MOTORS & DRIVES

SPEED TORQUE CURVES

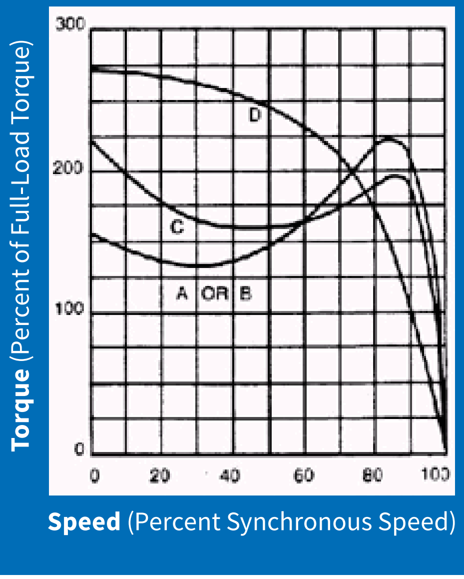
Torque refers to the turning effort exerted by the motor shaft. NEMA defines various torque characteristics for motors, which are designated as Designs A, B, C, and D, with Design B being by far the most common design used in the industry. For each design classification, NEMA specifies performance parameters such as locked rotor torque, pull-up torque, breakdown torque (except for Design D), inrush current, and slip. The NEMA-required minimum values are dependent upon the motor size and speed. Three values of torque are generally of particular interest:

1. Locked Rotor Torque (LRT) - the torque developed by the motor at stand still, also known as Starting Torque
2. Pull-up Torque (PUT) - the minimum torque developed by the motor as it accelerates from zero speed to the speed at which breakdown torque occurs
3. Breakdown Torque (BDT) - the maximum torque that the motor is capable of developing

Figure A indicates typical torque vs speed curves for typical NEMA Design A, B, C, and D motors. Motor torque at any given speed is proportional to the square of the applied voltage. Thus, a 10% voltage dip during starting would result in (0.9) 2 = 0.81% available torque. “Accelerating Torque” is the difference between the motor torque and the load torque. Load Torque is the torque required to drive the load, and includes the friction, windage, etc. of the motor’s load.

TORQUE vs. SPEED CURVES

Figure A



In order to determine the acceleration time of a motor driving a particular load, the torque vs. speed curves of both the motor and motors load must be provided, in addition to the load inertia and the power system information. The torque-speed curve for a given load is a function of the specific nature of the load. For instance, centrifugal loads such as centrifugal pumps and fans follow a square law relationship of torque vs. speed. That is, at zero speed, virtually zero torque is required, but the torque requirement increases as the square of the speed (to 100% torque at rated speed) as the load accelerates. Loads of this nature are generally referred to as “Variable Torque” (V.T.). Loads such as conveyors, screw pumps, crushers, etc. are generally referred to as “Constant Torque” (C.T.) loads, as they can require 100% torque (current) at any or all motor speeds. V.T. loads are therefore less demanding on motor starting performance, from the standpoints of torque and motor heating at less than full load speed. LRT and BDT are interdependent — each can be increased, but at the expense of the other. It is relatively easy to design a motor for a particularly high LRT, or a high BDT, but this would be at the sacrifice of the other. A thorough design should attempt to optimize both the LRT and BDT, and both should be considered when comparing torque.

When a motor is started with a solid state reduced voltage starter, current is reduced in proportion to the applied voltage. For example, if ½ rated voltage is applied, ½ of the motor's inrush current will be seen by the power supply system. The downside of this type of starting system is that the torque that the motor produces is proportional to the square of the applied voltage. Using the same example, if ½ of rated voltage is applied to the motor, (0.5)2, or ¼ of the starting torque is available. This means that if this example motor has an starting current inrush of 600% of motors full load current, only ¼ of the rated starting torque is available for a current draw of 300% of rated full load current. Applications that require low inrush and high starting or breakaway torque are not well-suited to solid state reduced voltage starters.

A voltage souce adjustable speed drive (ASD), however, provides the best of both worlds, with very low inrush and high breakaway torque.To get a feel for why this is, let's review the basics:

- Powerin = Powerout (note losses are minimal and have been ignored)
- Vin x Iin = Vout x Iout (where Vin = input voltage, Iin = Input current, Iout = output current and Vout = output voltage) (PF has also beenignored. Actually PF on the input is better than the output which further helps reduce inrush current)
- Assume at start, Iout = 150% & Vout = 5%, 1.5 x 0.05 = 0.075 = 7.5%
- Vin is always 100%, therefore input current must be 7.5% to balance the equation.
- This means that at start, the drive provides close to 150% of full load torque at the motor while only drawing approx. 7.5% of full rated motor current. As the motor speeds up, the current on the input will steadily rise.

