

INTRODUCTION

Servomotor sizing is the process of selecting a servomotor for a particular application. The size of a servomotor or how big a motor is can be judged in terms of how much torque it can provide because the torque output of a servomotor is generally proportional to its physical size. A servomotor is rated by how fast it can spin as well as how much torque it can provide. The process of selecting a motor is to determine how much speed and torque an attached mechanism needs, then to pick a motor capable of providing both. This book brings together all the material needed to analyze an attached mechanism with the goal of selected a suitably motor. Typical mechanisms are also discussed along the way to show how servomotors are applied. Chapters are devoted to individual topics and several complete examples are provided to bring it all together.

Torque is proportional to acceleration, so the required acceleration of the motor must be determined. This is found by performing kinematic calculations. Kinematics is the study of motion and it provides the relationships between time, position, velocity and acceleration. You start by choosing how the load moves, then relate it to how the motor moves. The load is generally the part of the mechanism you are interested in, such as the product to be transferred or the motion of a tool.

Judgment on your part is needed because there are many ways to get from point A to point B. How the load moves from one point to another is called its *motion profile* and there are many motion profiles to choose from. A profile can be chosen to make the movement of the load as smooth as possible or to minimize the total amount of energy required, for instance. The choice of motion profile impacts motor size. It thus becomes a matter of balancing how you wish to move the load with how big a motor you will have to use. To this end the most popular motion profiles are discussed and compared to help you decide how to move your load.

The torque output of a servomotor varies over time as it moves its attached mechanism and how the torque varies with time, referred to as a torque profile, can be predicted. Motor selection depends on knowing the peak and effective torque required to move the mechanism and both values can be found from the torque profile. The peak torque is the greatest value of torque and a motor must have a peak torque rating greater than this value or the motor will simply not be able to move the mechanisms as we desire it to. The temperature of a motor is proportional to torque output and it's important that a motor never exceeds its temperature rating. Short circuits in a motor's copper windings are a common failure mode when the temperature rating is exceeded. Motor temperature increases when the motor has a high torque output and the temperature decreases at lower output levels. The effective torque determined from the torque profile helps to predict the temperature a motor will reach even when torque varies with time. The maximum motor temperature is expressed as a continuous torque rating and a motor must have a continuous torque rating greater than the required effective torque. The chapter on duty cycles discusses how to calculate the peak and effective torque required by an application and how these results relate to motor size.

Force is proportional to how much mass you are trying to accelerate in a linear system and torque is proportional to moment of inertia in a rotary system. Moment of inertia is like mass but also factors in how far away the mass is from the axis of rotation. The farther away the mass is from the axis of rotation, the more torque the motor has to provide for a given rate of acceleration. You need to know the moment of inertia of the system you are trying to accelerate because moment of inertia multiplied by acceleration equals torque. The chapter on inertia shows how to calculate the moment of inertia of the components in a system and how to add up all the individual moment of inertia. As shorthand, the word inertia is used rather than moment of inertia throughout this book.

The purpose of having a mechanism and a motor is to perform some kind of task (for our purposes, at the end of the mechanism). The motor is selected based on how the motor sees the task, which is called the "load." The mechanical components connect the load to the motor and include devices such as bearings, gearboxes, lead screws, and linkages. Their characteristics form a relationship between the motor and the load that allows us to relate the motion and force at the load to motion and torque at the motor. A gear reduction device such as a gearbox changes the speed of the motor relative to the load to make the motor rotate faster and a lead screw changes rotary motion to linear motion. The chapter on gear ratios discusses the common mechanisms to show you how they relate load con-

ditions to motor conditions and it focuses on how to select an appropriate gear reduction component.

Friction opposes motion and is present whenever two masses are in contact with each other and have relative motion between them. Also, the components of the system are not perfect, as measured by their efficiency. Friction converts energy to heat and the motor has to provide sufficient torque to offset these losses in order to be able to move the load as expected. The chapter on friction discusses these losses and shows how much torque is needed to overcome them.

Most servomotor applications make use of relatively simple devices such as lead screws. They get the job done and most applications don't require anything fancier. Linkages, on the other hand, offer a substantial number of motion possibilities. Crank arms are perhaps the most common (and simplest) linkage, and robots represent the pinnacle of linkages. I personally believe that more linkages would be used if more people knew how to design them. Understanding vector math is an important prerequisite to understanding linkages so a chapter on vectors is provided. The chapter discusses a powerful method of constructing vector relationships for modeling linkages. Chapters on crank arms and a two axis parallel robot are also included to illustrate how to create equations that yield required motor torque.

I won't deceive by saying that math is kept to a minimum. Servomotor sizing is computationally extensive and software that relieves you of the computational burden is highly recommended. My first choice is sizing software from the servomotor manufacturer representing the motors you intend to use. My next choice is software that allows you to enter equations and plot the results. Even spreadsheet software is better than pencil and paper. Software will free you up for creative thought. It will also allow you to change a variable and immediately see the result. This is necessary because motor selection will require some trial and error.