Choosing the Right Motor Technology for Miniature Pumps

Medical Design Technology

As medical device trends continue toward smaller devices, manufacturers are looking to miniature components for greater capabilities. As such, miniature pumps are being sought that deliver more enhanced performance. However, ensuring the right motor technology is driving the pump to achieve the desired result can be just as great a challenge.

Miniature pumps are devices that utilize different technologies—diaphragm, gear, vane, peristaltic—to pump a fluid or create pressure or a vacuum. These pumps are typically less than 5 in. in height and draw <100 Watts of power.

Blood gas analyzers, gas samplers, and oxygen concentrators are a few of the applications these pumps serve. Today, they use a variety of motor technologies, ranging from DC to AC to stepper. Engineers are confronted with requirements for flow, pressure, lifetime, and noise, just to name a few. While there are parameters of design that can be changed within the pump, the critical item to the pump performance is the motor selected, since it generates the flow, pressure, or vacuum.

Proper motor selection leads to optimum pump performance, resulting in a more efficient end product. The spectrum of applications these pumps serve have different price to performance needs. Pumps are customized to meet these needs; engineers may select a different motor and/or technology for the same pump.

Three primary motor technologies are used in miniature pumps—brush DC, brushless DC, and stepper—but each category has at least two sub-technologies as well. This presents the pump design engineer with multiple options from which to select, each having advantages and disadvantages. How do they make the motor technology selection? What factors are involved in the decision? First, a little more information is needed about the available technologies and then, the decision making process can be reviewed.

Brush DC

Brush DC motors have two basic categories—iron core and coreless. Iron core technology consists of a skewed piece of iron surrounded by a conventional winding, covered by the magnet. The motor is encased in an all-metal housing. Coreless motors feature a self-supporting ironless coil, giving them low inertia and high efficiency. Iron core motors are easier to manufacture, based on their simple design, while the coreless coil is more complex. This complexity limits the maximum length for the coreless design, which is not the case for the iron core. However, coreless motors provide advantages in efficiency (30% higher), weight (20% less), and inertia (60% less). In addition, Neodymium Iron Boron magnets provide an increased power density for coreless motors, reducing the package size of any application.

Brushless DC

Brushless DC motors also have two basic categories—slotted and slotless. Slotted motors are based on an iron core technology, utilizing a wound stator typically with nine to 12 slots. These motors are typically four pole and three phase, and feature high power density and a small thermal resistance between the coil and the housing. Slotless motors are based on an ironless core technology, utilizing a custom wound coil. The motors are typically two pole and three phase, featuring zero cogging, reduced iron losses, linear torque versus speed and excellent speed control. Slotted motors typically run at a lower RPM (2,000 to 4,000 RPM) and produce higher torque, making them ideal for lower flow applications. Slotless motors run at a higher RPM (8,000 to 16,000 RPM) with lower torque, suited for higher flow applications.

Stepper

Stepper motors have three basic technologies—can stack, hybrid, and disc magnet. Can stack is the most basic technology with components made from stamped metal parts. A multi-pole rotor and multi-tooth stator are surrounded by two wound bobbins, producing rotation as current passes through the coils. The mechanical poles provide fine precision but prevent higher speeds from being achieved. Hybrids are made from machined parts, so step resolution is finer and torque is greater. These motors are typically larger than can stack. Disc magnet technology is unique, using a thin disc magnet versus the typical cylindrical rotor. This thin disc provides lower detent torque and enables higher speed rotation. The reduced magnet material produces lower torque, while enabling higher accelerations.

Pump Application Factors

With three primary choices of motor technologies, a pump design engineer has the difficult task of selecting a technology to meet application costs and performance needs. Fortunately, the motor technologies offer distinct advantages and disadvantages as it applies to the basic pump variables—flow/pressure, life, weight, noise, temperature, feedback, and current draw. The pump application will dictate the importance of each of these criteria, which guides the engineer’s decision on motor technology.

The flow or pressure of a pump is the key driver of the output for the application. Maximizing the flow or pressure in the smallest package leads to the optimum end product. The key variables for the motor are the torque and speed, directly affecting the pump flow or pressure. Steppers and DC motors have lower top end speeds than brushless DC motors, but sub-technologies can offer different performance gains. Disc magnet steppers can run at higher speeds while slotted brushless DC motors can offer increased torque. The flow or pressure dictates the working point—the torque requirement at a speed. A chemical pump application may require a different flow depending on the viscosity of the chemical being pumped. The working point required may cross several motor technologies, so the other requirements of the application are then considered.

Pump life (hours of operation) can be a key consideration for the application. Medical products, such as oxygen concentrators and anesthesia machines, require the pump to last many hours of operation without degradation in performance. The key point of wear common to all motors is the bearings. Two main types of bearings are available—sleeve and ball. Sleeve bearings have lower force and life ratings (approximately 3,000 hours), but at a lower cost. Ball bearings offer significantly longer life (approximately 20,000 hours) and withstand higher radial and axial loads (typically twice as high as sleeve bearings), making them ideal for demanding applications, such as medical therapy systems. The increased life does carry a higher cost.

Another consideration for pump life deals with the commutation used for the motor—brushes or electronics. Iron core and coreless motors utilize brushes for commutation, which wear over time due to friction and arcing. Motor life is dictated by the material of the brushes used. Options are available to extend the brush life, including precious metal materials. Brushless DC and stepper motors commutate via electronics, so there is no need for brushes. As such, there are no brushes to wear out and the motor life is limited mainly by the bearings. Again, medical applications, such as nebulizers and ventilators, require the long life of brushless DC motors.

Efficiency is measured by the effectiveness of the motor to convert electrical power input into mechanical output power. This is critical for applications that run via battery, since lower power consumption leads to longer battery life, or longer time between battery charging. The coil plays a key role in the efficiency of the motor, with slotless or coreless designs providing the most efficiency. Based on their unique coil design, the mechanical losses are minimal and the power provided to the motor can be converted into output power most effectively. Slotted design, seen in the stepper and iron core motors, are the least efficient as the high iron content produces significant electrical losses. Another advantage of the slotless coil design is reduced weight. Portable applications, such as gas analyzers, benefit from utilizing coreless and slotless motors.

Conclusion
With all of these pump requirements affected by the motor selection, it is easy to see why selecting the motor would be a challenge, much less the optimum technology. Often, a tradeoff must be made between parameters, in order to satisfy the end customer requirements. The engineer will benefit from the education of the features and benefits by technology, which will make his or her job simpler and easier.

Dave Beckstoffer *is a project manager for* Portescap *[1]. He is responsible for evaluating North American strategic opportunities for ideal motor solutions and managing them from concept to final design. Beckstoffer can be reached at 610-235-5499 or* sales.america@portescap.com *[2].*

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