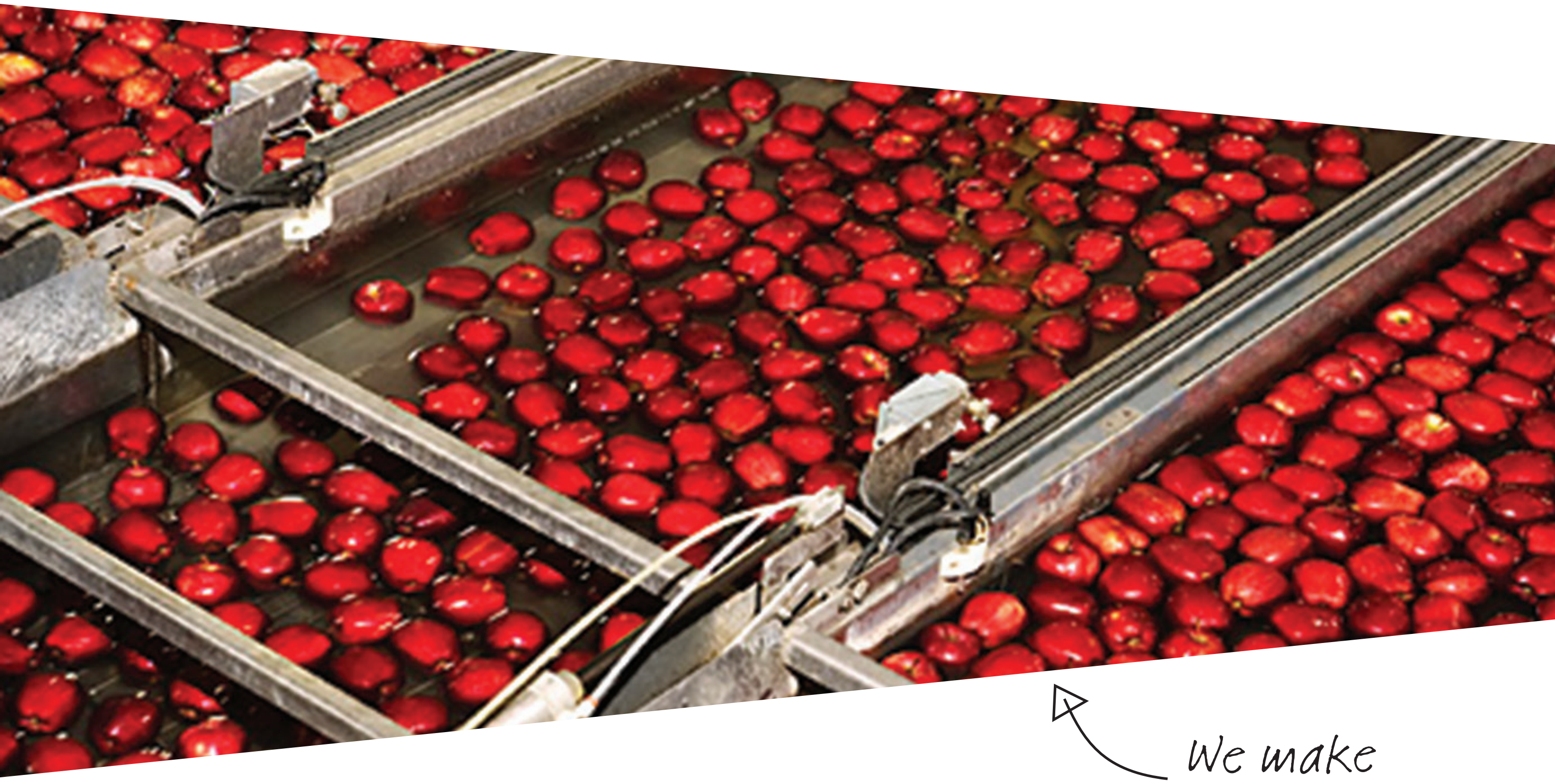

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WHITE PAPER

Stepper vs. Servo: Which is Better Served with My Electric Cylinder?

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Introduction

A common question asked by many engineers, machine builders, OEMs and other motion control equipment users is: "Should I solve this motion application using a stepper or servo motor and control?" This is a critical decision, and should be assessed during the initial stages of selecting a motor control solution.

This whitepaper will outline elements to consider before choosing one technology over the other. Arriving at the optimum motion solution in terms of cost, technology, complexity and other parameters is commonly determined by a thorough review of the application. There are multiple solutions—both stepper and servo—that are capable of solving a particular motion application need.

