Review 3

1. Two types of servomotors used in motion control drives are _____ and _____ .

2. Phase windings in a 3-phase motor are located _____ degrees apart.

3. The speed of the rotating magnetic field is known as _____ speed.

4. The difference between rotor speed and synchronous speed of an asynchronous motor is known as _____ .

5. The output of a PWM type drive is _____ .

   a. sinusoidal
   b. pulse width modulated

6. The temperature rise of insulation class F is _____ K.

7. A motor that is dust tight and protected against splashing water would have an IP rating of _____ .

Speed-Torque Characteristics

Duty Cycle

All motors are limited by the amount of heat that can develop in the motor windings. Speed-torque curves are based on standardized duty cycles which lead to the same temperature rise. The number of possible duty cycle types is almost infinite. To help promote a better understanding, duty cycles have been divided into nine standardized categories, which cover most of the applications encountered.

S1 Continuous Running Duty
S2 Short-Time Duty
S3 Intermittent Periodic Duty Without Starting
S4 Intermittent Periodic Duty With Starting
S5 Intermittent Periodic Duty with Starting and Electric Braking
S6 Continuous Operation Periodic Duty
S7 Continuous Operation Periodic Duty with Starting and Electric Braking
S8 Continuous Operation Periodic Duty with Related Load/Speed Changes
S9 Continuous Operation Duty with Non-Periodic Load and Speed Variations

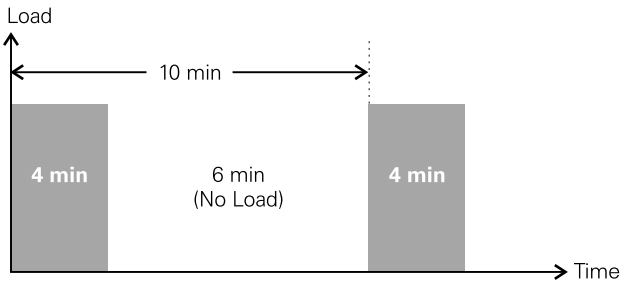
Duty cycle profiles can become complex. S1, S3, and S6, however, are three common duty cycles. Part 2 of the General Motion Control Catalog provides speed/torque curves for S1 and intermittent/periodic duty cycles where applicable.

S1 Duty

Each duty cycle is characterized by cycle times, cycle durations, and load. S1 duty cycle, for example, characterizes a condition where the motor operates under constant load of sufficient duration for thermal equilibrium to be established. All motors listed in the Siemens catalog are designed for continuous duty type S1, unless otherwise indicated.

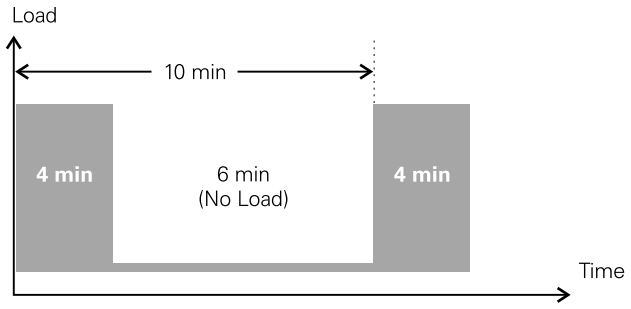
S3 Duty

S3 duty operation is comprised of a sequence of identical duty cycles, each of which consists of a period of constant load followed by an interval of no load. Starting current has no marked effect on the temperature rise of the motor. Operating time is given in minutes, such as 10 minutes, 30 minutes, or 60 minutes. If no time is given a 10 minute cycle time is assumed. Cycle duty is given in a percent such as 15%, 20%, 25%, 30%, or 40%. An S3 duty cycle of 40% for 10 minutes, for example, would indicate a motor load would be constant for 40% of the time (4 minutes). A no load condition would occur for 60% of the time (6 minutes).



S6 Duty

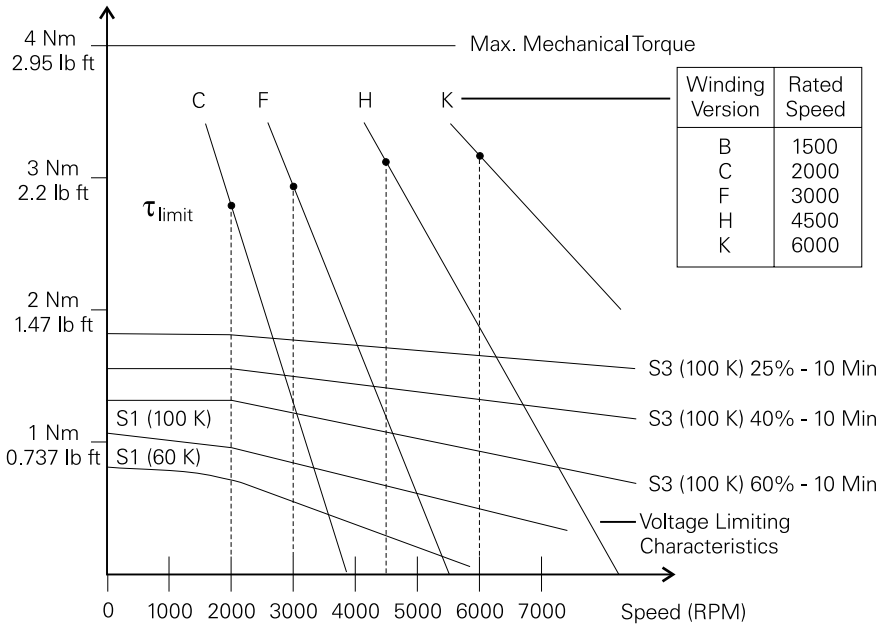
S6 duty operation is similar to S3 duty operation. The main difference is that there aren't any de-energized intervals. The motor remains energized during the no load interval. Operating time and cycle duration are given in the same manner as for S3 duty operation.



