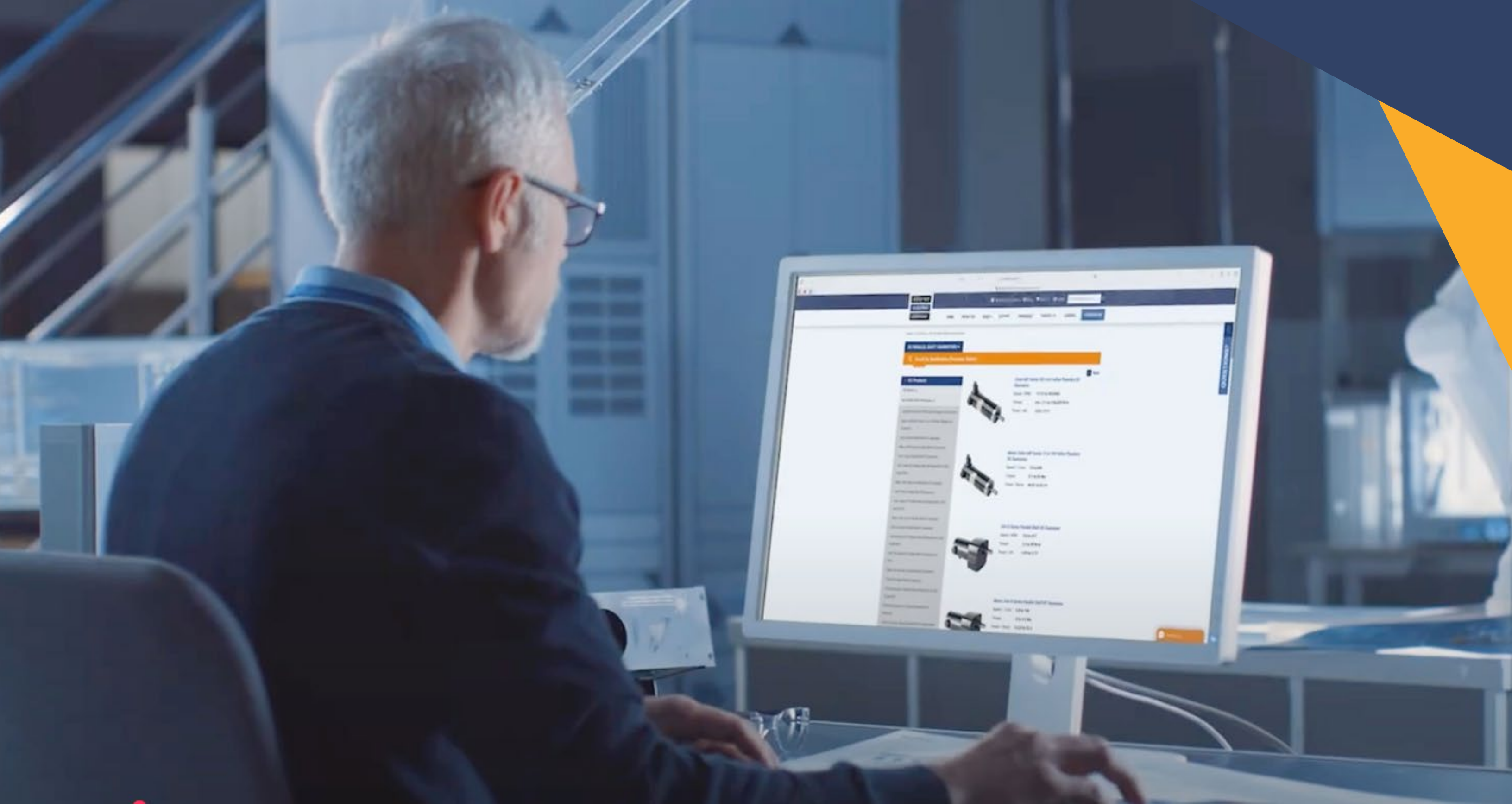


The Engineer's Guide to Selecting the Best Gearmotor

BODINE ELECTRIC COMPANY

Modern machine design is evolving rapidly. Manufacturers increasingly require variable-speed capabilities, and there is a growing shift toward low-voltage configurations. Motors are expected to deliver significant power while meeting long-life demands, which means energy consumption must be kept low to reduce wear-down of a battery-powered system.

