PART TWO

The Basics of the **Electric Linear Actuator**

What is an electric linear actuator?

- *An electric linear actuator is a device that converts the rotational motion of an electric motor into linear motion (push or pull movement).*
- *It can be used anywhere a machine pushes or pulls a load, raises or lowers a load, roughly positions a load, or rotates a load.*

By Jon Mueller, Tyler Pocock, and Samantha Rosenfeld - TiMOTION

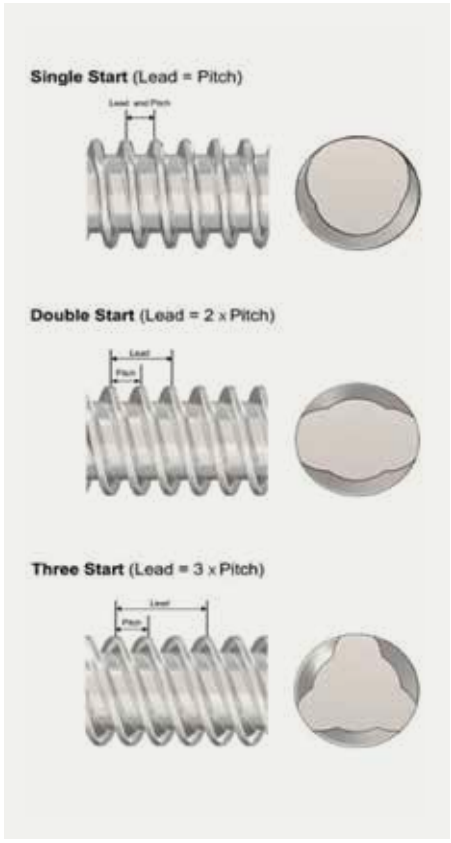
There are many components and options to an actuator. We will discuss a new subject in each section related to the basics of an electric linear actuator and the factors to consider when purchasing. In first portion of the article featured in the February issue of Valve World Americas, we discussed the common styles and configurations, and reviewed the internal and external components of a linear actuator. Now, we explain the various load and speed characteristics to consider and how it can be adjusted to meet your applications' needs. We will follow that with the various levels of IP ratings an actuator can have for liquid and dust protection as well as lubrication used, as well as consider the certifications and standards that are needed to meet certain market and country requirements. Lastly, we will discuss the importance of feedback sensors in electric linear actuators.

Load and Speed Characteristics of an Actuator

Whether you are working on your company's next large project, or a DIY project at home, there are many factors to consider when choosing the correct electric linear actuator system for your application. By tailor fitting various combinations of spindle type, spindle specs, motor revolutions per minute (RPM), gear ratio, and the amount of power supplied to the actuator, it is possible to control the load and speed capabilities of the actuator. These characteristics are all dependent upon each other in order to operate a quality and durable linear actuator.

The type of spindle (or screw) is going to partly determine how fast the electric actuator moves, and also its load capability. Electric actuators can feature two types of spindles, lead screws and ball screws. There are three thread types for a lead screw: a square thread, acme thread, and buttress thread. Acme threads have a high load capacity, but are not as fast as a ball screw due to increased friction caused between the nut and thread. However, the acme lead screw is a more economical, and highly reliable, solution which we are able to pass along to our customers.

The other type of screw utilized within electric linear actuators is the ball screw. The ball screw creates less friction than the acme screw because the threaded shaft provides a circular pathway for ball bearings (in a ball nut) which act in a more precise manner than the sliding friction caused on the acme nut. Because of this, the ball screw is more efficient and able to move at a higher speed. However, there is generally no self-locking force on a ball screw, so a brake mechanism can help with back drive and holding the load in place.

