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White Paper

How to Acquire the Best Application Advantage

Content contributed by Motor Consultants, LLC

Brushless motors are used worldwide for their basic benefit of optimizing performance per package size - - no other technology can match it. In addition, brushless brings tremendous advantages to many applications, combining the best features and benefits of past successful designs while incorporating unique advantages.

Industry Pushed Developments

At the dawn of the industrial age, the predominant machine was the AC induction motor, which is basically a constant speed device. Thus when applications required different speeds, the pulley would be changed, resulting in significant production down time - - it took a long time to change pulleys.

Industry needed a more efficient method to attain different speeds. And it wasn't until the development of the DC motor that this would be accomplished. By simply changing the applied voltage, motor speed could be varied. DC motors remain in use today in applications needing variable speed control.

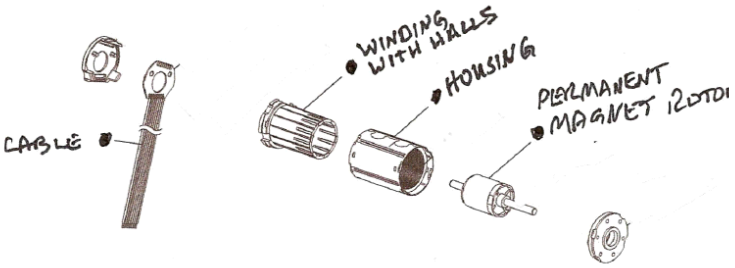
The next design was the DC PM (permanent magnet) motor. Since the stator field is generated with permanent magnets the field remains constant, this provides linear and predictable speed-torque characteristics, ie speed is dependent upon applied voltage, and torque delivered is dependent on current. Since PM (permanent magnet) torque/current relationship provides high torques, these motors are used in applications where accurate positioning control exists.

The next motor technology enhancement was the brushless motor. This design has tremendous advantages it combines the best benefits of both AC and DC designs plus brings its' own unique advantages to applications. It combines the long life of the induction motor and linearity of the permanent magnet motor, plus adds higher speed range capability (productivity), size weight reduction (compact design), and improved torque capability (precision). Therefore it provides machine designers with a competitive edge in their marketplace by increasing production capability, improving machine reliability and increasing life.

Brushless Concept

Brushless motors are used in markets worldwide from medical to electronics, from robotics to security, from cash dispensers to industrial automation, from instrumentation to automotive as well as many other applications.

A brushless motor is similar to other motors the design consists of: housing, windings, permanent magnets and a shaft (see figure 1). Note all motor technologies have a means for switching power between electrical windings, termed commutation, that result in shaft rotation. The AC motor uses alternating power and the DC PM motor uses a mechanical commutator. Brushless is a PM motor however does not incorporate a mechanical commutator in the design and this is the basic concept that makes a brushless motor uniquely different than other motor technologies it utilizes "electronic commutation".



Actually, the brushless motor has no part in "commutation" it is accomplished by the control, that is supplying power running the motor, which accomplishes the "electronic commutation". Figure 2 illustrates the concept of how electronic commutation works. For this example, the brushless motor consists of a rotor with permanent magnets, stator with windings and a small feedback device (that consists of a small magnet and three Hall sensors).

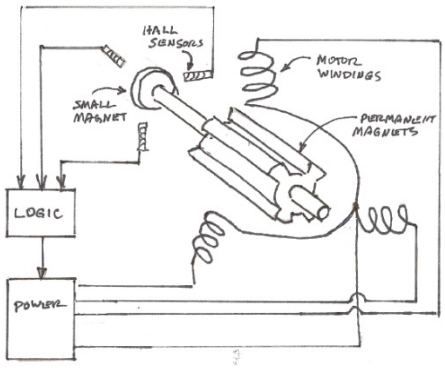


Figure 2 Electronic commutation of brushless motors

As the rotor shaft turns, the small feedback magnet passes by and causes the Hall sensors to turn "on" and "off". This provides information about rotor/shaft position. Of course, other feedback devices may be used to detect rotor/shaft position, however this was chosen for simplification. This rotor position information is fed into the control's logic circuitry.

The logic circuitry uses rotor/shaft information to turn "on" specific power devices applying power to specific stator windings, thus generating a stator magnetic field. The PM rotor follows it. The Hall sensor feedback information allows for maintaining the optimum angle for rotation and for maximizing torque.

Note that commutation information for servo positioning applications may be obtained via Halls, encoder, or resolver feedback, and for non-servo simple speed control applications via back-emf.

Features & Advantages

Brushless motors provide a long, maintenance-free, trouble-free life. This is because, as indicated, there is no mechanical commutator, no parts (ie brush/commutator) to wear which limit life. Of course life is also dependent on some other application factors, such as shaft loading (axial and radial), application profile (accel, duty cycle, and environment), etc. Brushless motors can provide a long life of 10,000 – 15,000 operating hours.

Since the brushless motor stator field is produced by permanent magnets, the field remains constant at all motor speeds - - this provides linearity to speed-torque characteristics, which makes it easy to design into applications. It's simple to predict performance when loads vary; it's simple to predict performance when voltage/current become limited such as low line voltage conditions; and it's simple to predict outcome with temperature variations.