"Over the last 10 years, we've also seen more compact designs come into play where people want more torque in a smaller package," says Eman Elashye, application engineering manager at Bodine Electric Company.

These shifting demands make it essential to size and select gearmotors with precision. If a gearmotor is oversized, it adds unnecessary cost. On the other hand, undersizing a motor may result in damages.

"The motor could overheat and fail if undersized," says Terry Auchstetter, director of marketing and product development at Bodine Electric. "Or short brush life might be a consequence—or short gearing life, where the gears wear out prematurely if subjected to a load greater than designed for."

This whitepaper provides a structured approach to selecting and sizing gearmotors for optimal machine performance. By carefully evaluating application requirements and translating them into gearmotor specifications, engineers can select the best gearmotor for their machine design.

Reviewing Application Requirements

Power Supply - The nature of the machine being designed, and its intended point of use, dictates whether the available power supply is AC or DC. A machine that is installed inside a building and is stationary, like a conveyor, would normally be powered from the building's AC line. But a mobile machine, like a factory robot, and a stationary machine installed in a remote area, like a chemical pump in an oil field, would normally be powered by a DC battery.

Note that an AC power supply does not automatically dictate the use of an AC motor.

"One of the things I would say is that even in a factory where the power supply is AC, that doesn't necessarily rule out using a brushed DC motor," says Auchstetter. "They can operate from controls that convert AC to DC."

Mike Wojciechowski, regional sales manager at Bodine Electric, explains further. "There are times when a customer will call me and say they need an AC motor, not even considering that a DC motor might work as well. But I can suggest a DC motor operated from a 115 VAC power supply by feeding it through a speed controller. So, 115 VAC into the controller comes out as 90 VDC or 130 VDC to run a DC motor."

Besides operating DC motors from an AC supply, there is also the possibility of operating 3-phase AC motors from a single-phase AC supply. "There are AC controls (inverters or variable frequency drives) that take 115 V single-phase in and can provide 230 V three-phase out of the speed control to drive a 3-phase inverter-duty motor," explains Wojciechowski. "So, while the power supply is very important, it's not as limiting as a design engineer might think."

Motion Characteristics – The nature of the machine being designed can also influence the type of motor selected, or the size of the motor selected, or both. One consideration is whether the application requires adjustable output speed from the gearmotor. "If it's a fixed-speed application, we can stick with AC motors if the power supply is AC," says Wojciechowski. "But if it is a variable speed application, we can explore both AC and DC options." That option was already covered in the discussion of power supply.

Image: Bodine.

Another consideration related to motion characteristics is the duty cycle expected for the gearmotor in the machine — i.e., whether the motor will run continuously, operate intermittently, or experience fluctuating loads. An example of continuous operation is a High-Volume Low Speed (HVLS) fan in a factory which runs for as long as the factory is open for business. An example of intermittent operation is a security gate at a parking lot. The gearmotor runs briefly to raise the gate, stops, then runs briefly again to lower the gate, and finally rests indefinitely while waiting for another vehicle to enter or exit.

"An example of a fluctuating load is a conveyor belt on a checkout stand in a grocery store which runs at a steady pace, but when a customer places a heavy bag of dog food on it, the motor needs to handle a short-term surge in torque," explains Wojciechowski. "If a gearmotor isn't designed to accommodate these peaks, you're going to have problems eventually."

One reason the motion characteristics can influence the type of motor selected is that some motor types are not suitable for frequent starts and stops. For example, a split phase AC motor draws much more current during starting and can overheat if started more than six times per hour. The duty cycle can influence the size of the gearmotor that can be selected. In an intermittent duty application, a gearmotor can be sized based on its peak torque capability rather than its continuous duty rating by using the Root-Mean-Square (RMS) Torque calculation shown in Figure 1. Using a smaller gearmotor can reduce the cost of the machine. A smaller gearmotor also takes up less space and can allow the machine to be designed to be more compact.