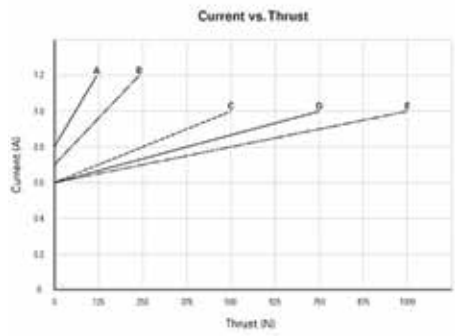


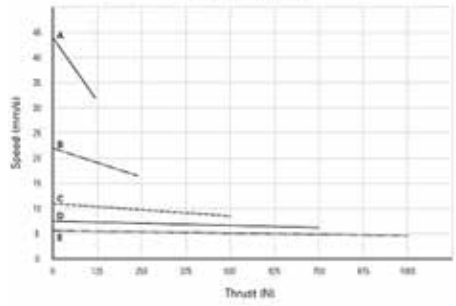
The specifications on the spindle also have a large effect on how fast the actuator moves, but mostly how much load it is capable of holding. The specs on a spindle (or screw) include the pitch, lead, and number of starts. The pitch is the axial distance from a crest on a screw thread to the equivalent crest on an adjacent thread. The lead is the linear distance the screw travels in one complete turn (360 degrees) on the shaft. The start is the number of independent threads wrapped around the screw. What does all of this mean? The angle of the thread determines how fast the nut travels up and down the shaft. The steeper the angle, the faster it moves, and vice versa. The more starts there are on the spindle, the steeper the thread angle (as shown in the picture above). However, there is a trade-off between speed and self-locking ability. The faster the nut travels up and down the spindle, typically means that the self-locking force decreases (the natural ability to hold a load in place once the nut comes to a stop).

Another thing to take into consideration when controlling the speed and load of an actuator is adjusting the RPM and gear ratio of the gear set. The gear ratio is the ratio of number of revolutions per minute (RPM) of the driver vs. the revolutions per minute (RPM) of the driven gear. For example, if a driver spur gear has 12 teeth on it and the driven spur gear has 24 teeth on it, the driven spur gear is twice as big as the driver gear. Since the driver gear must turn two times for every one turn of the driven gear, it has a 2:1 gear ratio. There can also be additional gears added into the equation, depending on the trade-off between force and speed that is required, because force and speed are linked in an actuator by the formula "Mechanical Power = Force * Speed".

When manipulating the load and speed of an actuator, one can also consider the amount of mechanical power required for the application (the power is measured in watts). The main idea to remember about current, speed and load in DC motors is that when the load increases, the current will increase and the speed will then tend to decrease (as shown in the charts above). Besides this main relationship, there are many other electro-mechanical parameters that influence load and speed like the kind of power supply used or the efficiency of the motor.

Many actuators run on direct current (DC) power, making it beneficial for control boxes to have the ability to convert alternating current (AC) power to





DC power so a customer's application can be plugged into the wall. SMPS transformers (switch mode power supply) and toroidal transformers can be integrated into the control boxes. SMPS transformers support 110V AC and 220V AC inputs, allowing custom-

ers' products to be plugged into different outlets around the world.

Below are three charts to help with term usage and conversions. The first is common voltage expressions that can be used interchangeably, the second is the conversion of Newton (N) to Pounds (Lbs.) and kilograms (kg), and the last is the conversion of Millimeters (mm) to Inches (In):

IP Ratings and Lubrication

Not only do the internal parts of an actuator effect it's life span, but the ability to protect the actuator from intrusions such as solid objects and liquids will ensure its' long lasting life as well. This can be ensured this by adding a protective seal around the outside of our electric actuators and lifting columns.

To take this a step further, depending on the environment that the application will be in, it is possible to customize the level of protection around the outside of the electric actuator. These levels are calculated based off the IP Rating. The IP Rating stands for International Protecting Rating that consists usually of two digits following "IP" that describes its level of protection. The first digit indicates the level of protection against ingress of solid foreign objects such as dust and debris. This scale ranges from 0 (not protected) to 6 (high level of protection from dust). The second digit indicates the level of ingress protection against liquids such as water. This scale of protection ranges from 0 (not protected) to 9 (high level of protection from liquids).

Linear actuators can be sealed to the customized level of protection that a customer desires, with most common levels of protection being ratings of IP42, IP54, and IP66, and IP69K. The IP42 protection can be used typically in an indoor application where dust and liquid are not large factors such as in a TV lift, household couch, chair, or adjustable bed.