Speed-Torque Curve of Synchronous Servomotor

A motor can be identified by its frame size, which is associated with useful mounting information. The speed and torque characteristics for a given frame size depend upon the motor windings available. A common approach for representing the range of speed and torque characteristics available for a given motor frame size is the speed-torque curve.

A speed-torque curve, like the one shown in the following illustration, shows a motor frame which can be wound for various speeds and duty cycles. A letter in the catalog number is used to designate the speed of the motor. A speed-torque curve will show the expected torque performance of a motor for a specific duty cycle at a given speed. The motor frame for a permanent magnet synchronous motor illustrated by the following speed-torque curve is used on four different motor windings: 2000, 3000, 4500, and 6000 RPM. Torque ratings in this example are shown for S1 and S3 duty cycles.

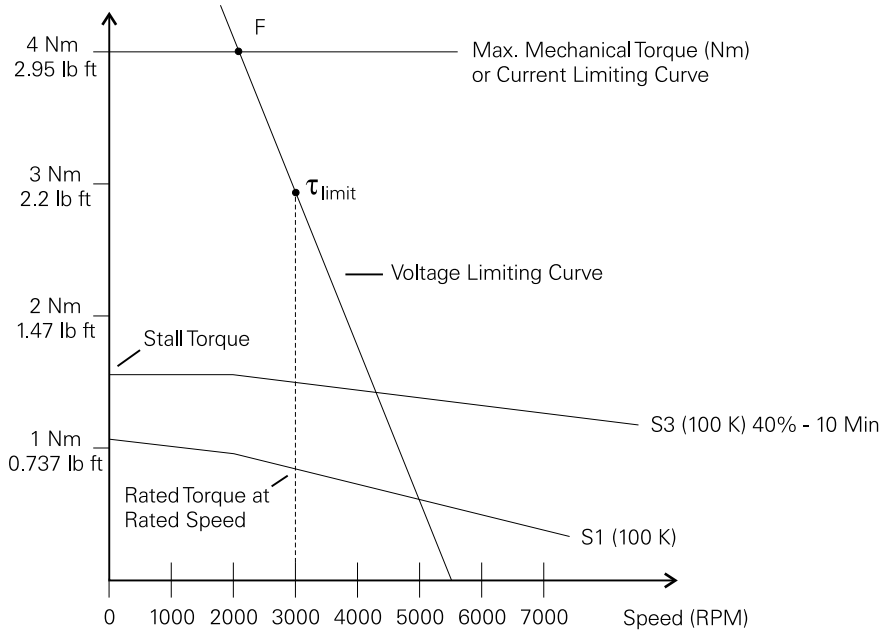


The speed-torque curve can be made less confusing by filtering out information so that only the applicable winding and duty cycles are shown. In the following illustration a motor with an F winding (3000 RPM) is used. The rated stall torque (zero speed torque) when operating the motor in S1 duty is about 1.1 Nm (0.81 lb ft). As the motor accelerates to rated speed, torque decreases to approximately 0.9 Nm (0.66 lb ft) due to friction (bearings) and stator losses (mainly eddy currents). The maximum torque that the motor can supply for a short period of time at rated speed is called τ_{limit}.

If the motor speed is increased beyond rated speed (3000 RPM) continuously available torque, indicated by the S1 line, continues to decrease. The maximum speed is defined by the intersection of the S1 line with the voltage limiting curve. The voltage limiting curve must be followed from that point on. Higher speeds result in reduced available torque.

The maximum torque or current limiting curve indicates the maximum available short-time torque of the motor. Exceeding the limit results in a sudden demagnetizing of the permanent magnets, destroying the synchronous motor.

The rated stall torque when operating the motor in S3 duty is approximately 1.5 Nm (1.1 lb ft). Torque will remain constant until about 2000 RPM. Torque will then decrease slightly to approximately 1.4 Nm (1.0) at 3000 RPM. Torque will continue to decrease as motor speed is increased above the rated speed of 3000 RPM.



Speed-Torque Curve for Specific Motors

Speed-torque curves can also be supplied for a specific motor. Larger motors are rated in Newton meters (Nm) and pound-feet (lb-ft). Smaller motors are rated in Newton meters (Nm) and pound-inches (lb-in). The following speed-torque curve, for example, shows the operating capabilities of a 1FT6082 motor. The motor associated with this curve can deliver 13 Nm (115 lb-in) at stall and 10.3 Nm (91.2 lb-in) at rated speed (3000 RPM) continuously. The region in the light grey area of the graph represents a continuous operating range (S1 duty cycle). The area represented by the dark grey region of the graph represents the intermittent operating region.