

# Gaining a Competitive Edge Using “Slotless” Brushless Servo Motors

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Most machine designers have heard about slotless motors and their capacity to improve machine performance. Benefits of slotless motors include more torque per frame size, higher speeds, more power, and smooth operation. When choosing a servo motor for a particular application, many designers pose two fundamental questions about brushless servo motors:

1. How is this technically possible? Did you re-write the laws of physics?
2. How can I leverage this capability to increase my machine performance?

## Understanding the Technology

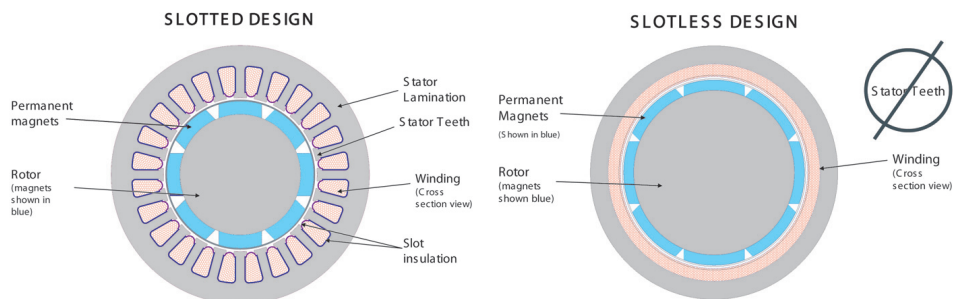
To understand the technology, let's examine the basic construction differences between a traditional slotted and a “slotless” motor.

A slotted motor has a stator (the stationary part) made of stamped metal sections called laminations that are combined together to form teeth. The wire is wrapped around these teeth, and when current flows in the wire an electro magnet is created. The permanent magnets are fixed to the rotor (the rotating part).

The slotless motor stator is built without the use of stator teeth. The windings are wound on a mold and encapsulated in some fashion to hold them in place. The elimination of the teeth yields many benefits. Similarly to the traditional slotted motor, the permanent magnets are fixed to the rotor.

## Why slotless motors perform better

**Higher Torque** – Redesigning the stator allows the rotor to be significantly larger. Torque increases proportionally to



the diameter of the rotor, so a significant increase in torque can be realized in a similar motor size. Torque is further increased because the area available for the winding is greater, due to the absence of the teeth. The resulting torque at speed can be increased by 10 to 25% compared to a slotted motor.

**Higher Speed** – As the magnets pass by the teeth in the slotted motor, a change or modulation in the magnetic flux is created, which in turn causes an induced voltage in the surface of the magnets per Faraday's Law ( $e=d\phi/dt$ ). The magnets are conductive so a current flows in them. These currents, called Eddy currents, increase exponentially with speed and create heat in the magnets. Magnets lose strength as they get hotter. Because these teeth do not exist in a slotless motor, speed in excess of 32,000 rpm can be achieved.

**Higher Power** – Power is a measurement of the work that is done. It is calculated by multiplying torque x speed. The result is that a slotless motor can produce more than twice [2x] the power of a slotted motor.

**Smother Motion** – As the magnets on the rotor of the slotted motor move past the iron teeth of the stator, they are magnetically attracted to the teeth. This creates a torque disturbance known as

cogging. Because there are no teeth in a slotless motor, this magnetic cogging effect is eliminated, yielding smoother motion.

**Easier Tuning** – Motors with larger rotor inertias can be easier and simpler to tune. If the load becomes momentarily decoupled from the motor (a common phenomenon), the servo loop is less likely to become unstable if the motor inertia is high relative to the load. Advanced servo tuning and filtering can be difficult to achieve and may not be required with a Slotless motor.