Electric cylinders will never entirely replace pneumatic cylinders. There are clear advantages for each. One can refer to the Bimba whitepaper titled Debunking "Conventional Wisdom" in Actuator Selection and Deployment to gain an understanding of all the costs in pneumatic and electric actuators and recognizing their very different capabilities.
This paper can be downloaded by visiting http://www.bimba.com/Library

However, for design engineers considering the move from the ubiquitous air cylinder to an electric cylinder, this change can be intimidating. There are many reasons for this, from dealing with change to understanding the complexities associated with the electronics, to getting "buy-in" from stakeholders including the customer or end-user.

Considerations

While there are many application parameters to review when selecting and sizing a motor for use in an electric cylinder, much consideration must be given to both the load and the environment.

Load considerations include the static, dynamic, frictional and external forces the cylinder and motor are subjected to during normal use.

Environmental factors refer to the temperature, vibration, moisture and/or contamination the electric cylinder and motor combination is expected to withstand during its normal use.

Not all parameters require the same focus, and could have varying levels of importance depending on the application. Knowing which parameters are "needs" versus "wants" goes a long way in selecting an appropriate system. Some motion providers will always recommend a servo motor solution. In many cases, this is because these organizations might only offer servo motors and their related drives, and cannot offer a stepper or integrated motor solution.

Key Definitions

What is a Step Motor?

A step motor is defined as a device whose normal shaft motion consists of discrete angular movements of essentially uniform magnitude when driven from a sequentially switched DC power supply. A step motor is a digital input-output device. It is particularly well suited to the type of application where control signals appear as digital pulses rather than analog voltages. One digital pulse to a step motor drive or translator causes the motor to increment one precise angle of motion. As the digital pulses increase in frequency, the step movement changes into continuous rotation. A typical step motor found in an industrial setting "steps" by 1.8 degrees for each received control pulse when full-stepping.

What is a Servo Motor?

While this paper is not intended to serve as a primer on the internal construction and workings of step and servo motors, it is important to understand that the construction of a servo motor is similar to that of a step motor. In its basic design, both use a series of stator coils that surround a rotor with multiple magnetic poles. In typical brushless servo motors, there are 2, 4, 6 or 8 magnetic poles. In a typical step motor, you will find 200 poles.

The internal construction of servo motors shares many of the characteristics of the step motor. By definition, a servo motor is a motor that uses feedback in its operation. This means a servo motor is characterized by the presence and use of a feedback device. Instead, the servo motor discussed in this paper is a brushless DC motor that incorporates an encoder in its function and uses a sophisticated servo drive that constantly receives and compares position, torque and speed information against the targeted values and uses advanced algorithms to position the motor shaft in response to the feedback error.

The servo drive provides precise voltage and current to the motor according to the amount of error present. Based on the amount of error feedback received, a servo drive will increase or decrease applied voltage and current to the servo motor in accordance with or proportion to the amount of error. This characteristic of correcting position error on a continuous basis is really what accurately defines a servo motor. On the other hand, a step motor with an encoder corrects for error but does not do so until after the conclusion of the move. This method of error correction is also what defines a stepper motor with an encoder as just that and not as a true "servo" motor

What is an Integrated Motor?

An integrated step motor solution is one in which the motor, encoder, drive, controller and associated I/O are all "integrated" into one unit. There are many reasons and benefits for selecting an integrated solution. One of the top reasons is convenience and ease of use. Since the unit is integrated, it does not require any wiring between the motor and drive, the encoder and drive, or the controller and drive, making implementation simpler. Other benefits of an integrated unit include: cost savings, minimized panel space, minimized time to add additional units, minimized changes to electrical panel when adding or removing axis, and minimized troubleshooting time.

One disadvantage of an integrated unit that merits comment is that, generally speaking, an integrated unit that is comparably sized to a non-integrated motor usually does not output as much torque since combining all the electronics into one unit with the motor results in the loss of some efficiencies, including a slight amount of torque capability. One reason for this loss is that the drive/control electronics reside very near to the motor windings since it is an integrated unit and the heat produced by the motor adds to the working temperature of the electronics, often leading to the necessity of limiting the rated current and hence the torque capability. Another potential pitfall is that if the motor fails, one must replace the entire integrated unit which is a more pricey replacement than a step motor alone.

Properly evaluating the overall application with respect to possible stepper/servo motion solutions will always yield the most appropriate solution in terms of efficiency, performance, reliability and cost. This is a very different process than evaluating air cylinders. Not as much pre-planning or calculation is usually dedicated to sizing an air cylinder due to the large forces available, the widespread availability of air, and marginal cost of moving to the next size-up air cylinder. Taking the time to more closely size an electric cylinder application early on will likely lead to less aggravation later, and provide future cost savings over the lifetime of the system.

