Basic Maintenance and Testing of DC Electric Motors

Part 2

Howard W Penrose, Ph.D., CMRP
President, SUCCESS by DESIGN

Introduction

In Part 1, we discussed the basic makeup and operation of DC electric motors. In this article, we are going to discuss two key components of the DC motor system which are the brushes and the commutator. The key to proper operation of a DC machine is its ability to have an alternating current available in the armature such that the magnetic fields are about 90 degrees from each other. This means that there must be a contact system that acts as a 'switch' to allow current to flow in a specific direction such that the fields remain at 90 degrees.

The switching system used to convert the incoming DC to AC, in the DC motor, are the brushes and the commutator. In this article, we are going to discuss some of the conditions that must be considered for both components of the system.

The Commutator

The commutator is made up of many copper/copper alloy bars with mica insulation between each bar. These bars are normally linked together with a core, or hub, that can be tightened to ensure a tight fit for the bars. When installed, the commutator should have a shiny, protective gloss that is made up of a surface film of copper oxide and graphite. The film, after the machine has been running less than 24 hours, will vary based upon the environment, but should have an appearance color of light straw to jet black. The normal color normally falls somewhere in between. Water vapor absorbed by this layer actually provides lubrication that reduces both the brush and commutator wear.

A commutator that is out of round, grooved, burned, has flat spots or is in otherwise bad condition, should be turned and undercut. Many years ago, the commutator surface could be ground by hand, but safety requirements will normally not allow for it, so we will not cover that option in this article. Instead, we will assume that the commutator will be cut when the machine is out of service and the armature is on a lathe, or a portable lathe is being used.

When turning a commutator, it is first important to check for loose bars. This can be accomplished using some modern instruments that provide information on commutator roundness. An older method was to use a light-weight hammer and tap gently on each bar. If there is a bell-like tone, then the bar is OK, if there is a dull thud, then the bar is loose. In these cases, the commutator can be tightened to manufacturer's specifications using a torque wrench as too much pressure may cause the bars to distort.

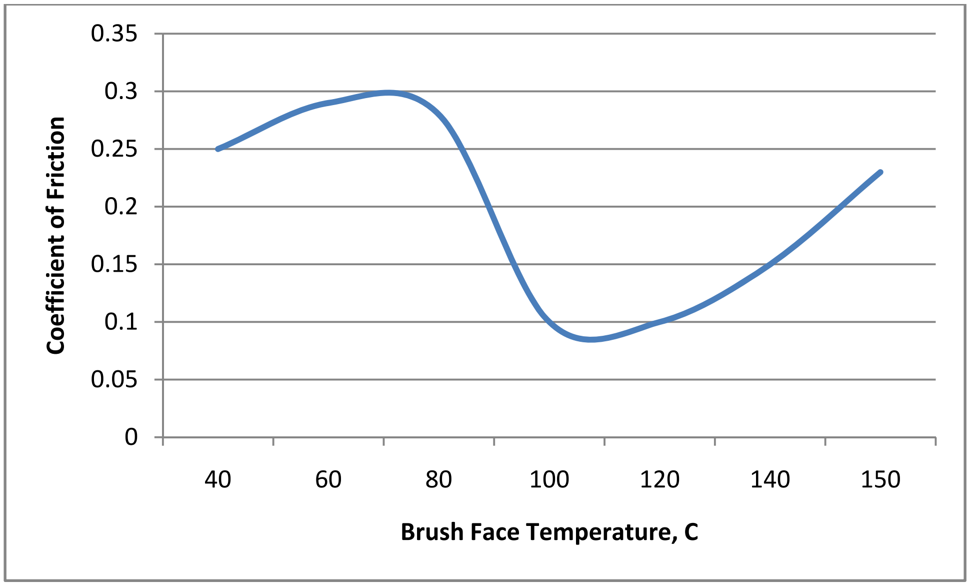
The cut, itself, should be just enough to remove any imperfections from the bars and to ensure that it is round. Once the commutator is 'turned,' it should be polished to an exceptionally smooth finish with a mirror-like appearance. Some repair shops will 'thread' the commutator slightly with the explanation that this will seat the brushes in operation. Instead, this will end up causing excessive brush and commutator wear while reducing the contact surface area.

Once the commutator has been turned, it must be undercut to ensure that mica is below the copper bars. The optimal cut is when the depth of the mica is equal to the thickness of the mica between the bars. This is important as it maintains the mechanical integrity of the commutator while preventing the mica, which is harder than copper, to create ridges as the copper wears. These ridges will cause sparking and chipping of the brushes. Following undercutting, the edges of the cuts should be chamfered to ensure a smooth transition of the brushes across the bars. After the commutator has been prepared through turning and undercutting, it must be handled in a way that contaminants, including finger prints, do not come into contact with the surface of the commutator.

Brush and Commutator Operation

The surface film, or glazing, on the commutator is extremely important for proper lubrication and requires some level of humidity for proper lubrication between the brushes and bars. Raw copper surfaces can be caused for a number of reasons such as brush grade, low current density, or gritty contaminants. When this occurs, the brushes will wear rapidly.