The IP54 rating is more universal because it has a higher level of protection which can allow the actuator to operate in a more volatile environment such as a hospital, dental office, or warehouse.

The IP66 rating is one of our highest-level seals, which makes it a waterproof linear actuator. It can be placed typically into an outdoor environment where harsh conditions are present such as a farms construction sites. In addition, IP66 can also be very important for medical and patient mobility equipment such as pool lifts and medical beds.

An IP69K level of protection can also be offered, which is considered to be one of the highest in the industry. IP69K is a protection provision of high temperature and pressured water. An actuator with this level of protection can be sprayed down with a high-pressure hose such as in an agricultural setting where dust, dirt, and chemical levels are high.

The type and amount of lubrication used in a linear actuator will greatly affect its life span. Think of lubrication as the blood of the linear actuator, without it, all of the parts to the actuator won't work together and will NOT last. Lubrication helps reduce friction, which in turn helps regulate temperature within the motor. It also keeps moving parts separate, reduces noise and vibration, and prevents corrosion to the machine.

The two main types of lubrication used are grease and oil. Grease is thicker than oil which will allow it to hold higher loads and also requires less frequent maintenance. A specific type of grease is used depending on the load/speed requirements of the actuator. Generally speaking, grease with a higher viscosity (thinner) will be used in lower load applications and grease with lower viscosity (thicker) will be used in higher-load applications.

Voltage Expressions

12 Volts DC	12V DC	12 VDC
24 Volts DC	24V DC	24 VDC
36 Volts DC	36V DC	36 VDC
48 Volts DC	48V DC	48 VDC
110 Volts AC	110V AC	110 VAC
220 Volts AC	220V AC	220 VAC

Weight Conversion
(N to lbs. and kgs)

1 Newton (N)	.22481 Pound (lbs)
1 Newton (N)	.1 kilogram (kg)

Distance
(mm to in.)

1 Millimeter (mm)	.03937 Inch (in)

Certifications

In order to standardize quality expectations within different industries and countries, companies can acquire various certifications to ensure they are producing a quality product. These certifications are important to keep in mind when you are producing a product that will be going into various markets.

Medical

- IEC 60601-1: IEC stands for the International Electro-Technical Commission. The 60601-1 is specific to medical electrical equipment being commercialized to make sure it is operating at a safe level.
- UL 60601-1: The American deviation of IEC 60601-1. UL is a nationally recognized testing lab which has their own codes. These codes are similar to IEC; however, the UL code is the safety standard for the U.S.
- IEC 60601-1-2: This sub-section of 60601-1 specifies testing for Electromagnetic Compatibility (EMC). EMC ensures that electrical devices with electromagnetic energy do not interfere with each other in the same environment. Specific requirements and tests are done, making sure electric waves being produced by the equipment are within an acceptable range in a given environment.
- ISO 13485:2003 - Requires a company to demonstrate its ability to provide medical devices and related services that consistently meet regulatory requirements applicable to medical devices and related services.

Household / Furniture

- UL 962 – UL is a nationally recognized testing lab. The UL code is the safety standard for the U.S. The UL 962 code is a standard for household and commercial furnishings to ensure a safe product.
- RoHS - (Restriction of Hazardous Substances) restricts the use of hazardous materials including lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls, and polybrominated diphenyl ethers. RoHS was originated in the European market; however, most products being sold in the U.S. market are also RoHS compliant. Products that are RoHS compliant include electric and electrical products found in household appliances, computing/communications equipment, consumer electronics, lighting, and many other products.
- BIFMA - The trade association for business and institutional furniture manufacturers. They develop, maintain, and publish safety standards which provide healthy, comfortable, and productive workspaces.

General Practices

- ISO 9001 - Is essentially a formal document supported by management of a company that follows and measures continuous improvement and consistency of the company's standard operating procedures.