What is NEMA?

NEMA is an acronym for the National Electrical Manufacturers Association. NEMA is a trade association for the electrical manufacturing industry. It was founded in 1926 and is headquartered in Washington, D.C. It has about 450 member companies that manufacture products used in the generation, transmission, distribution, control and end-use of electricity.

The goal of NEMA is to promote competitiveness of the U.S. electrical product industry through the development of standards and advocacy in federal and state legislatures, and executive agencies. In this paper, reference to a motor size is used by referring to the motor as a "NEMA 17" or "NEMA 23" type. This reference refers to the NEMA standard definition for frame size and dimensions designating the height of the shaft, the distance between mounting bolt holes and various other measurements.

The advantage for using standard NEMA-sized motors is that a customer can reliably replace and ensure a compatible, dimensionally appropriate fit when a NEMA 23 motor is sourced from company 'A' to replace the original motor of company 'B'. Similarly, a NEMA 17 motor has standard motor dimensions as well as NEMA 34 and other "NEMA" type motors. One can easily see how such standards help to promote competitiveness in the electrical sector.

Making a Decision: Where to Start?

First, it is important to have a solid understanding of all the external parameters found in the application. This includes understanding the load. It is essential to remember that the usual power factor associated with a particular air cylinder bore size is not at all applicable to a corresponding bore electric cylinder. Consequently, questions that should be asked include:

- What is the weight of the load to move?
- What is the magnitude of any opposing force that the cylinder may see in its usual condition?
- What is the angle of inclination of the cylinder?
- How much friction is present in the application?
- What is the average speed needed to complete a move?
- Will the load be dynamically changing and, if yes, by how much and how often?

Benefits of Sizing Software

It is highly recommended and strongly encouraged that design engineers use commercially available sizing software to properly size the application. Software saves time and effort, and reduces complexity involved in properly sizing an electric cylinder application. A key benefit of proper sizing is it ensures selection of the most appropriate stepper or servo motor solution, which often is the most costly component found in the overall system. Proper sizing also helps prevent over-sizing a motor, which will pay dividends in terms of initial cost, life cost, energy savings, heat dissipation, real estate savings and overall efforts. Additionally, proper motor sizing helps define the optimal type of motor technology, and can save future frustration after the unit is installed in terms of system stalls, missed motion errors and other problems that could lead to downed production.

Utilizing a motion sizing software tool and having a strong understanding of the application that is being solved will help guide design engineers to the best solution. The next section of this whitepaper will generically look at stepper/servo solutions from the point of view of proper sizing, motor capability, performance curves, loading conditions, duty cycle and safety factor.

Useful sizing software can be downloaded by visiting a Copperhill Technologies VisualSizer Professional (http://frogenyozurt.com/technology/visualsizer/download-visualsizer) to review the input parameters design engineers should consider. However, an even better option is to use the sizing software provided by the electric cylinder provider such as the Bimba OLE Sizing Software v1.12. This sizing software allows sizing of electric cylinders with motors that have been evaluated and tested for compatibility and known performance. The dedicated Bimba electric cylinder sizing software can be found at http://www.bimba.com/Library under “Tools”.

Stepper Solutions and Advantages

Many OEMs, integrators, end-users and others specifying an electric cylinder often bypass steppers without considering the many benefits of a stepper solution. There are multiple reasons for this, the largest of which is the belief that a stepper motor electric cylinder solution is simply not capable of providing robust, repeatable and reliable motion control. This belief could not be more inaccurate. Stepper motors are very capable motion solution providers, and in many cases offer distinct advantages over their servo counterpart. When comparing a stepper versus servo solution in this paper, it is assumed that stepper versus servo is an apples to apples comparison. It is important to understand and contrast comparable motors as far as size, weight and with torque versus speed curves that are commensurate with each other. This provides a fair evaluation and leads to the most optimum motion solution.

Cost

Generally speaking, stepper motors can be up to four times less expensive than a servo motor of about the same power rating. Servo motor construction is inherently more complex than a stepper motor, and therefore more expensive. All things considered, there is no reason to move to a more expensive servo solution if the electric cylinder application can be solved adequately and reliably using stepper technology.

