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How Hybrid Stepper Advancements Improve Medical Pump Performance



by Dave Beckstoffer

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Improve Your Medical Pump Performance With Hybrid Stepper Motors

Designers of medical pumps often have to deal with the challenge of implementing precise yet low cost motion control. For most medical pumps, there are three basic technology alternatives for implementing such electronic motion control: permanent magnet brush DC motors, brushless DC motors or step motors. Step motors (sometimes called stepping motors, stepper motors, or simply steppers) are a solid choice for position or speed control. Steppers are inherently digital - a pulse applied to the drive electronics results in a shaft movement of one step. They are commonly used “open loop”, meaning without feedback, due to their ability to achieve the desired number of steps every time (if sized properly). The number of incoming pulses and the rate at which they are fed can be used to implement very precise, yet very simple motion (position, speed and acceleration) control. As long as the speeds required are not too high (less than 3000 RPM, typically), steppers often offer a far simpler, lower cost and maintenance free alternative.

There are three types of rotary step motors: canned stack, VR (variable reluctance) and hybrid step motors. Canned stack or PM (permanent magnet) steppers are made with “claw toothed” (stamped) parts and permanent magnets (radially magnetized) in the rotor. Unlike canned stack steppers, VR steppers do not have any permanent magnets in the rotor and they rely on an induced magnetic field in their serrated (notched) rotor for their operation. A hybrid of the two technologies (permanent magnet as well as “reluctance” serrations in the rotor and stator) has resulted in hybrid stepper motors.



Hybrid steppers are generally made with precise machined parts and offer finer resolutions (usually 1.8° or 0.9° step angles) when compared to canned stack steppers, which normally have coarser resolutions (3.6° to 18° step angles). The canned stack design however is less expensive, based on its stamped metal parts versus the machines parts for a hybrid design. Hybrid steppers are an excellent choice where low cost yet precise shaft position control with fine resolution is required, such as hospital infusion, syringe and peristaltic pumps. In each of these types, the delivery rate will vary based on the medicine and status of the patient.



Hybrid Motor Construction

The operation of any electric motor can be viewed as the interaction between its stator and its rotor. In a hybrid stepper, electrical current in the coils around each stator slot creates electromagnetic poles in the stator. The serrated teeth in the rotor, which also has a permanent magnet ring in it for reinforcement, line up with the serrated teeth in the stator. The force with which this alignment takes place produces the torque (or rotating moment) in the rotor shaft. With switching electronics, the next coil is energized and the rotor moves (steps) again to align itself to the new position of the magnetic pole in the stator. As the coils are energized sequentially, smooth rotating movement is achieved. If more torque is required, it can be seen intuitively that either the stator's magnetic pole has to be strengthened (more coils, more current or larger diameter) or the rotor's magnetic pole has to be strengthened (stronger magnets or larger diameter rotor).

The number of coils, the number of wire turns in each coil, the relative number of teeth in the stator and rotor, the diameter and flux density of the magnet, are all of the parameters that are used in the design considerations of

the motor. From an application stand point; it is sufficient to say that the geometry of the motor and therefore its step angle per step are all fixed when the motor is chosen. There is generally a great deal of flexibility in the windings however for trading off speed versus the torque produced for a given power output which is a product of speed and torque.

The method of driving the hybrid stepper can be full step, as described above, moving from one mechanical step to the next. Microstepping is an extension of the concept of half stepping, the creation of an electrical step between the mechanical steps of the motor. The current levels are increased sequentially in the windings in smaller increments, further improving the position resolution. It is common to see drivers that can deliver 1/4th step per step, 1/8th step per step, 1/16th step per step, 1/64th step per step and so on. Beyond 1/256th step, such finer resolutions are beyond the mechanical accuracies of the motor. With the declining costs of microstepping and the benefits to be had in terms of smoothness of operation, it is always a good idea to consider microstepping as an option even in cost sensitive applications.

Neodymium-iron-boron high energy magnets
Deliver optimized torque density

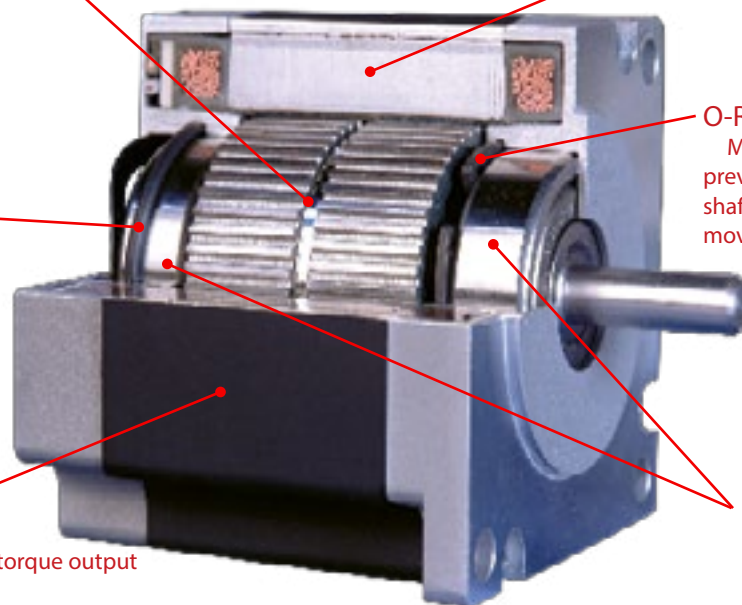
Stator-enhanced magnets
Deliver up to 30% more torque in the same package

O-Ring
Prevents bearing spinout

O-Ring
Minimizes motor noise, prevents spinout, and eliminates shaft axial play from bearing axial movement

Aluminum Housing
Helps dissipate heat for improved torque output

Larger Bearings
Allow higher side and radial load capacity



Hybrid Stepper Motor Improvements

Today's design engineers have been given a new weapon to combat their design goals. The challenge to the engineer is decreasing the overall size of the pump, while maintaining or even improving the performance of the pump. The mechanical design will influence the overall package size of the pump, making the motor selection critical. Advancements in the design of hybrid steppers have allowed design engineers to reduce that package size while even adding performance to the pump. I will review these advancements and how they assist the engineer in the design of their medical pump.