To explain the above in more detail, you must understand that ASDs vary both Voltage and Frequency across the speed range, and because a motor's impedance is reduced with frequency, not as much voltage is required to create the rated torque levels at speeds lower than 60 Hz. Therefore for constant torque, operation across the speed range the voltage out will vary at approximately 10 V/Hz, assuming voltage is 600 V at 60 Hz. At startup 3 Hz, Vout = 30 V (or 30 V/600 V = 5%). A motor and ASD system speed-torque curve will vary depending on the motor, the current capability of the ASD, and the ASD technology used. Every motor will have its own performance characteristics; if two competing drives are both rated at 30 HP but one drive has 10% more continuous current capability, the higher output current-rated drive will have the ability to generate approximately 10% more torque. This can make the difference between having to oversize the drive for a specific application or not. Flux Vector drives have greater control capabilities and can provide more torque at low speeds than standard PWM ASDs. Toshiba 'G' series drive overloads are 110% continuous and 150% for 2 minutes; the Torque-Speed curve as illustrated in *Figure B*.

Estimated Maxium Torque of Toshiba G3 and Toshiba Motor (120 Second/O/L Capability) as related to Motor HP

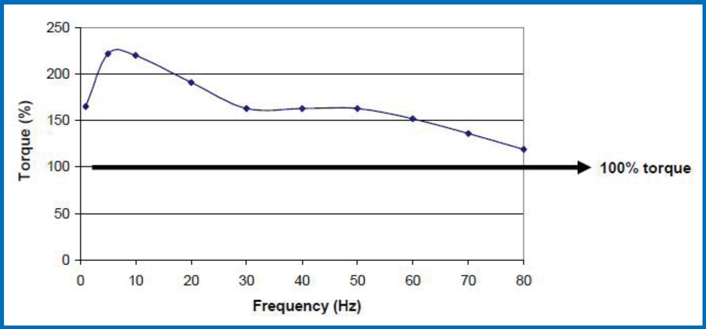


Figure B

Toshiba's drive performance testing has yielded the tools needed to accurately size a drive/motor combination to meet and exceed customer's expectations and requirements. The following is a sample of some of the information gathered which includes raw test information. Figure C shows torque capability of a 5 HP G7 and 5 HP motor with the drive set in sensorless vector control. (Drive settings were not tuned for optimum speed regulation)

Note:

- G9 FLA is 9.1 Amps, EQP Global SD FLA is 6.5 Amps.

SPEED TORQUE CURVE

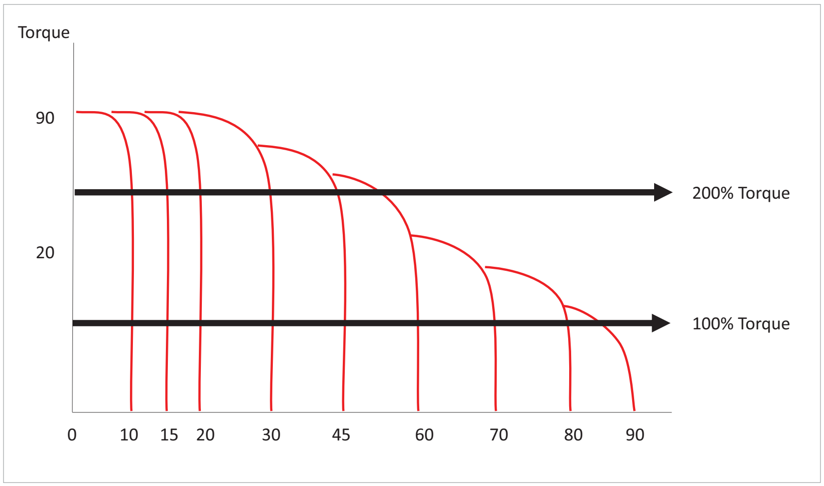
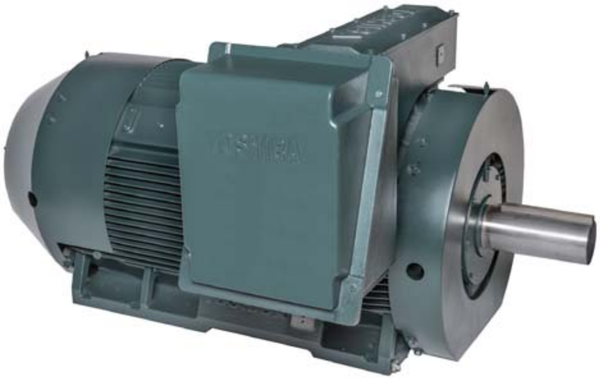


Figure C

Using Vector control does two very basic things:

1. The first is to control the flux of the motor to produce the optimum amount of torque and speed response. As can be seen, the drive produces more torque as the speed decreases.

2. The second is to increase the output frequency as the load increases, this will help to compensate for the motors slip; hence, providing good speed regulation.



Notes:

- The Speed Torque Curve for the above *(Figure C)* does not show a typical P.U.T . region (similar to that of an across the line start), because as mentioned earlier, impedance reduces with frequency / speed, thus allowing the extra available voltage to go towards extra flux/torque production.
- The above torque is available only for a limited time period, and limited by the drives overload - current rating, Toshiba G series drives are capable of 150% current for up to two minutes, which is significantly higher than industry norms.