Figure 1.

TIME (seconds)	TORQUE (oz-in)
0.5	140
30	100
300	0
0.5	140
30	100
300	0

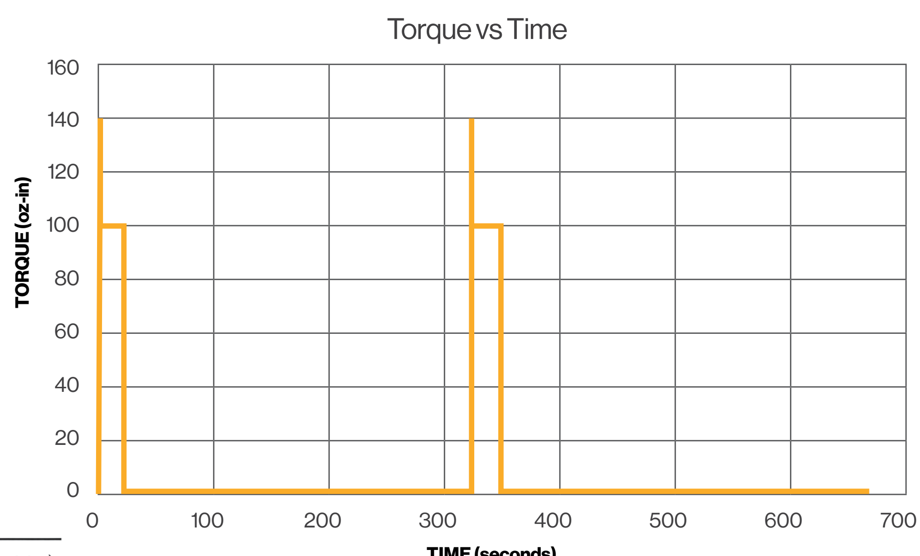
$$T_{rms} = \sqrt{\frac{\sum (T_i^2 \times t_i)}{\sum (t_i)}}$$

where T_i = torque required during each time interval
t_i = length of each time interval

In our example, the result is:

$$T_{rms} = \sqrt{[140^2 \times .5) + (100^2 \times 30) + (0^2 \times 300)\,] \div (.5+30+300)}$$

$$T_{rms} = 30.6 \text{ oz-in.}$$



Gearmotor Output Speed – The output speed required from the gearmotor can usually be calculated. In many machines, the rotational motion of the gearmotor is translated to a linear motion like a conveyor. The output speed of the gearmotor is dependent on the linear speed of the belt, the diameter of the rollers, and whatever the ratio is for the linkage between the gearmotor output shaft and the conveyor roller (chain & sprocket or belt & pulley, for example). See Figure 2 for an example calculation.

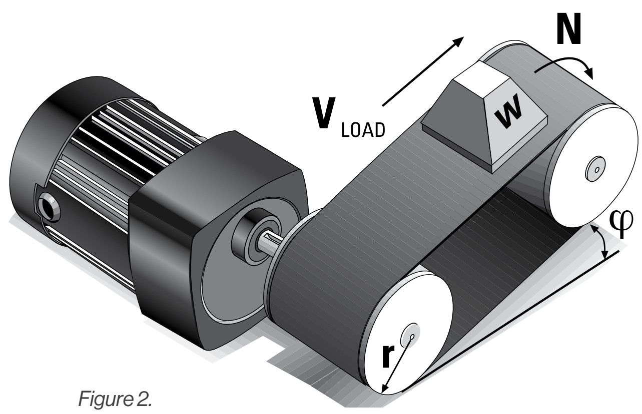


Figure 2.

EXAMPLE:
If the linear speed of a belt is 5 m/s and the pulley has a radius of 0.25 meters, then the angular speed would be:
ω = 5 m/s / 0.25 m = 20 rad/s.

