Brushless Servo Motors; How Are They Different?

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Brushless servo motors are being used in industry for many different applications. However, the primary industrial use for these motors is in automated machinery for the accurate positioning of the work piece or work tool.

The brushless servo motor will have many features that are different than the standard induction or brush type DC motor. Most repair shops are familiar with the operation and characteristics of three phase induction motors and with DC motors with a commutator and brushes.

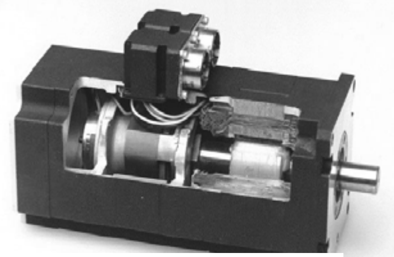


Photo by Baldor Electric

The brushless servo motor will usually have a stator winding similar to a three phase stator with three power leads. It will have a rotor that instead of an induction squirrel cage rotor or a wound armature will have permanent magnets that match the number of poles in the stator windings.

Since the brushless servo motor does not have an induction or squirrel cage rotor, it will not run directly from three phase AC power. Instead it must be powered from a control or drive unit commonly referred to as an amplifier. These motors will have a feedback device that will communicate to the amplifier and furnish information to the amplifier concerning the position of the rotor. Based upon this position information, the control will furnish power to the leads of the motor of the correct polarity and sequence to cause the motor to rotate and develop maximum torque.

Although the stator and rotors are very similar, the feedback devices that are used on these servo motors vary greatly, and are designed to meet the requirements of the drive. Once the requirements of the drive are met, the drive will cause the motor to operate with the correct direction of rotation and correct speed.

The devices that are used to communicate the rotor position to the control are referred to as commutation feedback devices. The switching of the current through the windings of the motor is similar to what occurs in an armature winding as the current is switched on and off at the commutator and brushes of a DC motor.

These feedback devices may also send information to the drive on other parameters. Other parameters may be speed, acceleration, direction of rotation, number of turns etc. Feedback devices used on these motors could include resolvers, encoders, Hall Effect sensors, or tach generators.

Some of the differences

1. There are very few standards utilized by all servo motor manufacturers. This requires that the repair shop become familiar with the differences of each manufacturer's motor that they will be servicing. The motor from one manufacturer will not usually be interchangeable with that of a different manufacturer.

2. Operating speeds may be higher than other motors. It is not unusual that they will operate up to 6000 RPM or higher.

3. Brushless servo motors cannot be test run on the shop test panel.

4. There will be auxiliary feedback devices attached to the motor that must be tested and adjusted.

5. If the rotor in the brushless servo motor is rotated, it will act as an AC alternator. This AC voltage in the stator windings is caused by the magnetic flux from the permanent magnets on the rotor moving past the coils in the stationary stator winding.

6. If a DC Voltage is applied to the stator windings, then the resultant magnetic poles in the stator winding will cause the rotor to “lock” in position where the poles in the stator align with the poles of opposite polarity on the rotor.

Using these differences

The differences identified in above items number 5 and 6 are unique to these motors because they are equipped with permanent magnet rotors. These differences, when they are understood and utilized in the repair of these motors will become powerful tools to be used by the repairman.

If the permanent magnet rotor is rotated in a servo motor by coupling it to a variable speed motor as a driver, then the stator winding will act as the armature winding in an alternator and produce an AC voltage. If the windings are physically laid out with three circuits that are displaced one hundred twenty electrical degrees apart, then the voltages produced by the rotating permanent magnet field will be one hundred twenty electrical degrees apart also.

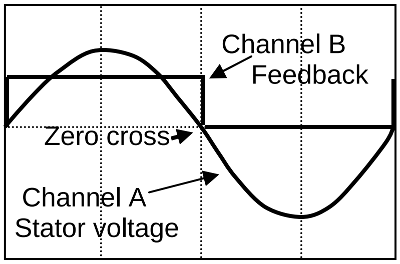
This counter generated voltage will be similar to the three phase AC voltages with which we are familiar. The phase sequence will be determined by the direction of rotation. The voltage and frequency of the generated voltage will vary with the speed that the rotor is rotated.
Higher speed will result in higher voltage and also higher frequency.