Holding Torque

In order to reduce the overall package size of the pump, the engineer can overdrive the hybrid stepper to increase the output torque of the motor. While this is an acceptable practice (as long as the duty cycle is considered), it brings into play the temperature rise of the motor, both in terms of generated heat as well as torque degradation over temperature rise. The addition of an aluminum housing to enclose the stator laminations improves both of these issues. Heat dissipation in a typical hybrid stepper is accomplished only through the aluminum end bells, which requires additional consideration in the machine design such as airflow or a Heatsink. The aluminum housing, however, provides a conduit to dissipate the heat along the entire length of the stepper, making it much more efficient. Torque loss due to temperature rise is decreased, providing more output performance given identical conditions as a typical hybrid stepper. This combination allows the engineer to increase the duty cycle of the pump, allowing more efficient dosage to the patient. By generating less heat during operation, the pump stays cool to the touch, when patients or nurses need to adjust the medication.

Larger Captured Bearings

Hospital pumps that reside by the patient's bed need to be

quiet during operation, to keep from disturbing the patient during rest. Audible noise from the motor, therefore, is a key design consideration for the engineer. Noise from step motors can be generated by the bearings; any slight movement from the bearings at operating speed will create audible noise. Capturing both the front and rear bearing will provide a significant reduction in the noise generated by the motor. A snap ring for the front bearing and an O-ring for the rear bearing do just that, preventing the bearing movement during operation. An additional enhancement for the pump design engineer is the virtual elimination of shaft endplay. For pump designs, this prevents movement from the shaft-coupling device, which increases the lifetime of the pump since the risk of mechanical failure is significantly reduced.

Torque Linearity

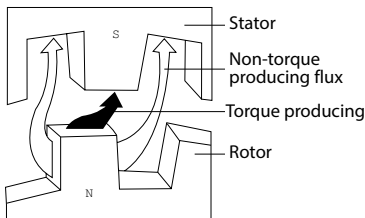
Dosing requirements for the pump can vary, depending on the fluid or drug being dispensed. In many applications, the amount of fluid can be quite small, which requires the hybrid stepper to be micro-stepped - creating electrical steps between the mechanical steps of the motor. Typical hybrids have stator laminations that are indexed and stacked, being secured between the two end bells via four screws. The use of the aluminum housing better aligns the laminations during manufacturing, creating a more uniform air gap between the stator and rotor teeth. During microstepping, this creates improved torque linearity - the torque output consistency for each microstep. Further improvements in torque linearity are seen using the stator-enhanced magnets, providing the maximum performance capability of the motor. In drug delivery pumps in hospitals, both infusion and syringe, this gives the Medical staff the ability to utilize finer doses of medicine to their patients. In addition, it ensures that the precise amount of medicine is dispensed to the patient each and every time.



Enhancement of Magnetics

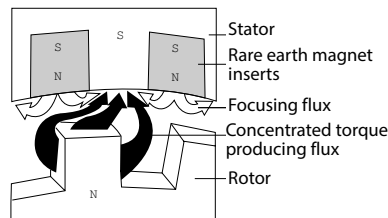
Another key requirement of any pump application is pullout torque, the torque the motor will produce at a given speed. Since a motor has a defined amount of torque it can produce at certain drive conditions, this will dictate the size of the motor required in the application. So an increase in the torque of the motor will correspond to a reduction in the size of the overall pump. The magnetic design of the hybrid stepper plays a significant role in the torque produced by the motor, and two magnet advances are giving design engineers added flexibility.

Standard Stepper Motor



Typical paths of flux transfer in an energized conventional hybrid step motor. Some flux leakage occurs in normal operation.

Enhanced Stepper Motor



Patented enhancing technology redirects magnetic flux to inhibit leakage and optimize torque production.

First, high-energy Neodymium magnets are used in place of previous materials, producing a higher magnetic flux, which translates to higher torque. Second, additional

stator magnets are inserted between each stator tooth, which block the magnetic field from flowing around the stator teeth. This forces more of the magnetic field to flow through each tooth, increasing the torque output by up to 30%. Both of these design improvements allow engineers to specify smaller motors, reducing overall package size and weight.

Holding Torque

Typically, the design engineer will specify a standard motor in the initial stages of development, performing a variety of tests to ensure that it meets the application requirements. Several iterations of the motor are common, since the mechanical design will change over the course of the project, changing the requirements of the motor. But the advancements in the hybrid design have shortened this design cycle, since the motor has been optimized for operational performance. Changes in the requirements of the motor have less affect on the motor selection, especially since the same size motor can have its torque increased up to 30% using the stator enhanced magnets. Speed to market is always a key performance indicator in any project; exceeding initial projections can result in increased revenue for the company.

Summary

The hybrid stepper advancements are indeed enhancing the ability of design engineers to bring exciting new pumps to the market. The medical professionals, as well as patients, are requiring constant innovation in design, challenging the engineer to be creative on the drawing board. By taking the hybrid advancements from the drawing board to production, the motor engineers have bolstered the arsenal when it comes to choosing steppers.

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