

- **Amps/field amps:** designations for armature and field winding amps, respectively. These ratings are needed when programming the protection features in a drive controller.
- **Base/max. speed:** indicates the rated speed in rpm, when operating at rated armature and field amps, as well as rated load. The *max speed* indication is the maximum safe operating rpm possible, while remaining within the limitations of the motor.

Additional ratings include enclosure type, thermostat type, ambient temperature rating, catalog and serial number, and tachometer type and rating. These ratings have been previously discussed. Refer to Chapter 5 “Drive Control and Feedback Devices,” for more information on tachometers.

Most DC motors also carry one of three duty ratings:

- **Continuous duty:** rating given to motors that will continuously dissipate all the heat generated by internal losses without exceeding the rated temperature rise.
- **Intermittent duty (definite time):** rating given to a motor that carries a rated load for a specified time without exceeding the rated temperature rise.
- **Intermittent duty (indefinite time):** rating given to a motor that is usually associated with some RMS load of a duty-cycle operation.
- **Peak torque:** the peak torque that a DC motors can deliver is limited by the load point at which damaging commutation begins. Brush and commutator damage depends on the sparking severity and duration. Peak torque is limited by the maximum current that the power supply can deliver.
- **Calculating torque:** An easy means of calculating the available torque from a DC motor is to use the following formula:

$$\text{Torque} = \frac{\text{HP} \times 5252}{\text{Speed}}$$

where:

Torque = torque available from the motor in lb-ft

HP = nameplate horsepower at base speed

Speed = rpm

As an example, assume a 10-HP DC motor has a 240-V armature, 39.2 amp with a speed of 1775/2750. We will insert the needed numbers into the formula and determine the base speed (1775) torque:

$$\text{Torque} = \frac{10 \times 5252}{1775} = \frac{52520}{1775} = 29.5 \text{ lb-ft}$$

The above formula will work for determining torque at any speed up to base speed. (Again, remember that base speed in rated: armature voltage, field current, and load.)

To determine the torque per amp ratio, simply divide 29.5 by 39.2, which equals 0.75 lb-ft of torque per amp. Determining the torque per amp ratio above base speed is also possible by calculating the torque, using the above formula for the speed over base, then using the ratio of the calculated torque and the amp meter reading at that speed. As expected, the amount of torque developed is less, above base speed, compared with below base speed.

## DC Motor Types

### *Introduction*

Basically, four different types of DC motors are used in industrial applications: series wound, shunt wound, compound wound, and permanent magnet. Several factors must be considered when selecting a DC motor for a specific application.

First, decide what the allowable variation in speed and torque can be for a given change in load. Each type of motor has benefits that are advantageous for certain applications. The following review will help you decide which motor may provide better performance in a given application. The DC motor and drive specifications should always be consulted to determine the specific speed and torque capabilities of the system. The speed/torque curves listed below are for illustrative purposes.

### *Series Wound DC Motors*

A series wound DC motor has the armature and field windings connected in a series circuit. Figure 3-17 shows a series wound DC motor, with an associated speed/torque curve.

As seen in Figure 3-17, this type of motor configuration features very high breakaway torque. Typical applications for this motor would be printing presses, ski lifts, electric locomotives, cranes, and oil drilling.

The starting torque developed can be as high as 500% of the full load rating. The high starting torque is a result of the fact that the field winding is operated below the saturation point.

An increase in load will cause a corresponding increase in both the armature and field winding current, which means that both armature and field winding flux increase together. As you recall, the torque developed in a DC motor is the result of the interaction of armature and field winding fluxes. Torque in a DC motor increases as the square of the current value.

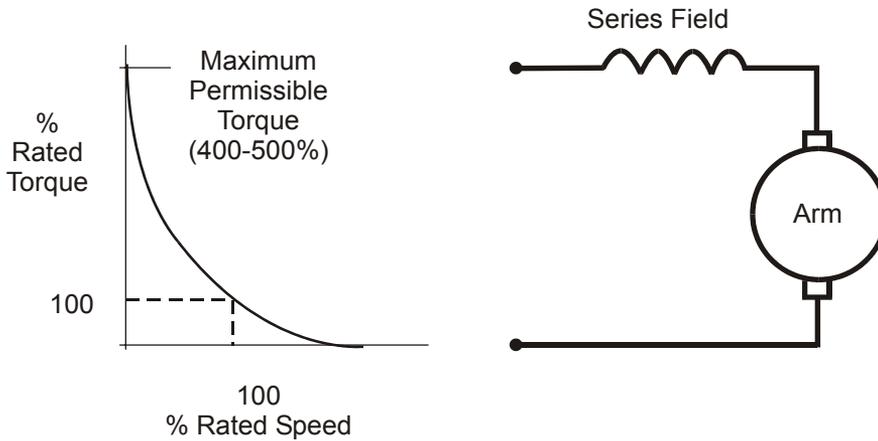


Figure 3-17. Series wound DC motor circuit and curve

A series wound DC motor will generate a larger torque increase compared with a shunt wound DC motor for given increase in current.