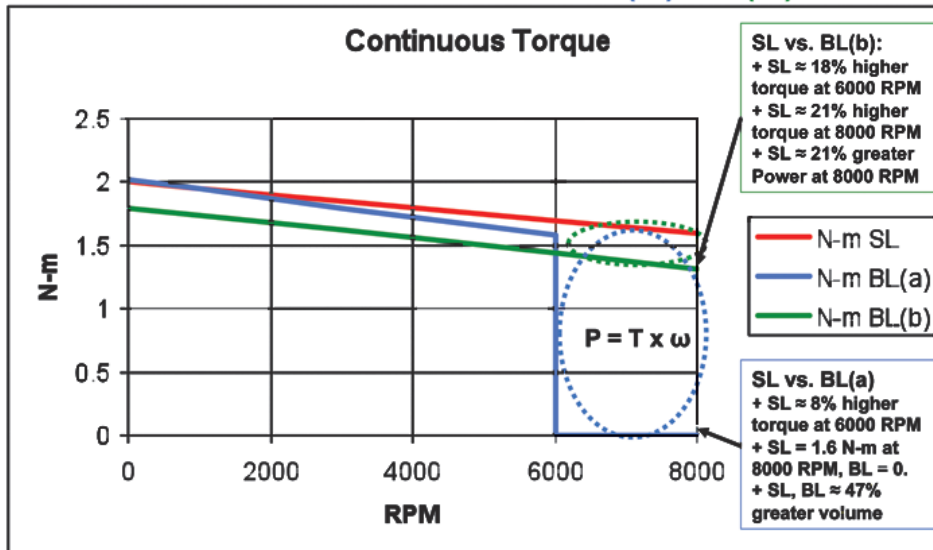
**Stiffer System** – A rotor with a larger diameter has greater stiffness because torque increases with rotor diameter, and a higher torque motor responds faster to any displacement from the commanded position. The torque displacement curve is steeper.

**Higher Efficiency** – All of the above items have an effect on motor efficiency, and improvements in the range of 5-25% can be appreciated relative to slotted motors.

## Technical disadvantages of slotless motors

For a given motor size, slotless motors generally have larger diameter rotors. Because the inertia of the rotor increases exponentially with the diameter of the ro-

## Slotless vs. Slotted (a) & (b)



tor, the inertia can increase significantly. In applications where the load inertia is very low compared to the motor inertia and very high acceleration rates are required, a slotted system might be able to accelerate faster if the extra torque in the slotless motor can not compensate for the higher torque required to accelerate the system.

A slotless motor can be more difficult to manufacture. The motor manufacturer might need to develop its own custom winding equipment, as standard equipment will not do the job. If the choice is made to encapsulate the windings in a resin to enhance performance and create a more rugged motor, a good deal of experience with resin materials and the potting process is required. The difficulty in manufacturing can lead to higher cost for the motor manufacturer.

### Application Benefits

Now that you understand the advantages and disadvantages, the next logical question is: How can I utilize the advantages? The answer, as always, is – “it depends!”

Higher torque is beneficial for most applications. It is the first thing you look for when you select a motor. More torque usually equates to higher acceleration or greater machine output (more widgets per minute). More torque out of a smaller motor allows a physically smaller motor to be selected. This can save money and if the motor is part of a moving component – a smaller motor will weigh less so it will be easier to move.

A motor that can run faster is obvi-

ously better for high speed applications such as centrifuges, but faster speed can also help reduce machine cost and increase machine output. If the mechanics can handle higher speeds, a faster move time is possible, and if the gear reduction can be selected to optimize the torque at higher speed, a smaller motor can be utilized, saving money.

Broader power may allow you to eliminate costly secondary mechanics that can also lead to short machine life or maintenance cycles.

A smoother motor is important to sensitive applications such as grinding, because the cogging effect can produce an undesirable finish on the final parts.

A more efficient motor will require less energy to run, so battery operated applications will benefit from longer battery life.

### Pick your supplier carefully

Be sure they have the product breadth and customization capability to meet all your needs, and have the experience and knowhow to produce a highly reliable motor. Reliability equates to improved machine “up time” and that leads to more widgets per day / week / month / year and a better return on your investment.

For more information about slotless servo motors and how they can help you achieve your production goals, contact Infranor Inc., 299 Ballardvale Street, Suite 4, Wilmington, MA 01887; toll-free 800-237-3786; locally at 978-988-9002 or visit [www.infranorusa.com](http://www.infranorusa.com).



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