To convert this to RPM:
N = ϖ * 60 / 2π.

A conveyor dryer used in the t-shirt screen printing industry. Image: Bodine.

The linear speed of the belt is dictated by its function. For example, the conveyor that transports a freshly screen-printed t-shirt through a dryer must run at a specific speed for the t-shirt to spend enough time inside the oven to dry completely. The speed can be calculated from the length of travel inside the oven and the time required for that travel.

Gearmotor Output Torque – Various methods exist for measuring forces such as breakaway and friction torque, from simple string-and-pulley setups to torque wrenches and test motors. See the sidebar "Methods for Measuring the Breakaway and Friction Torque of a Machine."

The Test Motor Method is especially popular with Bodine Electric's application engineers. In many cases, engineers test with a DC motor because of its direct relationship between current and torque. "I can take a DC gearmotor that I think is close to what the customer needs, install it in their application, and evaluate its performance in real-time," says Wojciechowski. "During load testing, I can see if there are any intermittent current spikes or if there is a consistent, continuous overall draw of the current — so we know it's a smooth load."

This hands-on approach helps identify whether a motor accelerates properly, runs at the right speed and delivers the necessary torque under load. If adjustments are needed, fine-tuning often comes down to modifying the gear ratio or making minor design tweaks.

"When we're able to measure the current draw in the application, we're able to get a pretty accurate torque requirement," says Elashye. "That helps us design a motor — whether it's DC, AC or brushless DC — that truly matches the application."

Methods for Measuring the Breakaway and Friction Torque of a Machine

Excerpt from the Bodine Handbook, chapter 7, and the Bodine Selection Guide

The String and Pulley Method

Affix a pulley to the shaft of the machine to be driven (see Figure A). Secure one end of a cord to the outer surface of the pulley and wrap the cord around it. Tie the other end of the cord to a spring scale. Pull on the scale until the shaft turns. The force, in pounds indicated on the scale, multiplied by the radius of the pulley (in inches) gives the breakaway torque in pound-inches.

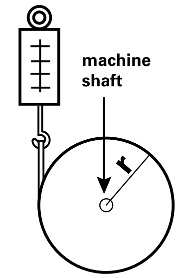


Figure A–Simple "string and pulley" method of torque measurement (Torque = Force reading on spring scale mulitplied by radius of the pulley)

Torque Wrench Method

A simple torque wrench can be applied to the shaft of the machine to be driven. Turn the wrench as you would an ordinary pipe wrench, and when the shaft begins to rotate, read the value for $T_{BREAKAWAY}$ (in ounce-inches or pound-inches) on the torque wrench gauge.

Test Motor Method

Both AC and DC test motors or gearmotors can be used to measure breakaway torque, ($T_{BREAKAWAY}$), and friction torque, ($T_{FRICTION}$). This method requires more time and instrumentation, but can be well worth the expense in the long run. It is the best way to optimally match machine and drive unit, and is popularly used for all high volume OEM (original equipment manufacturer) applications. After using these methods, contact the motor manufacturers' sales engineer for help in interpreting the data.

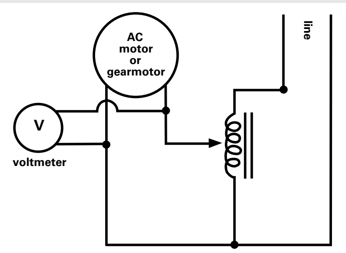


Figure B–AC motor or gearmotor with adjustable autotransformer, and voltmeter connected for load measurement.

Test With An AC Drive– Use a torque wrench or "string and pulley" to find the approximate size of the test motor or gearmotor needed. An AC motor or gearmotor whose rated output speed is close to the desired "final" speed of the machine should be obtained. Next, hook up the AC drive, along with a variable autotransformer to the load (See Figure B). With a voltmeter connected to the line, increase the voltage supplied by the autotransformer until it starts and accelerates the load up to speed (to check speed use a tachometer or stroboscope).Record the starting voltage at all possible starting locations of the device. This is proportional to the $T_{BREAKAWAY}$. Next, back off slowly until the motor stalls. Read the voltage. This is proportional to the $T_{FRICTION}$.