From this we find that if the rotor of a servo motor is driven from an external source such as another variable speed motor, then the counter voltage generated in the stator windings will be similar in voltage level, frequency, and phase sequence to the voltage required to cause it to run in the direction and speed that it is being driven.

Since the counter EMF or voltages that are generated when the motor is driven externally are closely equivalent to the voltages that would be applied to cause the motor to rotate at the driven direction and speed; these counter generated voltages may be used to compare the relative stator voltages to the feedback devices that the drive will use to determine when the stator (or armature) winding should be commutated.

The signals from the feedback device, which is also mounted on the motor rotating shaft, such as a resolver or encoder may then be compared to the stator winding counter EMF for the purpose of setting the timing relationship between these signals. This comparison may be accomplished through the use of a dual channel oscilloscope. One channel of the oscilloscope is connected to the counter EMF and the other channel of the oscilloscope is connected to the feedback device signal. If both of these signals are displayed on the oscilloscope screen together then the relationship of the two voltages may be compared and adjusted as needed.

Oscilloscope traces



The use of this Counter EMF may be utilized, as shown above, for checking alignment with a commutation feedback device.

The alignment of the commutation is an electrical alignment not mechanical. For this reason there are rarely any physical markings used by the factory. Usually the alignment will be an electrical alignment of the zero cross points.

That is, the point that the counter EMF crosses zero will align with a point where the commutation feedback signal also crosses zero.

As shown in the oscilloscope traces above, while back driving the motor, the alignment of the zero cross points of the counter EMF (channel A) and the zero cross points of the commutation signal (channel B) are aligned together. If the commutation feedback device were physically moved or rotated with respect to the shaft then these zero cross points will move away from each other. This is an example of 120 degree pulse alignment such as you would have with Hall sensors sensing the position of the rotor. This is also an example of back driving and using the counter EMF to obtain alignment.

Another important use for this characteristic of brushless servo motors is that it may also be utilized to determine the condition of the magnets on the rotor.

If a servo motor with a permanent magnet rotor is coupled to a drive motor that can be operated with variable speed, then the variable driven speed can be used to vary the counter generated voltage level. This voltage level is determined by the strength of the magnets and the speed that the motor is being rotated.

The condition of the magnets is reflected in the magnitude and shape of the counter generated EMF produced when the motor is driven as a generator.

If the counter EMF of one of these motors is measured at a fixed RPM (usually 1000 RPM), then this voltage may be compared to the rated Ke as specified by the manufacturer. If the manufacturer's specification is not available, then comparison may be made between similar motors.

The counter EMF level is directly related to the strength of the magnets hence it is an excellent gauge for judging the condition of the magnets.

If the voltage level and waveform are checked on a consistent basis, such as at 1000 RPM, and the generated waveform is saved then comparisons between similar units can be very meaningful. Comparison of voltage level and waveform will indicate the condition of the magnets.

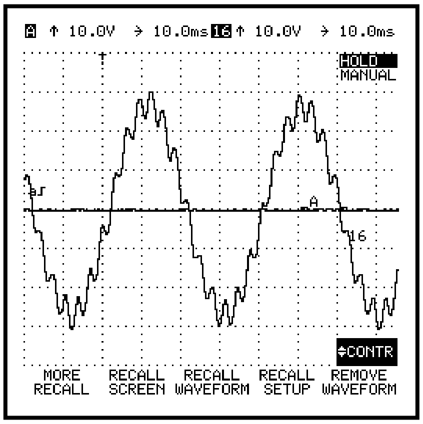
Defective magnets in a brushless servo motor will have three symptoms:

