Selection factors for clutches & brakes

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10/01/1999

Clutches and brakes are effective devices for the control and transmission of torque and speed in many rotating drive systems. Their function is to transfer torque from an input shaft to an output shaft by clutching, or to stop and hold a load by braking. Though offered as separate components, their functions are often combined into a single unit (Fig. 1).

When starting or stopping, they pass energy between an output shaft and input shaft through the point of contact. This energy becomes heat and is equal to the energy imparted to, or absorbed from, the load. The point of contact, or engagement, is friction, electromagnetic, or mechanical lockup; and has a variety of configurations, including disk, caliper, and drum.

Along with several interfaces and designs, clutches and brakes have various actuation forces that control the action of the interface: mechanical, electric, pneumatic, hydraulic, and self-actuation. Clutches and brakes are categorized by the methods of engagement and actuation. So many variables pro- vide for a large selection of products. This variety may cause some confusion, but also provides choices to fit almost any application.

Characteristics such as torque, response time, envelope size, configuration, control medium, repeatability, cyclic requirements, and thermal capacity are all affected by clutch or brake geometry, interface, and actuation force.

Peak input usually depends on the area of the facing material. One-stop capacity depends on the weight of heat-absorbing material built into the unit. Continuous thermal capacity is based on the safe operating temperature of the unit. One more variable is the method of mounting. Shaft, flange, and foot mount are the most popular choices (Fig. 2).

Engagement

The three methods of clutch and brake engagement provide varying degrees of slip from zero to feather light.

Friction

This factor is the most popular method for general purpose clutching or braking. One surface is usually metallic and shaped into single or multiple disks, band, or drum. The other surface has a friction facing in the shape of a plate, shoe, or caliper pad.

Friction facings are made from several types of material, depending on application requirements. Metal chips, often brass or aluminum, are included in the facing material to extend life and improve heat dissipation.

Simple disk-type clutches and brakes have a single friction plate and disk. A clutch-brake combines clutching and braking into one unit with a friction plate and disk for each function. Various mounting arrangements and means of actuation are possible.

In more complex designs, multiple disks and friction plates are used to increase the friction surface. Disks can be immersed in oil to increase cooling efficiency. Some disk brakes use calipers in place of a friction plate. Additional calipers can be added to increase braking torque. In this design, brake pads are easily serviced.

Drum clutches and brakes have cylindrical friction surfaces with a common mounting axis or shaft (Fig. 3). They are either contracting or expanding types; the drum is contacted on its outside or inside diameter. Drum clutches and brakes wear evenly and transmit high torque. Contracting types respond quickly because centrifugal force helps withdraw the shoes rapidly, making them suited for high cycling operations.

Band or strap brakes are simple and reliable. They consist of a rotating drum and flexible steel band lined with friction material. A mechanical linkage tightens the band around the drum. If the pull on the band, during actuation, is in the direction of rotation, the brake is self-energized. Band brakes wear unevenly and dissipate heat slowly.

Electromagnetic

Nonfriction electric clutches and brakes use electromagnetic attraction to transfer torque. They are used primarily in applications where positive contact is not required. Applications include variable slip drives and soft starts and stops. They aren't as rapid or accurate as friction clutches and brakes.

Magnetic particle clutches have the space between the input and output members filled with dry iron particles (Fig. 4). When a coil is energized, magnetic flux lines span this space, lining up the particles to form a rigid bond between the members and locking them together. The amount of particle bonding determines the amount of torque transmitted and is directly proportional to current, which can be varied.

Eddy current clutches and brakes are used in variable speed drives and have slip or nonpositive engagement. The only link between the input and output rotors is magnetic flux. Eddy currents, developed when the input drum rotates, create a magnetic field that interacts with the field in the pole assembly, creating a coupling torque. Torque is proportional to coil current. Clutches and brakes cannot perform at zero slip. Brakes have no torque and cannot hold a load. They tend to run hotter than other nonfriction designs, sometimes requiring special cooling.

Hysteresis clutches and brakes are constant-torque devices that can provide any amount of slip, as long as the heat-dissipation capacity of the unit is not exceeded. A coil in the input rotor generates a magnetic field in both the rotor and drag cup. Hysteresis losses in the drag cup set up a torque reaction from the turning rotor. Torque is proportional to coil current and independent of low to medium speeds. Precise control is a feature of hysteresis brakes. They exhibit very little wear and a long service life.

Mechanical

Direct mechanical connection between input and output shafts is one of the most basic clutching methods. Members engage by direct metal-to-metal contact, without the use of friction surfaces. Control and simple design dictate their use where no-slip registry is required.

Jaw-type clutches come in two designs: square- and spiral-jaw (Fig. 5). The *square-jaw* clutch has square teeth that lock into mating recesses in facing members. It provides positive lockup.

Spiral-jaw clutches use sloping engagement surfaces to overcome the limited engagement speeds of square-jaw types. They can operate in one direction only and have a tendency to freewheel.

Multiple-tooth clutches combine the advantages of mechanical lockup with remote actuation. Their small size gives them an advantage over friction types in certain applications. For a given size, they have higher torque capacities. Teeth run the full circumference of each mating face and there are as many engagement positions as there are teeth (Fig. 6). However, engagement positions can be limited by modifying the number and spacing of teeth.

Wrap-spring clutches link input and output shafts in one direction with a coiled spring whose inside diameter is smaller than either shaft diameter. Rotation in one direction tightens the spring around the shafts and transmits torque. Rotation in the opposite direction expands the spring and disengages the shafts.

