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Servo Motor Sizing Concepts

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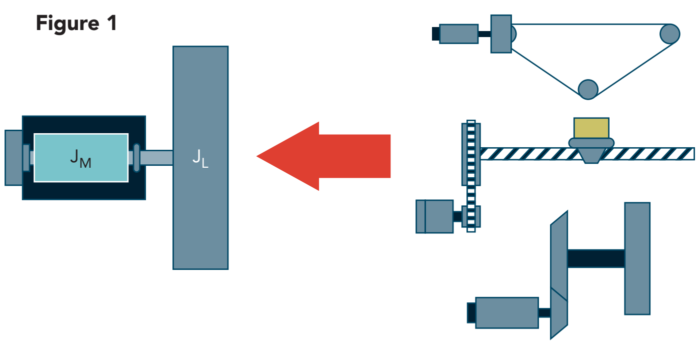
Understanding key parameters helps overcome misconceptions when sizing servos

Servo motor sizing is the process of selecting the best motor for a servo application. Misconceptions engineers can fall into when selecting a motor include: sizing based on the horsepower rating of the presently installed motor or sizing based exclusively on the application's torque requirements.

Another common misconception is that the inertia ratio must be 1:1. However, the goal of sizing is not to achieve a specific inertia ratio, but rather to select the best motor for the application. It's not important to rely on a hard rule for inertia, but rather to consider each application separately.

Many secondary factors are important for servo motor sizing including: cost, encoder resolution, environmental ratings, power requirements or space limitations. But the most critical factors in the core process of servo motor sizing can be narrowed down to just four: inertia ratio, speed, max torque @ speed and RMS torque @ speed. Understanding these four critical factors is a vital step for the design engineer to select the best servo motor for the application.

Figure 1



Motor inertia, JM, is specified by the supplier, while load inertia, JL, must be calculated based on the components in a specific system.

INERTIA RATIO

The first key sizing factor is the Moment of Inertia Ratio. Any rotating object has a moment of inertia. The moment of inertia is a measurement of how difficult it is to change the rotating velocity of that object. The entire moment of inertia of a servo system can be divided into two parts: motor inertia and load inertia.

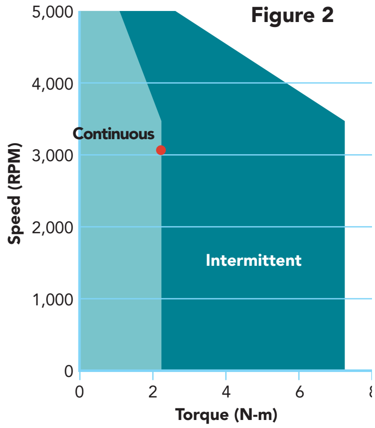
Motor inertia, JM, is part of the design of the servo motor and is typically listed in the manufacturer's catalog. However, the load inertia, JL, often consists of many components. Each component that is moved by the motor contributes to the total load inertia which is determined by using proper equations for each component. These calculations can be handled well using a manufacturer's sizing software.

Inertia ratios around 5:1 are typical for many applications. Performance tends to go up as the inertia ratio is lowered, often down to 2:1, 1:1 or lower. But when high performance isn't as critical, ratios of 10:1, 100:1 or even higher are not uncommon. In general, ease of control loop tuning and machine performance goes up as the inertia ratio goes down. So if all other factors are equal, a lower inertia ratio is better. An excessively low inertia ratio can indicate an excessively large, expensive and bulky motor with little performance increase. If inertia ratio is the limiting sizing factor, it's important to fully understand the application's performance requirements before ruling out a higher inertia ratio.

SPEED – TORQUE CURVE

Several motors that provide a suitable inertia ratio may be available. So the task is to find the smallest, most cost-effective motor that has the ability to produce the speed and torque required for the application. A motor's speed and torque capability is described in the company's catalog using an individual speed-torque curve for each motor.

The speed-torque curve displays several points of interest. Rated torque is the maximum torque the motor can produce continuously at rated speed and lower, and is limited by motor heating. This rated torque is given the



The Speed-Torque curve shows the relationship between motor speed and motor torque.

value of 100 percent torque. Likewise, rated speed is the highest speed at which rated torque is available. The motor can continuously run faster than rated speed, but the torque available drops significantly the faster the motor runs. The motor's maximum attainable speed is listed at the top of the speed torque curve, and the motor's maximum torque is at the far right (see Figure 2, left).