In today’s competitive global economy, more end-customers continually seek cost effective options in order to compete in the global marketplace. As such, machine builders are considering lower cost alternatives to better serve their customers. One easy alternative for lowering the cost of an electric cylinder is to implement a step motor option. Additionally, stepper motors are most often run without feedback. That is, stepper motors can often be used to propel a linear cylinder without the need for an encoder. An encoder is a feedback device that provides constant feedback in the form of pulses or counts delivered from the encoder device. These encoder pulses are fed back to the drive to keep track of the rotary position, and therefore the linear position of the electric cylinder. Many encoder types are available today. Those employed with electric cylinders are usually optical, but magnetic types are also readily available.

Adding an encoder to a stepper motor can add three or more times the cost of the stepper motor alone. For this reason, it is important to conduct a thorough review of the application and have a clear understanding of the load and the step motor characteristic curve. Knowing where your load falls in the thrust versus speed curve is paramount to the decision to include a stepper motor solution with encoder. In the ideal situation, the cost advantage becomes most obvious when an electric cylinder can solve an application with a step motor that is run open loop without the need for an encoder.

> **“When properly sized for the application and when speeds and torque are taken into consideration, a stepper motor solution can offer significant savings over a servo system.”**
>
> **-Scot Sutton, Cleveland Tubing, Bimba Customer**

Ease-of-Use

Step motors running in an open loop configuration—which is often the case—do not require or use an encoder. A step motor without an encoder can be easily integrated into a machine or system simply by providing a step and direction signal that is usually readily available and provided by a PLC stepper card, indexer or motion controller.

A step signal for a step motor consists of a series of digital pulses or pulse train provided to the step drive in which the frequency of this pulse train is translated by the drive into an appropriate motor command. In many cases, a PLC stepper card is the means by which the control signal is provided to the drive. Once received at the stepper drive, the drive translates the received pulse train and provides the motor with an appropriate amplified drive signal required to move the electric cylinder.

The step drive also has another input provided by a PLC or similar control that accepts a direction signal. This direction signal ensures correct motor shaft rotation, either CW or CCW, and therefore the correct linear motion of the electric cylinder. The advantage of not employing a feedback device on a step motor means that the configuration, degree of difficulty and time to get “up and running” are significantly reduced as compared to a servo motor or an identical step motor using an encoder. A feedback device introduces another hardware component that requires wiring, configuring, monitoring and one type of decision-making or another to deal with the feedback. While it is becoming more commonplace to find step motors used with encoders, it is unquestionably easier to install an electric cylinder with step motor without the subtleties introduced by an encoder.

High Torque

Another benefit of a stepper solution is the high torque rating in a stepper motor characteristic curve. Stepper motors have a very distinct thrust versus speed performance curve. As shown in Figure 1, the torque available from a stepper motor at relatively low speeds, especially under the 1,000 RPM threshold, is quite robust. That is, for electric cylinder applications that are intended to move heavy loads at relatively low speeds, a stepper motor offers great torque advantages. The result of this torque advantage is a clear benefit for moving a load over the capability of a comparably sized servo solution.

A key caveat to this advantage is that the load must be well- defined and relatively static. The distinction here often lies in the dynamic component of the total load or how much acceleration is required. A slowly accelerating heavy load does very well with steppers, while an application where the actuator is required to adapt quickly and change speeds, often resulting in more vigorous acceleration and deceleration rates, lends itself towards servo control. However, many electric cylinder applications are used in applications where the load is well-defined and predictable over time.

An example of a predictable application is a rail adjustment used to alter a conveyor in response to different inputs. Often, these kinds of adjusting applications are used under well-defined, static load conditions and require multiple positioning points that are easily configurable using an electric cylinder with stepper motor. Simply signal the PLC to provide a pre-defined step and direction signal in response to an operator input, and within a short period of time the adjustment will be complete in a fraction of the time needed to perform a manual rail adjustment.

In cases where even higher torque is needed, one might select a larger stepper motor with the same motor frame such as a double or triple stack motor. Double and triple stack motors offer longer motor length featuring more magnetic laminations. These magnetic laminations work together to offer increased magnetic force, which in turn provides increased torque capability and performance.

Another method to achieve higher torque capability within the same step motor is to take advantage of the improved torque versus speed curve that is realized with an increase in bus voltage and current. As illustrated in Figure 1, there is a drastic improvement in speed at a given torque as the input voltage is increased. What this effectively means is that the same step motor can expect approximately 25% to 100% increase in available torque as the voltage is increased in multiple increments. Many step motors are designed with multiple input voltages starting at about 12Vdc up to and including 70Vdc or more. One way to increase the torque output of a stepper motor for a given speed is by simply increasing the applied voltage.