Feedback Sensors

When an electric linear actuator is equipped with feedback sensors, the actuator can actively communicate its stroke position to the control system (sometimes referred to as positioning). These output sensors also allow for the control box to precisely control the actuator's stroke at all times. While this is not required on all linear actuators, positional sensors are required on those with more complex functionality. For example, if an actuator needs to move synchronously with another, feedback sensors are necessary for monitoring and ensuring both linear actuators remain in sync, regardless of differences in load. Additionally, feedback sensors are crucial for memory positioning and other special features that require knowing where the actuator's stroke position is at all times. This can include, but is not limited to, motor speed, conditional movement, and other features.

The four main feedback/positioning sensors used within linear actuators are:

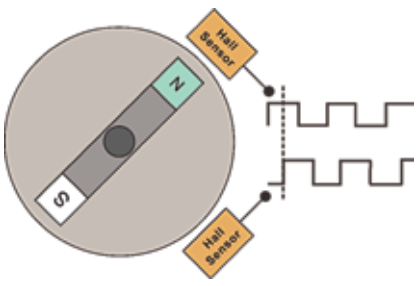
- Hall Effect Sensors
- Potentiometers
- Reed Sensors
- Optical Sensors

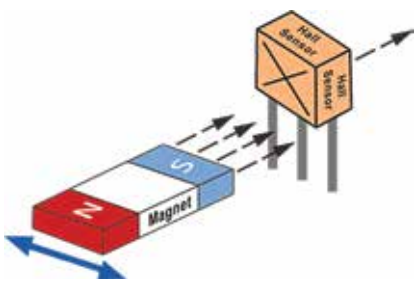
Hall Effect sensors are the most recommended type of positional sensors for electric actuators because they are small

enough to fit in compact spaces, providing higher resolution and digital output for positioning and synchronization.

These Hall Effect sensors are activated by a magnetic field, which is comprised of two important characteristics: flux density and polarity. The output signal from a Hall Effect sensor is the function of the magnetic field density around the device. When the magnetic field density around the sensor exceeds a certain pre-determined threshold, the sensor detects it and generates an output voltage call the Hall Voltage, or VH. Hall sensors are commonly used due to their cost-efficiency. These sensors also maintain their quality over time and generally have long lifespans.

Potentiometers, also known as POT sensors, are generally the most commonly used output sensor in the industrial marketplace. They have a wiper





contact linked to a mechanical shaft that can either be rotational or linear in their movement. This causes the resistance value between the wiper and the two end connections to change giving an electrical signal output that has a proportional relationship between the actual wiper position on the resistive track and its resistance value.

In other words, resistance determines position. As the linear actuator lead screw turns, the resistance value between the wiper and the two end connections will change, and each resistance value will correspond with the position of the linear actuator's stroke.

One advantage of the POT sensor versus a Hall sensor is that when the power is off, the POT will keep the information of the position, while a Hall sensor will lose the positional information and need to be reset. However, potentiometers are slightly less accurate in their readings in comparison to the Hall Effect sensor due to the initial installation process; however, this is not detrimental to the overall position reading.

Reed sensors are magnetic feedback sensors. There is an electrical switch which is operated by an applied magnetic field, and the sensor as a whole contains a pair of contacts on ferrous metal reeds in a hermetically sealed glass envelope. The contacts may be normally open, closing when a magnetic field is present, or vice versa. The switch may be actuated by a coil, making the reed switch return to its original position. With force from each rotation of the lead screw and position of the linear actuator stroke length, the reed switch will open or close. Reed sensors are specifically used inside the handsets with a safety key function to send a signal when the key has been removed.

Optical sensors are also occasionally used in electric actuators. An optical sensor functions by converting light into an electronic signal. As a lead screw rotates, a light blocking wheel will also rotate at the same time, blocking the light to the optical coupler. This optical coupler will send a signal each time it senses the light being blocked. The light blocking wheel revolutions will cause the optical coupler to send twenty-five signals each full revolution.

Overall, the process of choosing the right electric linear actuation system for your application is one that must be carefully researched prior to purchasing.

For Part One of this article please check out the February issue of Valve World Americas journal.

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