Sprag clutches are one-directional and use cylindrical inner and outer races, with sprags filling the spaces between them. Sprags are sized, shaped, and mounted to ensure they wedge and link the two races when rotation occurs in one direction. If rotation is reversed, the sprags disengage, and one race remains stationary. A variation of the sprag design uses rollers and a series of ramped surfaces to accomplish the same action.

Oil-shear clutches transmit torque through the shearing of an oil film between disks. There is no friction material-to-metal contact until the disk speeds are equal. Then the oil film breaks down, allowing full static engagement. Wear is greatly reduced by the oil film, which lubricates while transmitting torque. The heat of slippage is removed by the oil, which also absorbs the shock of engagement.

Actuation

The method chosen for clutch and brake actuation depends on the application and control system being used.

Mechanical

Mechanical actuation is the simplest and least costly way to engage a clutch or brake. Cams, cables, levers, or rods accomplish actuation. A major advantage of this type of actuation is the feedback the operator gets to gauge the amount of force to apply or the degree of slip occurring.

A disadvantage is the need for an operator. Actuation force is limited to about 75 lb and keeps response time and cycle rates low. Manual actuation is usually restricted to small industrial equipment such as light cranes and hoists.

Electric

Electric clutches and brakes are convenient for automatic machinery where control commands are electric signals. Electric actuation is an alternative when the clutch or brake is remote from the control point and mechanical linkages, hydraulics, or pneumatic power would be awkward to use.

Electric clutches use two different operating principles. One type uses friction or teeth that are engaged electrically and released by springs. The other type creates an electromagnetic field, which then causes hysteresis, eddy current, or magnetic particles to engage input and output shafts instead of a friction or mechanical connection. Nonfriction clutches can operate with continuous, controlled slip or can be locked up if required torque is less than clutch capacity.

Of the two types, electromagnetic clutches respond quicker and transmit higher torque. They do not wear and dissipate heat better. In general, most electric clutches run dry and do not have high thermal capacities.

Electric brakes operate in a fast, positive manner. They are essentially mechanical brakes actuated electrically. The most widely used electric brake uses disks, but is not like a mechanical caliper brake. It is similar in operation to a disk or plate clutch. Energy is absorbed by having a rotating plate engage the flat face of a mating plate or disk. Multiple-disk designs have greater capacity, if there is adequate cooling. Other brake designs are similar to mechanical drum types with electrical actuation.

Fluid power

Air or hydraulic pressure is frequently used to actuate clutches and brakes. These mediums offer quick response, a small mechanical package, and no heat generation or energy consumption during long periods of engagement (Fig. 7). In addition, air can be used as a cooling medium across friction faces, or units can be immersed in oil for better heat transfer.

Air actuation is widely used because plants generally have compressed air systems that can supply shop air at 80 psi, which is adequate for clutches and brakes. Cycle rates as high as 80 cpm are possible, though most applications call for 20 cpm or less. A degree of feel during actuation is achieved by using a hand-operated throttle valve.

Hydraulically operated units deliver more torque/unit volume because high oil pressure has more power density than pneumatic or electrically powered units. Hydraulic units offer low response times and smooth engagement when using pressure control valves.

A disadvantage to fluid powered clutches and brakes is the maintenance of support equipment, not the devices themselves. Pneumatics require pressure regulators, filters, lubricators, control valves, and exhaust mufflers. In addition, because air is exhausted to the atmosphere, a compressor is required to constantly replenish the air supply. Hydraulics requires similar valving, pump, and complicated piping and return lines.

Self-actuation

This approach usually applies to clutches. This form of actuation is automatic and does not require any external control. Actuation or release occurs from reaching a set speed, having a speed differential between input and output shafts, or changing the direction of rotation.

Plant Engineering magazine extends its appreciation to Nexen Group, Inc. (formerly Horton Industrial Products) for their assistance in the preparation of this article. The cover picture was taken with the cooperation of Warner Electric, Force Mfg., and Brown Paper Goods Co., Inc. -- Joseph L. Foszcz, Senior Editor, 630-320-7135, j.foszcz@cahners.com

Key concepts

Clutches and brakes come in many designs and fit most applications.

Friction engagement is widely used in clutches and brakes.

Electromagnetic engagement does not cause wear.

Fluid power actuation does not generate heat.

Application notes

- Pneumatic and hydraulic powered clutches and brakes have higher torque ratings than electric powered units.

- Electromagnetic tooth clutches have higher torque ratings than electromagnetic disk clutches and don't slip.

- Self-actuating clutches work best where motor speed is an adequate control, soft starts are acceptable, and energy savings are important.

- Magnetic particle clutches and brakes are useful in tensioning and positioning where there are continuous changes in speed.

- Eddy current clutches are useful for providing drag loads needed in tensioning.

- Multicaliper clutches with ventilated disks are designed for continuous slip duty.

- Square jaw clutches are limited to running engagements under 10 rpm.

- Spiral jaw clutches allow for engagement speeds up to 150 rpm.

- Multitooth clutches can have running engagement speeds up to 400 rpm.

- Oil-shear clutches and brakes can handle 100 cpm at constant duty.

- Disk clutches and brakes are preferred over drum-style units for frequent start-stop applications

- Band brakes are suited for occasional, high-energy, emergency stops.

- Eddy current clutches are used primarily in adjustable speed drives.

Selection criteria

- Maximum operating speed

- Maximum torque

- Type of actuation

- Type of engagement

- Response time

- Cycle rate

- Thermal capacity

- Space or weight restrictions

- Environmental conditions

- Acceptable service life

- Amount of routine maintenance

- Amount of auxiliary equipment maintenance