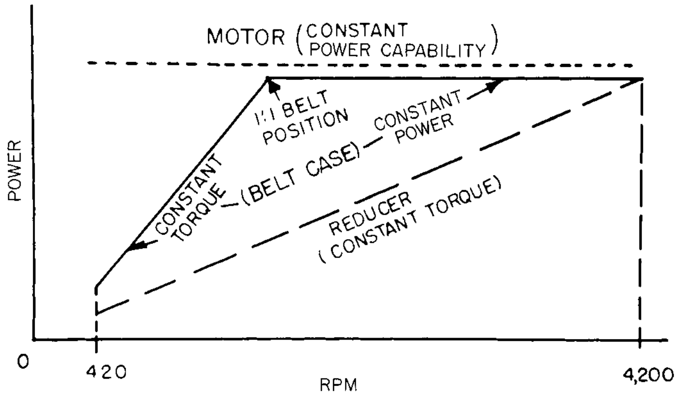

FIGURE 6 Power versus output speed relationship for the motor, belt section, and reducer section of a mechanical adjustable-speed belt drive

A drive unit is made up of three major components, each of which has its own individual torque or power output characteristics. For example, the ac induction-drive motor or prime mover develops constant power at a constant rotational speed.

The adjustable-speed belt section has an output torque characteristic that is a mixture of both constant torque and variable torque over its speed range. This section has a constant-power, variable-torque characteristic when operating above a 1:1 belt position and a constant-torque variable-power characteristic when operating below a 1:1 belt position. Finally, a parallel-shaft or right-angle gear reducer section has a constant-torque, variable-power characteristic. Figure 6 graphically illustrates these relationships.

Because the gear reducer section has a constant-torque characteristic, this section defines the output characteristic for the entire mechanical adjustable-speed drive.

It should be noted that virtually all manufacturers rate parallel-shaft drives using output shaft power as a base, whereas right-angle output shaft drives are rated on the basis of input power to the reducer minus reducer efficiency.

Because of the relatively low efficiency of the right-angle worm gear reducers and right-angle combination worm and helical gear reducers, the power transmission industry follows the practice of rating these units in terms of power at the input shaft. From the earlier discussion on operating principle, you will note that the adjustable-speed output shaft of the belt section of the drive becomes the input shaft of the reducer section of the same drive.

One or more sections of a drive, usually the belt and reducer sections, may be service-factored by frame or case oversizing to permit the rating of these sections for constant power over all or a portion of their speed range. Because the drive motor is a constant-power device, as already mentioned, oversizing of its frame is unnecessary.

SERVICE FACTORING

Service factoring of a mechanical adjustable-speed belt drive is common practice when the normal operating requirements for steady constant-torque loads running 8 hours/day, 5 days/week are to be exceeded.

Drives to be used other-than-normal service as previously described must be selected by use of modifying factors that will provide correct service capacity. Some unusual service requirements are moderate to heavy shock loads, 24 hours/day continuous operation, and constant-power demands over a wide speed range.

Other unusual service conditions may be suggested by the following information check list. This list itemizes required information data that should be furnished to the variable-speed drive manufacturer for those applications calling for unusual service.

1. Speed and torque required for the application
2. Value and frequency of peak-load conditions
3. Hours of operation per day or week
4. Frequency of starts and stops
5. Inertia (WK^2) of the load
6. Frequency of reversals of rotation direction
7. Electric and mechanical overload protection provisions
8. Method used to connect drive output shaft to driven load
9. Any unusual environment or other operating condition

METHODS OF CONTROL

A variety of control systems have been developed for use with mechanical adjustable-speed drives. For the majority of pump applications, speed is controlled manually through a lever, handwheel, or knob attachment. Remote semiautomatic and automatic control methods in mechanical, pneumatic, or electric forms are also being used.

For manual operation, vernier attachments are often useful to increase the accuracy of speed adjustment. Cams are occasionally employed, mounted externally or internally, to assure a prescribed pattern of output characteristics.

Remote control is usually obtained by means of a positioning motor, which is a fractional-power motor connected to the drive control shifting screw through reduction gearing. The output speed of the drive is then adjusted from a station at a remote location.

For semiautomatic or automatic operation, control systems usually consist of three elements: a sensing unit, a receiver, and a positioning actuator. The sensing unit detects changes in the process being controlled and transmits a signal to the receiver. At the receiver, the signal is analyzed, amplified, and transmitted to the positioning actuator, which adjusts the speed of the mechanical adjustable-speed drive accordingly.

If the process or load requirements can be adapted to produce a signal, there should be a suitable control system that can be used for speed adjustment. The only limitation is that the load requirements must follow a specific pattern of some type, regardless of whether the pattern is based on direct, inverse, or proportional relationships.

The pneumatic actuators used for speed adjustment are usually responsive to a 3 to 15-lb/in^2 (20- to 100-kPa) air signal pressure. These pneumatic positioning devices are actually analog piloted servovalve positioning devices that can be used in a great variety of open- and closed-loop process control applications. They can be used to cause a mechanical adjustable-speed drive to either flow or maintain a given process signal from variables such as liquid level, pressure, flow rate, or any other measurable value. The adjustable-speed drive thus becomes the final control element in a closed-loop process control system. Figure 7 is a typical drive equipped with a pneumatic actuator for speed changing.

APPLICATION GUIDELINES

The following is a listing of the more common items to consider when specifying a mechanical adjustable-speed belt drive for a specific application:

1. Manufacturer's size designation of the drive
2. Range of speed variation and actual output speeds

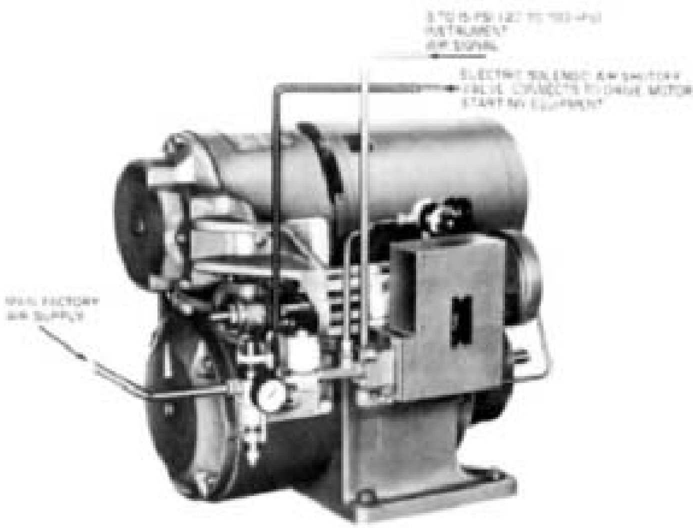

FIGURE 7 Mechanical adjustable-speed drive with pneumatic actuator for automatic speed changing (Reliance Electric)

3. Motor specifications: power rating, electric current (single or polyphase, frequency, and voltage), type of enclosure, and other special electric or mechanical modifications
4. Special drive output shaft extension
5. Type of control: handwheel, electric remote, mechanical automatic, pneumatic, and so on
6. Manufacturer's assembly configuration designation and type of mounting, whether standard floor type, trunnion, ceiling, sidewall, or flange
7. Accessory equipment, such as tachometer, magnetic brake
8. Power rating based on constant torque and maximum output speed
9. Type of case enclosure