Industrial Motors

Brush life in DC motors

Motor longevity depends on a good brush film that, in turn, depends on a lot of controllable factors.

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Do you want to reduce downtime and achieve longer, trouble free motor life? In your attempts, have you been stymied by DC motor brush and commutator problems? Would you like to know what is considered normal brush life? Are you looking for ways to get longer brush life? If your answers are yes, then this is just the article for you.

To ensure good brush life, we need to know the conditions that contribute to brush wear, the tradeoffs when we alter these conditions and how much wear is considered normal for the application. We can then look at, evaluate and change conditions to achieve the best compromise among brush life and the costs associated with things such as commutator wear, clean air duct work, production load changes, humidity control and the like.

Why brushes wear

DC brush wear results from mechanical friction and electrical erosion. Friction produces carbon dust. Electrical erosion vaporizes carbon leaving little physical residue.

Friction

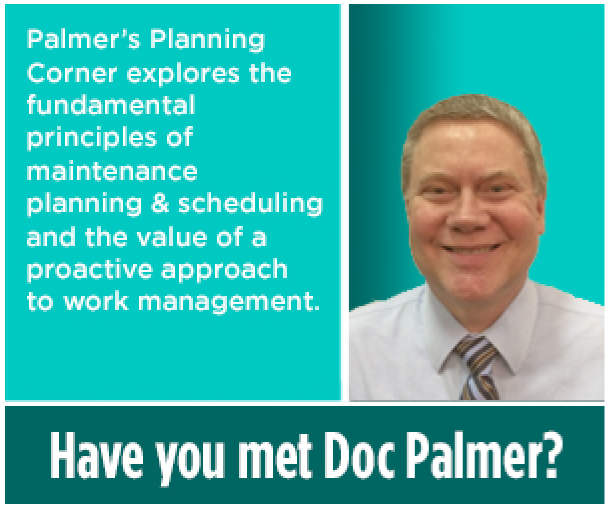
Carbon rubbing on bare copper has a high coefficient of friction. A standard, non-plated commutator with a good film achieves the lowest coefficient of friction. With good film, the coefficient of friction can be reduced to 10 % of the original bare copper value.

The coefficient of friction between the filmed commutator and brush decreases, up to a point, with increases in commutator temperature. For example, a given brush might have a coefficient of friction of 0.15 while running on a commutator with a surface temperature of 140 °F. When the surface temperature reaches 220 °F, the coefficient of friction could be 0.08. Higher temperatures result in an increase in the coefficient of friction.

Standard brushes on warm commutators at medium speeds have a coefficient of friction of 0.13 to 0.19 — a low coefficient of friction.

Table 1

Brush coefficient of friction	
very low	less than 0.10
low	0.10 to 0.19
medium	0.20 to 0.29
high	0.30 and higher



Some brushes with low coefficients of friction are not as hard as brushes with higher coefficients. A hard brush with a medium coefficient could provide longer life but could be noisier in operation. There are many exceptions however. There are a number of hard grades with low coefficients of friction.

Mechanical problems such as high mica, high brush spring pressure, a feather edge on a copper bar or other imperfections on the commutator surface also cause friction. Brush wear on an unpowered motor in a tandem motor-motor set or on an unloaded generator in a motor-generator set comes from friction. Friction is a function of the atmosphere, temperature, current loading and the mechanical characteristics of the motor.

Erosion

Erosion is the result of improper commutator film or a wear condition such as threading. Other motor set up conditions or mechanical problems such as the brush neutral setting, interpole strength, low brush spring pressure, poor brush seating, high mica, and commutator eccentricity can also cause sparking and erosion. Sparking increases with current loading and motor speed. Brush life decreases with increased sparking.

The condition of the commutator film directly affects friction and erosion and brush life. The commutator must have good film to get good brush life.

What is good commutator film

The proper current passing between the carbon and copper in the presence of water vapor forms a microscopic layer of copper carbon composite or film. This film color is chocolate brown or burnished bronze to dark brown or black and uniform. It is not bright copper or burnt black copper. Consult a commutator color and appearance picture chart to determine the condition of your commutator. There is a condition known as *false filming* in which brush graphite deposits cook on the commutator resulting in an appearance similar to dark film. Oil can also leave a coating that resembles film. If your film can be easily wiped away, it's not the desired good commutator film!

Commutator filming is a continuous process of forming and stripping away. A good film is only 0.000,000,2 inch (200 nanoinch) thick. Thus, the conditions required to build good film must always be present. Changes in current or humidity affect the commutator film.

Requirements for good film

Certain conditions develop and maintain good film. A majority of your operating time must be within the designed brush **current density** range. For some grades of brush on warm commutators, this range is generally 55 to 85 amps per square inch. If the current density exceeds this value for long periods, the commutator runs hot, blackens and brush life is reduced. If the current density is too low, the film will be striped from the commutator and begin to thread. If allowed to continue, sparking and threading increase, brushes wear rapidly and the commutator requires resurfacing.

Often, motors run continuously at light loads so brush current density is always below the minimum. Changing to a brush grade that films at lower current densities may solve the light loading problem.