*"Test" With A DC Drive–*The DC method requires that both voltage and amperage readings be taken from the armature circuit (See Figure C). Speed of the DC motor is proportional to the voltage while $T_{FRICTION}$ is proportional to the armature amperage.

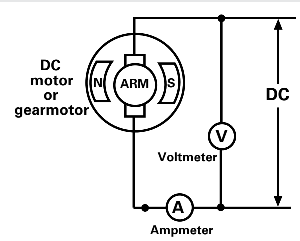


Figure C–PMDC motor or gearmotor with voltmeter and ampmeter connected for load measurement.

However, on-site load testing isn't always an option. Application engineers sometimes have to rely on customer-provided data and perform calculations internally. "A customer might say, 'I have an 8-foot disc, it weighs 100 pounds, and I need it to run at 10 RPM in so many seconds,'" says Elashye. "So, we end up running some calculations as well. It's nice to have both options."

Translating Application Requirements to Gearmotor Specifications

Once a machine designer has determined the basic requirements for the gearmotor he needs — Rated Voltage, Fixed/Adjustable Speed, Rated Speed, Rated Torque — they can then start the search for a specific manufacturer and model that meets those requirements. Many gearmotor manufacturers have a product search tool on their website to facilitate that search. But searching on those four criteria alone can produce many contenders to compare. How does the engineer choose between them?

Maintenance – One thing they might consider is the maintenance aspects of different motor types. As stated earlier, just because the available power supply is AC doesn't necessarily rule out using a brushed DC motor, especially where adjustable speed is needed. "But the maintenance needs might convince a customer to go with a three-phase inverter-duty gearmotor instead of a brush-type DC gearmotor," explains Auchstetter. Brushes in a DC motor naturally wear out over time and must be replaced by virtue of their function, like how the brake pads in an automobile wear out and have to be replaced. Going back to the duty cycle of the application, if the gearmotor operates intermittently in the machine, the brushes may never wear out and may never need to be replaced. But in a 24/7 operation, brush replacement may be so frequent as to be impractical.

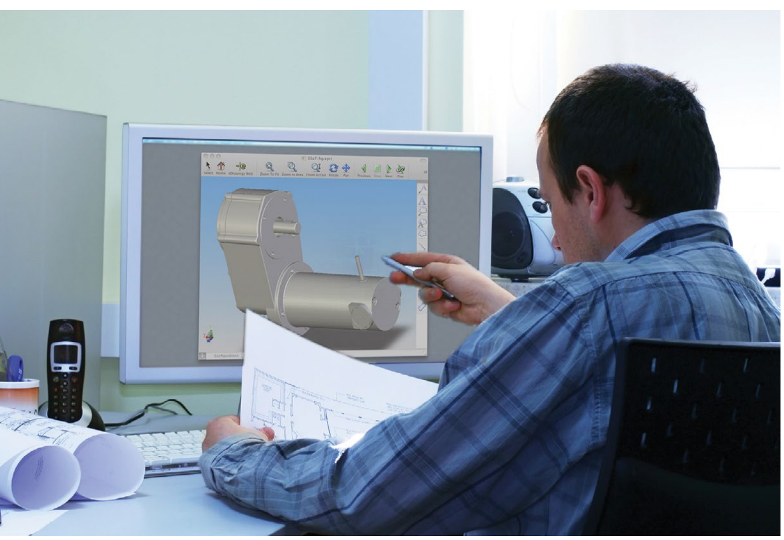


Image: Bodine.

Cost – A fixed-speed application in a factory environment where AC power is available presents the opportunity for the lowest cost gearmotor. A single-phase AC gearmotor can be used with no need for a speed control. If adjustable speed is needed and the duty cycle is not extreme, then a brush DC gearmotor with a basic SCR control is the least expensive system. If adjustable speed is needed and extreme duty is required where brush maintenance is impractical, then a 3-phase AC gearmotor with an inverter is probably the best cost option. But if extreme motion requirements like quick starts and stops, closed-loop speed control and point-to-point positioning are necessary, then the best option might be a brushless DC gearmotor with a servo controller.