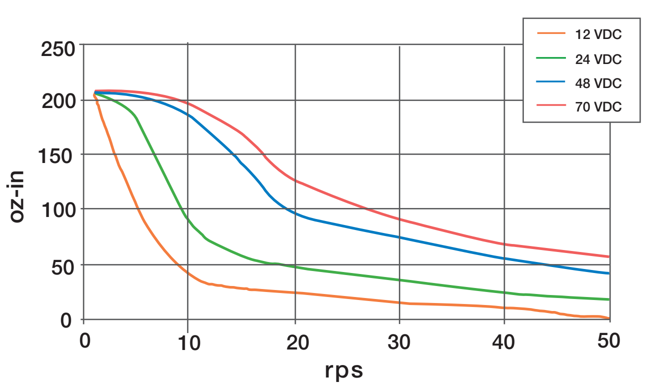

Figure 1

Safety Factor

When selecting a stepper motor based on robust torque at relatively low speeds, one must consider the safety factor. Safety factor refers to the level of "slush" built in to the stepper motor. If the result of using a motor sizing software indicates that 130 ounce-inch of torque is needed to reliably move the electric cylinder load, one should select a stepper motor that offers the required 130 ounce-inch of torque plus a generous "safety margin" of torque. Including an adequate safety margin will help ensure that the stepper motor will perform normally without fear of stalling or missed steps that can often occur when the motor is not sized properly or when a safety margin is not built in to the stepper motor selection.

A commonly used guideline is to select a stepper motor that offers about a 30% to 50% safety margin. So, in our example, if 130 ounce-inch of torque is calculated to move the load, one should select a stepper motor that offers at least 169 ounce-inch of torque. Additionally, one must be certain that when you review the needed torque for an application that the stepper motor offers this torque at the required motor speed.

Motor Speed

Speed is another key parameter that must be carefully selected when sizing a motor. Stepper motor speed is often given in revolutions per second (RPS). When calculating for an electric cylinder, one must know the speed required to solve the application. For example, if the application requires 130 ounce-inch of torque at a speed of 5 in./sec., and the electric cylinder has a 0.25 inch ACME lead or ball screw, one would have to make certain that the motor has a speed capability to turn the motor shaft 20 times per second. This translates to a stepper motor that has a speed capability of 1,200 RPM.

Many stepper motors have torque versus speed curves that begin to fall off sharply at around 1,500 RPM. As a result, one would have to be convinced that the stepper motor could provide the needed performance while ensuring the recommended safety factor. There are many different stepper motors on the market today and many manufacturers offer stepper motors that can meet this need. However, if the speed drop-off is significant at about the 1,500 RPM point, there are ways to cope with confidently sizing your electric cylinder.

One easy way to increase speed is to increase the size of the motor either by using a larger stack motor or moving to a larger frame size, for example, moving from a NEMA 17 frame step motor to a NEMA 23 frame step motor. Many electric cylinder manufacturers can accommodate different size motor frames for their cylinders by making available appropriate motor adapter plates. Choosing an electric cylinder vendor that can accommodate varying motor adaptations for an electric cylinder goes a long way towards achieving an optimal solution.

Electric cylinder speed can also be adapted based on the lead screw pitch used. The shorter thread leads can be used with the higher speed servos using their torque at speeds 2,000 RPM and up. Longer thread leads use the higher torque at lower speeds of the stepper motors. The critical speed of the drive screw is one factor that must be taken into account. The critical speed of the drive screw is that speed by which the screw rotates at an angular velocity, which approaches its extreme limit. Knowing the speed limitations present for a drive screw is a key characteristic that an electric cylinder manufacturer will publish and that a user must heed. One must be cognizant of the critical speed and make certain that the motor selected has a maximum velocity component that falls within the mechanical specification. Staying within the boundaries of the drive screw mechanical limits is critical to achieving smooth, quiet and reliable linear motion.

Holding Torque

Holding torque is yet another step motor characteristic that lends itself to applications requiring the load to be robustly held in position during the dwell portion of a move. Stepper motors, by their nature, are always energized with full motor current running through the stator windings. This is the case even when the motor is not turning. Since they are in an "always energized" condition, one can easily understand that a stepper motor naturally runs "hot," and is subject to more energy use on average than a comparable servo motor.

However, in situations such as vertical moves where the electric cylinder is required to hold a heavy load in a vertical position for a varying period of time, a stepper motor offers a clear benefit. Since the windings are energized 100% of the time anyway, a stepper motor is naturally suited to provide inherent holding torque. Of course, in cases of loss of power or power failures, a heavy vertical load supported by a stepper motor will experience a fall or drop quite suddenly leading to potential damage to equipment, product or people. Care must be taken to cope with these situations with options like a reliable power back-up or a holding break that engages and secures the load upon a loss of power.