As an example, figure 3 presents a speed-torque characteristic curve. The motor has a load of T1 and voltage V1 is applied; speed will be S1. If the load would be increased to T2, then motor speed will drop to S2. The question now becomes whether this is acceptable in the application. This analysis creates awareness on the designer's part and if it creates consequences for the application, then plans can be made to handle or correct the situation. It's easy to determine the operating point on this linear speed-torque characteristic curve, and thus the machine designer knows what performance will be delivered.

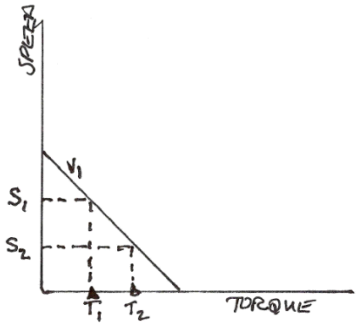


Figure 3 Speed-torque characteristic

An inherent design feature of brushless motors is the fact that they deliver more speed, torque and power. There are two ways in which brushless motor specifications will be reviewed: the first by comparing motors of similar torque and the second comparing motors of the same diameter.

Specs for motors with the same continuous stall torque are presented in figure 4, for brush motors (graphite brushes) and brushless motors. For this comparison, it can be seen that brushless motors provide a higher top speed capability improvement in excess of 5 times. However, in general top speed improvements of 3 to 5+ times may be expected. Power output capability shows an improvement of more than 3 times.

Motor	Diameter/ Length	Cont Stall Torque	Top Speed	Output Power
	mm	mNm	Krpm	watts
DCPM graphite brush model 2237 CXR	22/37	11	7	8.6
BLDC w Halls model 2444 B	24/44	11.8	38	36.0
DCPM graphite brush model 2342 CR	23/42	16	7	20.0
BLDC w Halls model 2057 B	20/75	16.5	52	62.0

Figure 4 Speed and power of DC PM and brushless with similar stall torques

Higher speed and power capability reflects directly to the potential of increased productivity rates - - ie producing more parts per hour. Applications have seen 80-90% productivity improvement with brushless motors. This directly reflects to the bottom line of businesses.

Additionally for motors with similar continuous stall torques, brushless technology will provide improved peak torque capability for many applications (see figure 5). In general a DC PM motor can provide 200 – 500% more peak torque (ratio of peak vs continuous capability), and brushless can provide 400 – 1000%. This peak torque capability aids in providing for high bandwidth that results in fast compensation for any machine load disturbances and therefore makes corrections faster for any errors that may occur. As an example, velocity loop bandwidths for motors with a feedback device can be on the order of 50 Hertz; brushless will have bandwidths of 100 Hertz and higher. The bottom line is that higher torques allow for accurate and precision in making corrections and parts.

Motor	Cont Stall Torque	Peak Stall Torque
	mm	watts
DCPM graphite brush model 2237 CXR	11	46
BLDC w Halls model 2444 B	11.8	111
DCPM graphite brush model 2342 CR	16	80
BLDC w Halls model 2057 B	16.5	113

Figure 5 Peak torques for DC PM and brushless with similar stall torques

Machines utilizing brushless have improved positioning and accuracy/precision which has reduced reject rates by up to 75%. If the distance to be moved is long or short, at slow or fast speeds, the brushless servomotor will provide precise and accurate positioning.

Specs for motors in the same package size are presented in figure 6. In this comparison, it is noted that brushless motors presents a higher top speed capability - - indicating potential for increased productivity. Brushless delivers more continuous stall torque, usually 20% or much more - - indicating potential for getting into position faster with more precision and accuracy. Additional brushless provide more peak torque capability. In other words for brushless motors, torque per volume is maximized.

Motor	Diameter/ Length	Cont Stall Torque	Peak Stall Torque	Top Speed	Output Power
	mm	mNm	mNm	Krpm	watts
DCPM precious metal brush model 2232 SR	22/32.2	10	46.8	8	8.7
BLDC w Halls model 2232 BX4	22/33.8	19	55.7	22	7.6
DCPM graphite brush model 3242 CR	32/42	35	181	5	24.7
BLDC w Halls model 3242 BX4	32/42	56	282	14.5	77.4

Figure 6 Comparison of DCPM and brushless in same package size

Using brushless motors in new designs or upgrading existing equipment will improve the machine's response, precision and productivity. For example, in an application of brushless servos used in labeling equipment, a builder boasted profits of $6000/day had increased to $11,250/day with the improvement in cycle time alone.

A concluding note: automation is one of the best investments a manufacturer can make in order to maintain a competitive edge. Brushless motors with their inherent advantages and benefits are designed to provide applications with high speed and continuous duty. The primary difference between brushless and other motor types is that brushless are electronically commutated. Motors by MICROMO are designed with a skewed wound coil technology that provides low cogging and thus very smooth operation. Brushless technology provides high power, high torque (upon demand), high speed (when needed) and long life (all the time). Controls are available to drive brushless motors. Additionally MICROMO application engineers are available to answer questions and assist in motor selection.

Markets & Applications

- Medical – surgical robots, dialysis systems, pressure monitor, lab diagnostics, prosthetic leg
- Electronics – feeders, wafer processing, camera crane, telescope control, optics, nano-testing
- Robotics – humanoid robot, 6-legged robot, service, robotic vehicle, assembly, sewer robots
- Security – video surveillance, mobile inspection, cash dispensers, electromechanical locks
- Instrumentation – precision scales, deep sea sensors, laser leveling, seismometers, measurement