The speed-torque curve has two regions, continuous and intermittent. If the combination of torque and speed required by the motor is found in the continuous region, the motor can produce that torque and speed forever without any chance of overheating the motor. If the combination of torque and speed produced falls in the intermittent region, the motor can only produce that speed and torque for a limited amount of time. If that time is exceeded, the motor will begin to overheat.

To prevent damage due to overheating, modern amplifiers automatically disable the motor and enter an alarm state if the time limit is exceeded. But when short bursts of high torque are required such as during acceleration and deceleration, the motor can run in the intermittent region safely. The amount of torque the motor can produce above rated torque, and the duration for which this torque can be produced, varies between manufacturers.

The application's RMS torque, however, must lie within the continuous region. If any combination of speed and torque required lies outside both the continuous and intermittent region, the motor is not capable of producing that combination of speed and torque. When selecting a motor, it is imperative to ensure that the speed-torque curve is used effectively.

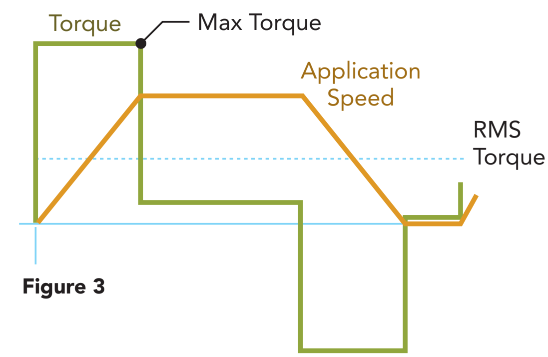
MOTION PROFILE

While a motor's capability is described by the speed-torque curve, the application requirements are best illustrated using a speed profile and torque profile (see Figure 3, above right). The speed profile is a graphical representation of the motor speed versus time, and the torque profile illustrates the motor torque required for the machine to follow the speed profile during that same time.

MAX TORQUE

The torque at the beginning of the trapezoidal move is highest because mechanical friction must be overcome and the load must be accelerated from rest. This point of highest torque is called the Max Torque. Once the traverse speed is reached, a nominal level of torque must be applied to overcome friction and maintain speed. To decelerate the load, often a reverse torque is required. The reverse torque during deceleration is not as high as the forward torque during acceleration, since friction also helps decelerate the load.

Typical Speed and Torque Profile

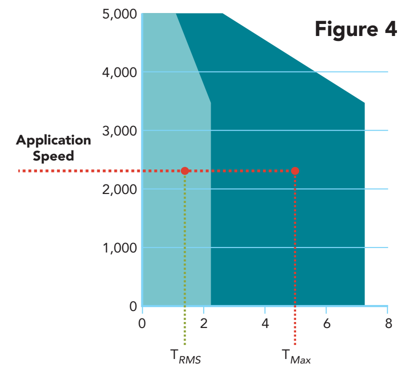


Speed increases at the beginning of the move, accelerating to a traverse speed and then decreases, decelerating to a stop. Due to its shape, this is referred to as a trapezoidal speed profile or trapezoidal move.

When friction torque is high, a forward torque may be required during deceleration so the motor doesn't slow down too quickly. It is important to ensure that the motor can produce the required Max Torque at the application speed. The Max Torque at application speed ideally falls within the intermittent region of the motor's speed-torque curve. It may also fall within the continuous region, but this may be an indication that the motor is oversized.

RMS TORQUE

Another torque calculation critical for sizing is RMS torque, the time-weighted average of the torque during a complete machine cycle or the equivalent of a steady-state torque level. For example, a servo motor with 1.2 N-m RMS torque will experience the same heat rise if it produces 1.2 N-m constant torque. So it is also important to ensure that the RMS torque at application speed falls within the continuous region of the speed-torque curve. The RMS torque calculation is easily calculated using sizing software.



RMS torque at application speed should fall within the continuous region of the speed-torque curve.

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