Electric Cylinders with Servo Motors

As stated earlier, some design engineers would defend servo motor technology as the only "real" option for precise and reliable control. However, we have already seen many instances where stepper motors offer clear benefits one cannot achieve using servo technology. This is not to say that servo motors offer no benefit. Actually, servo motors offer many significant benefits that a stepper motor simply cannot match. Thus, selecting and using appropriate sizing software can help guide you to the optimum electric cylinder motion solution.

Servo Solutions and Advantages

What are the application situations that lend themselves to a servo solution? What advantages do servo motors bring to an electric cylinder motion solution? The next section will explore some of the benefits that servo motors offer and application situations that clearly call for a servo solution.

As stated earlier, by definition, a servo motor is a motor that uses feedback in its operation. This means a servo motor is characterized by the presence and use of a feedback device. However, modern day step motor controllers have become much more sophisticated than in past years, and use much more complex step drives incorporating algorithms that allow for a feedback device to be used with a step motor. This effectively transforms the step motor into a "servo" since it now has feedback available. For this discussion, a step motor used with an encoder will not be considered a servo.

High Torque at High Speed

Many electric cylinder applications require high-speed travel. An example of this kind of application might be a multi-axis pick and place machine or a diverter function in a high-speed conveyor. In many of these situations, a step motor loses capability above 1,500 RPM and cannot cope with high-speed, heavy load applications. This is especially true in situations where the application is dynamic and the load is likely to change often. In these cases, a stepper motor is unable to cope and would quickly stall or miss steps. This would result in a number of different possibilities from frequent downtime and loss of production to potentially damaged widgets or damage to the machine itself.

In such cases, the benefit of a servo motor is clear. As shown in Figure 2, the characteristic curve of a servo motor is significantly different than that of a stepper motor. There is a prominent torque advantage for servo motors at high speed. In particular, many servo motors on the market today can easily achieve speeds of 3,000 RPM. It is not uncommon for some servo motors to achieve speeds of 5,000, 6,000 and even 8,000 RPM while maintaining usable torque. The advantage of using a servo motor in an electric cylinder solution for moving high loads at high speeds gives the servo motor a significant edge for these types of electric cylinder high-speed applications.

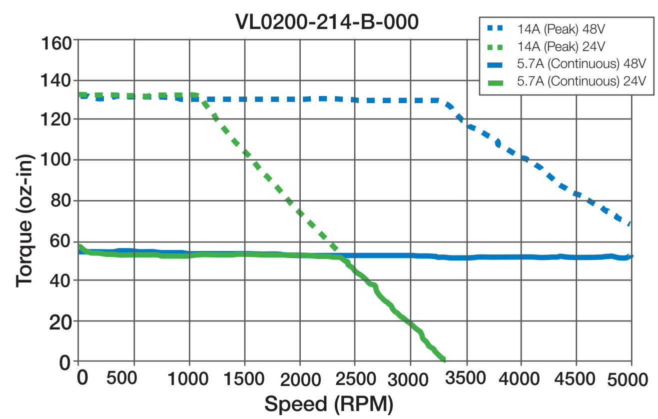

Figure 2

Accuracy

While accuracy and repeatability are very high in electric cylinders using step motors, there is always a chance that the step motor may experience a misstep or stall that could go undetected. In these situations, there is no indication from the step motor and by the time the error is noticed much time may have passed with undesirable results. With a servo motor, the inherent use of an encoder does not allow for position errors to go undetected. A servo drive continuously reads in current position data versus the commanded position data and provides current to the servo motor proportional to the degree of error. Therefore, a servo motor will continuously try to correct for any errors and will drive the motor as necessary to move the load to the desired position.

> **"The precision provided by the electric cylinder reduces waste and helps the bottom-line."**
>
> **-Herb McEvoy, EEC, Inc., Bimba Customer**

Servo drives have the added advantage of including a position fault error limit. In this way, if position error reported by the encoder exceeds the limit, the servo drive will fault the motor, thereby preventing any erratic movement that could lead to potential damage to equipment, product or people. And, the positioning error fault is configurable to allow for more or less error and hence tighter, better-defined control of the electric cylinder solution. For example, if you are using an electric cylinder with a 0.25" lead and electronic gearing of 20,000 with a position error count of 2,000, this means that the maximum error that can be experienced before the servo drive faults is an error of 0.025" (2,000/20,000 x 0.25). The advantage of constant feedback monitoring is more accurate and reliable linear motion control of the electric cylinder.