Space Constraints – It was already pointed out that sizing the gearmotor based on the peak torque requirement in an application with an intermittent duty cycle can provide a smaller gearmotor. But space constraints can also influence the choice between a right angle gearmotor and a parallel shaft gearmotor. "Other factors may dictate going with a right-angle gearbox versus a parallel shaft gearbox — for instance, size constraints," says Wojciechowski. "If a parallel shaft gearmotor sticks out too far and you just can't make it work, you must go with a right-angle gearbox." A common example of that is a conveyor, where a parallel shaft gearmotor may protrude from the side of the conveyor and present an obstacle to people walking around it.

Quiet Operation – Some applications are more sensitive to noise than others. Two examples are a motorized shelving unit in a quiet library and a test instrument in a quiet laboratory. The sound produced by the friction between the brushes and the commutator in a brush-type DC gearmotor may be objectionable in adjustable speed applications like these. An alternative might be a three-phase AC gearmotor driven by an inverter. But the high-pitched electrical noise from that system might still be objectionable. The best alternative might be a brushless DC gearmotor and speed control. The need for quiet operation can also influence the type of gearbox selected. Spur gearing, especially when made of hardened steel, is the least quiet. Non-metallic gears can reduce the noise, but in exchange for less torque capacity. Worm gearing, with its rolling action, may be the better option.

Environment – Environmental conditions are another consideration when choosing between several gearmotor options that all meet the basic speed and torque requirements. A wet or dusty environment may persuade engineers to go with a gearmotor having an ingress protection rating higher than that of an exposed IP20 product. A gearmotor rated IP44 is protected against splashing water, whereas a gearmotor rated IP66 is protected against high pressure water jets, and a gearmotor rated IP69K is designed for applications where it is exposed to high-pressure, high-temperature washdown in food processing facilities.

Self-locking – Right-angle worm gearboxes are often used in applications that require self-locking. That means that the gearmotor holds the load in place, usually opposing gravity, when power is turned off. "A good example is a stair lift," says Wojciechowski. "If the power goes out halfway up the stairs, you want that seat to hold in place." Any other gearbox type would require use of an additional holding mechanism, like an electromechanical brake, to keep the load in place.

Conclusion

When selecting the right gearmotor for a new machine design, Bodine Electric Company's approach is grounded in extensive experience.

"The advantage that Bodine brings is that we are a gearmotor manufacturer," says Elashye. "We are designing both the motor and the gearhead as a combination to provide the customer with the best product for their application, in terms of efficiency, torque and size."

Another advantage Bodine Electric has is their ability to offer custom solutions. While one of their 1,500 standard models may work in many cases, many other applications can benefit from a more tailored approach. Auchstetter encourages engineers to consult with Bodine to better address the unique demands of their projects — so that the right gearmotor is selected from the outset.

"A big chunk of Bodine's business is custom products," says Auchstetter. "The only way to get a custom product designed perfectly is to talk to our sales engineers."

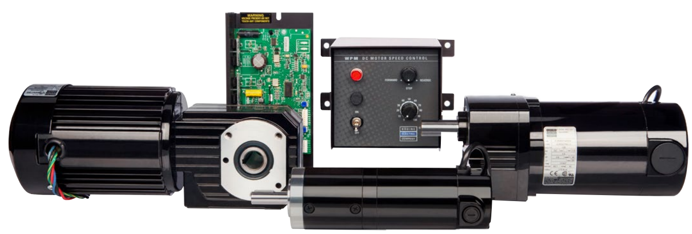


Image: Bodine.

To learn more about selecting the best gearmotor for your application, and then talk to a Bodine application engineer, visit www.bodine-electric.com/resources.

BODINE
ELECTRIC
COMPANY