Conversely, the speed regulation of a series wound DC motor is poorer than that of a shunt wound motor. As stated above, when the load increases, so does the armature and field winding current. When the load is reduced, so is the current, which causes a corresponding decrease in flux density. As a reminder of DC motor basics, when the field flux is reduced once the motor is running, a decrease in “hold-back” electromotive force (EMF) occurs. Therefore, when the load is reduced, speed increases. If the load were completely removed, the speed of the motor would increase to infinity—basically until the motor destroys itself. As a safety precaution, series wound DC motors should always be connected to a load.

**Parallel (Shunt) Wound DC Motors**

A shunt wound DC motor has the armature and field windings connected in parallel. Figure 3-18 shows a shunt wound DC motor, with an associated speed/torque curve.

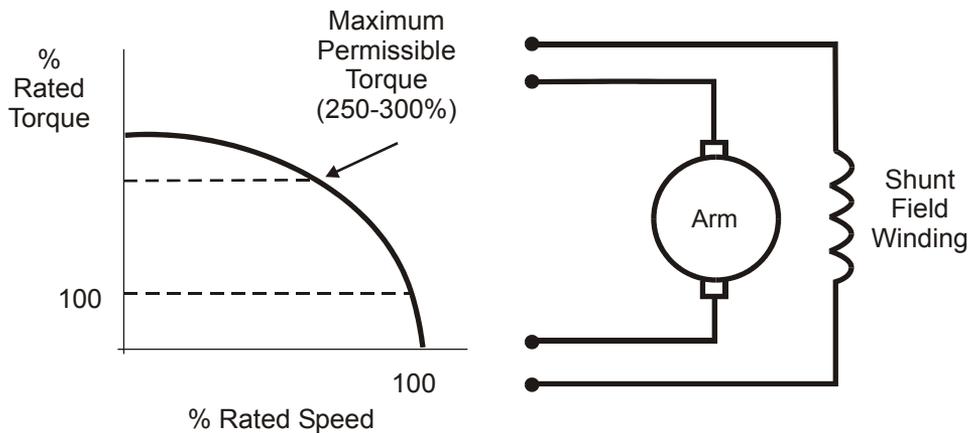


Figure 3-18. Shunt wound DC motor and curve

This type of DC motor is probably the most widely used motor in industrial applications. As indicated in the figure, this type of motor requires two power supplies—one for the armature and one for the field winding.

Typical applications for this motor would be printing presses, ski lifts, plastic extruders, conveyors, and practically any other application where DC motors are used. Because of the need for two power supplies, this type of motor is a prime candidate for a DC drive (converter), which usually includes a low-current field winding exciter (power supply).

With constant armature voltage and field winding excitation, this type of motor offers relatively flat speed/torque characteristics. The starting torque developed can be 250–300% of the full load torque rating for a short period of time. Speed regulation (speed fluctuation due to load) is acceptable in many cases between 5–10% of maximum speed, when operated from a DC drive. Regulation of this amount would be typical when operated from a drive controller, open loop (no electronic feedback device connected to the motor shaft). As discussed in Chapter 5, speed feedback devices such as a tachometer generator can dramatically improve the regulation (down to less than 1%).

Because of the need for two power sources, the shunt wound DC motor offers the use of simplified control for reversing requirements. Direction of any shunt wound motor can be changed by simply reversing the direction of current flow, in either the armature or shunt field winding. The capability of armature or field reversal is standard on many DC drive modules. (In many cases, the reversing of flux and direction is accomplished in the field winding control. The field winding consumes less than one tenth of the current compared with the armature circuit. Smaller components and less stress on circuitry is the result when “field reversal” is used for DC motor control.)

### ***Compound Wound DC Motors***

A compound wound DC motor is basically a combination of shunt wound and series wound configurations. This type of motor offers the high starting torque of a series wound motor. In addition, it offers constant speed regulation (speed stability) under a given load. This type of motor is used whenever speed regulation cannot be obtained from either a series or shunt wound motor. Figure 3-19 indicates a compound wound DC motor, with an associated speed/torque curve.

The torque and speed characteristics are the result of placing a portion of the field winding circuit in series with the armature circuit. This additional armature winding circuit is not to be confused with the commutating winding or interpoles. The commutation windings also have a few turns, but have the duty of neutralizing armature reaction.

When a load is applied, there is a corresponding increase in current through the series winding, which also increases the field flux. This in turn increases the torque output of the motor.