Speed and Acceleration

Another clear advantage for using a servo motor and drive with an electric actuator is the high-speed advantage gained using servo technology. Servo motors are inherently more capable of achieving high speed at relatively high torque values over a much larger spectrum of the servo characteristic curve. In Figure 2, there are two different curves: continuous curve and a peak curve. The solid green and blue lines represent the continuous curve. These lines represent the level of continuous torque performance that one can expect using this particular servo motor. In effect, the servo motor could be expected to perform admirably at the level for the corresponding torque and speed shown.

It is important to note that the continuous speed rating of the servo motor exceeds that of the comparable step motor. That is, the servo motor provides a respectable amount of continuous torque capability up to 5,000 RPM. Furthermore, increased speed performance is gained when the servo motor bus voltage is increased from 24 to 48 volts. Speed performance in RPM is effectively doubled from about 2,500 RPM to 5,000 RPM. It is evident that if an electric cylinder application is selected for a high-speed application that necessitates speeds beyond about 1,500-2,000 RPM, a servo motor is the optimum solution.

The other curve is defined as the "peak" curve and is represented by the dotted-line. It is well-defined beyond the continuous curve graph. That is, the peak curve advantage is that torque capability is up to twice that of the continuous curve. What does this peak torque do for the electric cylinder application? The peak curve defines the area that the servo motor can operate at extended current, and hence extended torque, for limited time durations from about 1 second to up to 10 seconds or more. The precise time period is motor-dependent and varies by manufacturer and motor type and is sometimes user adjustable.

This peak area offers increased torque capability that allows the motor to more easily cope with dynamic loading applications. Due to this extended working zone, a servo motor is capable of providing short bursts of additional torque over roughly the entire speed spectrum. This burst of extended current capability translates into increased acceleration performance of varying electric cylinder loads.

The improved acceleration performance contributes to completing electric cylinder motion profiles in a shorter period than what would be otherwise possible without this peak curve capability. The improved acceleration allows the maximum speed to be reached sooner and hence allows the electric cylinder move to be completed sooner. This increased performance also contributes to improved performance of higher inertia loads that require more torque to accelerate the load. In some instances, where loading is dynamic, the reserve of torque capability allows more dynamic, changing and flexible motion control that would potentially require a larger, more costly motor if not for the peak current reserve found in a servo motor.

Torque, Velocity and Position Control

Servo motors, taking advantage of their sophisticated control algorithms, provide some control features that are simply not available on step motors. One of these advantages is torque control. Many electric cylinder applications require pressing, holding, pushing and twisting motions all at very precise torques. If the torque applied is too high, crushing of the widget and similar damage can result. If the torque is too low, not enough holding force is created and the end result could be slippage resulting in defects or wasted product. Many servo drives provide torque parameters to allow one to quickly and easily control the needed torque for a particular application.

> **"We needed a very precise grip on our parts with no slippage but at the same time we have a need to not crush our part. The balance between the 2 positions can be as little as plus or minus .010" to meet our quality standards."**
>
> **-Scot Sutton, Cleveland Tubing, Bimba Customer**

This ability to precisely control torque levels at a particular position offers quite an advantage over a step motor. But, step motors and associated drives are not predestined for such control and certainly not for the level of precise torque control that can be accomplished by use of a servo motor and drive. Similarly, servo motors inherently provide the same level of precision accuracy for both velocity and position control.

Servo Disadvantages

Servo motors offer tremendous motion application advantages that should be leveraged in many electric cylinder applications. We have discussed a number of these advantages above. To be fair, there are some disadvantages that one should be cognizant of as well when selecting an appropriate servo motor electric cylinder motion solution. Let's briefly review these disadvantages.

Cost

A servo motor and drive solution is more expensive than a step motor solution because of the complex encoder feedback device found in the servo drive hardware and the algorithms required to drive the motor with the appropriate control signals. The added performance capability found in servo motors that we have described here comes at a premium cost when compared to a corresponding stepper motor solution.

Complex Configuration

Another disadvantage is the complexity involved in configuring a servo motor solution. Servo motors require tuning. Tuning is a method by which the user optimizes the internal algorithms and electronics for controlling the torque, velocity and position of the motor—hence the electric cylinder. In essence, tuning is a process of continually modifying and adjusting the servo drive output signals to the motor so the completed motion profile is achieved in the most smooth, accurate, efficient and precise fashion within the prescribed time frame. Servo tuning has gained a reputation of being an art in the best case and an arduous task in the worse case. Studies show that the task of tuning a servo drive has been found to take anywhere up to 6 hours or more to complete. To be sure, tuning a servo motor is often difficult and time consuming.