1. Lower counter generated voltage (Ke).

2. Lower than rated torque (Kt) at rated current.

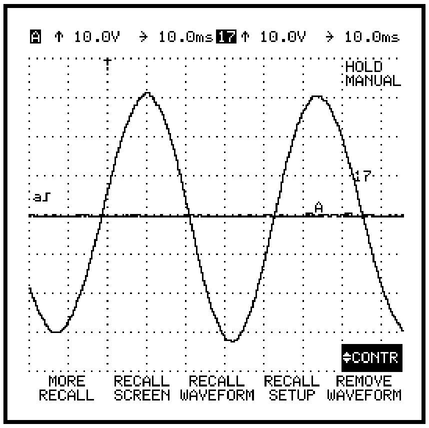
3. May have distorted counter generated voltage waveform

The following are actual oscilloscope waveforms of counter generated voltages taken from two similar servo motors. The motors were of the same type from the same manufacturer.



The first waveform taken with an oscilloscope was from a motor that had damaged magnets on the rotor. There is waveform distortion and the output voltage is low.

The waveform below was from a similar motor which had good magnets on the rotor.



The counter EMF is of proper voltage and there is no distortion of the waveform.

If a DC voltage is applied to the stator windings, then there will be setup by the DC current through the windings alternate north and south poles that will be of the same number of poles and polarities as the permanent magnets on the rotor. This will cause the rotor to align with the stator winding with the poles on the rotor aligned with the opposite poles on the stator since they will be magnetically attracted to each other.
The rotor will magnetically lock in this position so long as the DC voltage is applied to the stator.

There will be as many different lockup positions within the full three hundred sixty degrees of mechanical rotation of the shaft as there are pole pairs in the motor.

- Two pole rotor would have one lockup position.
- Four pole rotor would have two lockup positions
- Six pole rotor would have three lockup positions
- Eight pole motor would have four lockup positions
- Etc.

Understanding the relationship of these static lock-up points to the dynamic counter EMF waveform of the servo motor when the rotor is being back driven is the technology that is important in the setting of the feedback devices on these motors.

The setting of the commutation feedback device may be accomplished by using this method of locking-up the rotor and then aligning the feedback device with that lockup point.

If a DC voltage is applied to the stator winding then the rotor will lockup at one of the zero cross points of the counter EMF.

Understanding what polarity to apply and to which leads get you to the zero cross point that you want to put into alignment with the commutation signal is the process used for this static lockup method of setting the commutation feedback device.

With the rotor locked-up by applying a DC voltage to the leads and then moving the commutation feedback device, shown in oscilloscope traces above to the point that it toggles from high to low at that position of the rotor and then securing it in place will set the commutation feedback device.

If the feedback device is a resolver then locking the rotor as above and setting the resolver on an angular position of zero degrees would align the resolver for commutation of the motor.

These are examples of locking up the rotor to set the alignment of the feedback device.

This is a short description of the setup of these commutation devices. Understanding how all of the variables affect the setup is the secret of understanding how these motors tick.

Although there are many similarities between servo motor manufacturers, each one chooses how the feedback device will be set and designs the control for that setup.

Testing of the magnets may be done by measuring maximum stall torque of the motor with rated DC stall amps applied to two of the stator leads.

When a DC voltage is applied to the stator winding, the rotor will “lockup” at the zero torque position. By forcing the shaft to turn with a torque wrench the peak torque may be measured and compared with the manufacturer’s specifications.

If the magnets have the proper strength, then the peak torque will be within ten percent of the rated continuous stall torque when rated continuous stall amps are applied.

Summary

A through understanding of the unique differences found in brushless servo motors will give you the ability to comfortably inspect, test, and repair these high tech motors.

Two unique differences:

Back driving the motor and analyzing the counter EMF that is produced.

Appling DC to the stator winding to lockup the rotor.

These may be utilized for the purpose of:

1, Setting the alignment of commutation feedback devices.

2. Checking the condition of the magnets that are on the rotor.

3. Testing of the peak torque at rated current.