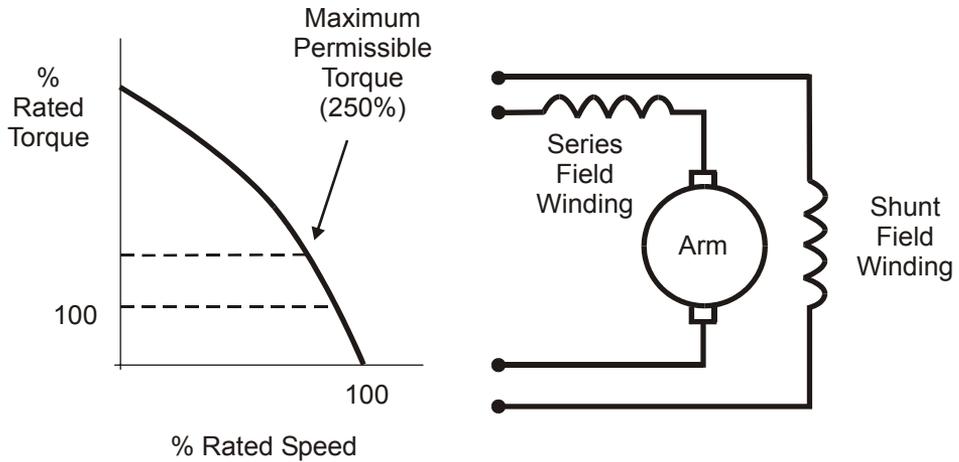


Figure 3-19. Compound wound DC motor and curve

**Permanent Magnet DC Motors**

A permanent magnet motor is built with a standard armature and brushes, but has permanent magnets in place of the shunt field winding. The speed characteristic is close to that of a shunt wound DC motor. When adding the cost of a DC motor and control system, this type of motor is less expensive to operate, since there is no need for a shunt field winding exciter supply. Figure 3-20 indicates a permanent magnet DC motor, with an associated speed/torque curve.

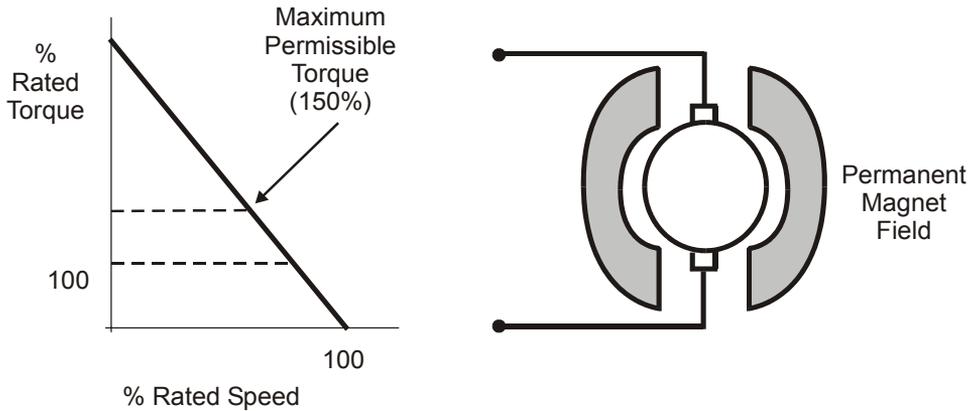


Figure 3-20. Permanent magnet DC motor and curve

Along with less expensive operation, this type of motor is simpler to install, with only the two armature connections needed. This motor type is also simpler to reverse—simply reverse the connections to the armature.

The permanent magnet poles are usually constructed of materials such as ceramic or alnico (aluminum, nickel, and cobalt). The ceramic magnets are used for low-horsepower, slow-speed applications because of their low

flux level generation. Though this type of motor has good operational characteristics and lower cost, there are several drawbacks to this type of motor compared with the others.

Materials such as ceramic have a high resistance to demagnetization. However, permanent magnets do have a tendency to lose some of their magnetic strength over use and time. This reduction in magnetic field strength causes a corresponding reduction in torque output. To counteract this possibility, some higher-cost permanent magnet motors include windings built into the field magnets for the purpose of “re-magnetizing” the magnets.

In addition to ceramic or alnico magnets, rare earth magnets are also a cost-effective means of generating magnetic field flux. This type of magnetic group includes the “embedded” magnet, which is only one of nine different magnetic materials available.

Though this type of motor has very good starting torque capability, the speed regulation is slightly less than that of a compound wound motor. The overall torque output makes this motor a prime candidate for low-torque applications. Peak torque is limited to about 150%. This limitation is based on the fact that additional “demagnetizing” of the field poles could occur if more torque was developed.

#### ***Specialty DC Motors—PM DC Servomotors***

Servomotors are considered “specialty” in that they are used in applications that require very fast speed response and accuracy. In many cases, the shaft speed is accelerated from zero to 6000 rpm in hundredths of a second. The same speed profile could be needed in the deceleration mode, as well as an immediate reversal of direction.

These types of motors must be designed to handle the stress of acceleration, plus not fluctuate in speed, once the desired speed is obtained. Special consideration is given to heat dissipation, since these motors must be small, yet generate enough torque to operate the machine. The small size allows this type motor to fit inside small packaging, palletizing, and processing machines. Typically, these motors are long and narrow, in contrast to a standard shunt wound DC motor. The long, narrow design results in low inertia armature assemblies, which can be accelerated quickly. Servomotor design with permanent magnets affords the smallest space possible. In comparison, shunt field windings must have laminations wide enough to generate the necessary field flux, which adds to the total width of the machine. Figure 3-21 indicates the physical appearance of a typical DC servomotor.

As seen in Figure 3-21, this type of motor is usually of a totally enclosed design to seal out most moisture, dust, and moderate contaminants. The physical frame of the motor acts as a heat sink to dissipate the heat generated.