While many servo motor manufacturers and providers continue to improve upon the tools available for performing the tuning task, it is always recommended to select a servo motor/drive combination that offers tools to help minimize the work required to tune the servo. An example could be selecting a matched servo motor with a drive that has been designed to function together. That is, the capability of the servo motor parameters such as number of poles, voltage, current capability and inertia are well-suited to the design of the servo drive. Additionally, some servo drive manufacturers provide "pre-tuned" files that eliminate much of the tuning headache by allowing a customer to upload a previously designed tuning file with ideal tuning parameters pre-loaded. In some cases, this pre-loaded tuning file will serve adequately with little or no fine tuning required. However, it is much more common that a user will utilize the tuning file as a starting point for additional manual tuning.

Selecting Your Electric Cylinder

This paper began under the guise that we would identify which motor technology is best suited for your linear electric cylinder solution. It should be clear now is that there is no choice that is better than another. Both step motors and servo motors can serve as the best electric motor solution depending on the motion control parameters involved. Beginning with an electric sizing software tool is often the best starting point. But an even better starting point would be to use an electric sizing software tool provided by a reputable electric cylinder manufacturer.

There are strong reasons for conducting your sizing task using that of a reputable electric cylinder manufacturer, including:

1. An electric cylinder manufacturer sizes mechanical components that are closely matched to that of the electrical specification
2. An electric cylinder manufacturer sizing software tool that offers both step and servo motor solutions without bias will always result in the optimum solution
3. An electric cylinder manufacturer can offer an end-to-end cylinder offering that consists of tested and documented motor, drive and cylinder combinations
4. An electric cylinder manufacturer clearly recommends a solution, and also makes alternative solutions (AC, DC, Integrated, frame size, etc.) available as well
5. With reference to number 1, oftentimes the mechanical limitations of the cylinder may make a particular motor cylinder solution combination appear as a perfect match on paper but not in practice. This means that not all mechanical electric cylinders are created equal.

All mechanical parts used in electric cylinders have limitations. For example, consider an ACME lead screw, ball screw or belt driven electric cylinder that uses a motor coupler to transform the electric rotary energy to that of mechanical linear motion. While it may be a relatively easy task to find a motor that has enough torque at the required speed, it is important to note that the mechanical drive components including lead nuts and motor couplers have limitations in the magnitude of torque and speed they can withstand before premature wear and/or damage may occur. For polymer plastic lead nuts, this limitation is called the PV value. The PV value represents the maximum magnitude of pressure and velocity that a lead nut is rated at and this value must be respected. Some electric cylinder manufacturers do not consider the PV value when specifying an electric cylinder motor solution, which can result in premature failure of the cylinder and associated downtime.

Other electric cylinder manufacturers include multiple specifications: one for the motor and one for the cylinder. In these cases, the two specifications do not match and the overall end-to-end system can only be employed based on the weakest link. Some electric cylinder manufacturers include a duty cycle within the small print of their specification. Duty cycle is a term associated with the amount or ratio of “on-time” of the electric cylinder versus “off-time”. The result of duty cycle is effectively a derating of the cylinder performance characteristic. It is not uncommon to find electric cylinder manufacturers that specify a duty cycle on their electric actuator of 15% or even 10%. This means that the user has to ensure that the motor and cylinder combination are “derated” such that the “on-time” vs. “off-time” is 15%. The end-result is that a cylinder destined for an application that runs 24/7, cannot be outfitted with an electric cylinder solution that has anything other than a 100% duty cycle. This provides more reason to be sure to select a reputable electric cylinder manufacturer that provides thorough electric cylinder performance data matched for the particular motor type and drive.

Conclusion

In conclusion, there are many reasons to use electric cylinders in applications that have traditionally been solved using air cylinders. These reasons include the extreme precision, flexibility, configurability and scalable nature of electric cylinders. In addition, there are many reasons for implementing an electric cylinder application using multiple electric motor alternatives, including step motors and servo motors. One of the best routes to take when selecting an electric cylinder motion solution is to use a manufacturer with sizing software tools that assess the application with respect to complete end-to-end systems. The luxury of a one-stop shop solution is the confidence that all the individual pieces that make up the complete electric cylinder are compatible. This makes the task of selecting an electric cylinder less daunting. As design engineers work to improve machine functionality and efficiency with an electric cylinder solution, remembering to select a manufacturer with a solid mix of tried, tested and verified motor/drive motion solutions along with a reputation for quality will always lead to the optimum solution.

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