Figure 1: Coefficient of Friction



The optimal current density of the brush and commutator contact is 40 $Amps/inch^2$ (average) to maintain a good surface film. Most DC machines are manufactured assuming that they will operate within a specific range and the current density of the brushes averaging in the range above. For light loads, a number of strategies can be considered, including reducing the number of brushes and using a 'softer' brush grade that will film easier. The brush company or distributor can often assist in the proper selection of a proper brush grade specific to an application. In addition to water vapor providing lubrication, the proper current density will cause the brush temperature to increase, reducing the coefficient of friction between the surfaces (Figure 1).

Another concern for the life of the brush and commutator is atmospheric contamination such as oil, saline (salty air), corrosive gasses, or silicone vapors. Of these, silicone vapor is insidious in its attack, as some maintenance staffs will use silicone sealant on brush rigging covers, connection boxes, etc. in an effort to seal the motor from contamination. However, it only requires a very little amount of silicone material such as silicone tape, silicone-rubber lead wire, sealant, or any other source of silicone to cause extremely rapid brush wear. The fast brush wear will generate a significant amount of carbon within the motor, causing low insulation to ground results, which will also accelerate brush wear, and will lead to both ground and inter-turn winding shorts.

Oil contamination is often indicated when a thick, black film builds up on the commutator surface. This film causes very poor brush contact and excessive heating at the few conductivity spots which can cause the copper to become excessively hot. When the temperature becomes high enough, very small globules of copper will come away from the commutator of which some will embed in the brushes causing threading of the commutator bars. In worst-case conditions, copper globules will be found within the motor that will often be described as 'thrown copper.' One of the more effective solutions for this condition, in addition to reducing the oily contamination, is to install harder brushes that will scour the contaminants from the commutator.

Another area of concern within the brush/commutator system is the connections between the brush shunts (conductors) and the brush rigging. If a shunt is loose, less current will flow in the affected brush, reducing its operating temperature while the brush with a good connection will have an increased operating temperature. As brushes are dielectric, as the temperature increases, the conductance will improve causing more current to flow in that brush. **In effect, when inspecting the brushes with infrared, the hotter brushes are actually the good brushes.**

Seating, Tensioning and Cleaning

When installing brushes, it is important to ensure that they are in proper contact with the commutator. This process is referred to as 'seating the brushes.' There are a number of ways of approaching this, for this paper we will discuss a common method used in repair shops:

1. Wrap sandpaper around the commutator such that the surface is facing outwards. If a significant amount of seating is required, start with a rough paper. The sandpaper MUST be sandpaper and not an emory cloth or paper that contains metals.
2. Place the brushes in the brush holders and use the brush springs to put pressure on them.
3. Rotate the shaft in the direction that the machine will normally operate.
4. Lift the brushes and ensure that over 95% of the brush surface is in contact.
5. Use a finer grade of sandpaper to clean up the surfaces of the brushes.
6. Remove all of the carbon using a vacuum cleaner or low pressure instrument air. Be careful that carbon is kept away from the motor windings.
7. Re-install the brushes and turn the shaft again. Over 95% of the brush surface should be in contact with the commutator surface.

If the motor is in operation, or to clean up the brush contact, a seating stone may be used. This is placed directly against the commutator while the machine is operated at speed. A seating stone is very soft and gritty. The grit is caught by the commutator and will cause the brushes to wear very quickly while at the same time being soft enough not to damage the commutator surface. All company and regulatory safety considerations should be met if performing this particular task.

Once the brushes are properly seated, they can be tensioned. This is normally done with a brush tension gage which is used to lift the brush directly out of the brush holder and observe the value on the scale. The value will depend on the brush type and application, however average brush tension values are in Table 1. Adjustments are normally made at the spring.

Table 1: Recommended Brush Tension

Brush Grade	**Tension, psi**
Carbon	1.75 – 2.5
Carbon-Graphite	1.75 – 2.5
Graphite-Carbon	1.75 – 2.5
Electrographitic	2 – 3
Graphite	1.25 – 2
Metal Graphite	2.5 – 3.5
Fractional HP Motors	4 – 5

Finally, cleaning of commutators and brushes should be performed periodically during operation. The commutator itself, can be cleaned using a canvas wiper, which is a system of canvas layers and an insulated pole. This is held against the commutator to remove grit, carbon and other contaminants from the film while not removing the film, itself. Carbon dust can also be removed using low pressure instrument air (<25 psi). In no case should solvents be used to clean the commutator or brush rigging and in all cases, all appropriate safety precautions should be followed.

Conclusion

One of the most significant areas for potential DC machine failure is the brush/commutator system. Both the brushes and the commutator are used as the switching system that allows the DC machine to operate and both require specific care such as testing, observation and specific preventive maintenance processes. In Part 2 of this series, we have discussed the proper care of both the commutator and brushes.

In Part 3 of the series, we will discuss setting neutral for a DC machine, the reasons why, basic troubleshooting and the use of modern motor diagnostic techniques for evaluating the condition of DC machines.

Bibliography

Hubert, Charles L., Preventive Maintenance of Electrical Equipment, McGraw-Hill, 1955.

About the Author

Howard W Penrose, Ph.D., CMRP is the President of SUCCESS by DESIGN Reliability Services and the Executive Director of the Institute of Electrical Motor Diagnostics, Inc. He has over 22 years in the reliability and rotating machinery industry across almost all types of industries and the military and performs off and on-site workshops on maintenance and motor diagnostics. Contact Dr. Penrose for questions via email at info@motordoc.net or through the company website at http://www.motordoc.net.