Many times the best solution is to remove one or more rows of brushes to bring the current density back into the acceptable range. When removing brushes from staggered brush sets, the remaining brushes on each stud must cover the same commutator surface arc as was covered prior to brush removal. This means removing the brushes from the center stager set on each stud first. When using wear indicator brushes, be sure that some remain. Usually this is not a problem since the wear indicator brushes are most often the inboard, middle and outboard brushes on the stud. Usually the manufacturer recommends the order in which the brushes are to be removed. Some system must be in place to ensure that the removed brushes are replaced if the load returns to near nameplate load.

Table 2

Degree of sparking guide		
No.	*Appearance*	*wear rate factor*
1	Black with no visible sparking	1.00
1-1/4	Light intermittent sparking	>1.00
1-1/2	Light continuous sparking over half of the brush length	>1.00
2	Light continuous sparking over the entire brush length	1.75
3	Light continuous sparking with one or two heavy sparks	2.50
4	Light continuous sparking with three heavy sparks	5.00
5	Heavy continuous sparking with few small sparks	12.50
6	Heavy continuous sparking with glowing spots; approaching flash-over	50.00

The commutator **temperature** at the face of the brush should not be less than 60 °C (140 °F). An insufficient layer of copper oxide forms if the commutator runs cold. Hot commutators from high ambient temperatures, overloads or loss of coolant not only increase brush wear but reduce insulation life as well. The motor thermal protection helps guard against this condition.

Building good film requires enough **water vapor** to give an absolute humidity of two to seven grains of water per cubic foot of air. When the absolute humidity is less than two grains (about 0.00457 ounces) of water per cubic foot (about 20%relative humidity at 75 °F or 40% relative humidity at 55 °F), brushes wear rapidly. High humidity causes over-filming, low insulation megohm readings or ground faults.

Use digital meters to measure temperature and humidity of air entering the motor and at several points around the motor. The readings should be in the same range. Motors some distance away may be in environments that give different results. Expect summer readings to differ from winter readings. Figure 2 is a graphical representation of the humidity relationships.

The running **brush pressure**, not spring pressure, concerns us. Brush pressure depends on spring pressure and the position of the brush. The friction between the brush and holder also affected brush pressure. Commutator speed, brush grade, brush holder finish and brush clearance in the holder affect the coefficient of friction of the brush and holder. It is difficult to measure brush pressure in the field, so measure spring pressure. With weak springs and light spring pressure, the brush sparks. If the pressure is too great, then friction and wear increase. Brush spring pressures of three to eight pounds per square inch yield good brush life and performance. Follow manufacturer spring pressure guidelines.

Table 3: Brush life as a function of load

Load type	Current density (amps/in^2)	Life (hrs)
Intermittent, light	down to 30	750-2,000
Within rated load	45 to 85	3,000-7,500
Intermittent, heavy	up to 125	1,000-4,000

The coefficient of friction between the brush and commutator increases linearly with **commutator surface speed**. Brush wear is proportional to the coefficient of friction. At higher speeds, above 5,000 or 6,000 feet per minute, may require greater brush pressure resulting in decreased brush life. At high field weakened speeds, commutation deteriorates and sparking increases. At higher speeds the film can be stripped from the commutators faster than it forms. If the motor runs at high speeds for only short periods, film can still be maintained.

For a given motor rpm, the smaller the commutator diameter, the lower the surface speed, the greater the brush life. In general, the commutator surface speed of industrial motors is limited to 8,000 feet per minute.

The **brush material or grade** has an effect on producing good commutator film on most integral horsepower DC motors. Special brush grades compensate for certain undesirable conditions.

Every brush fix is a compromise because it compensates for something in field operation that differs from the primary motor design mission. The fix sometimes introduces new problems.

Chemical **contamination in the air** becomes part of, or influences, the film. An absence of foreign chemicals produces good film. Silicone vapors, chlorine, sulfur, PVCs, dirt and oil are some of the industrial contaminants particularly harmful to commutator film.

Silicone based sealants must not be used in sealing motor air duct work, hand hole covers, or any mating surfaces on or near the motor. Silicone sealants release acetic acid vapors that destroy commutator film. Other sealants emit vapors that are harmful to commutator film. Non-silicone Permatex sealants can be used without harm.

The **mechanical integrity and setup** of the commutator must provide concentricity with a surface free of imperfections. The brush rigging needs to be sound and properly aligned. Check springs for tension. Checked brush holders and brushes to ensure that brush side-to-side movement in the holder is not excessive. Brushes must be free to travel in their holders and seated to the commutator. Brush shunts or pig tails must be tight in the brush and of sufficient size to handle overload currents in excess of the standard 150%.

The brushes must be on electrical neutral. Interpoles need to be properly adjusted, shimmed and secure.

Replace springs that measure outside the recommended range. If the brush is sloppy in the holder, compare the manufacturer's dimensions to the measured brush and holder dimensions to determine if the problem is with the brush or the holder. Replace worn parts as required. Failure to seat brushes results in sparking and can cause brushes to chip.

Seat brushes with sandpaper; never use emery cloth since the grit is conductive and can lodge between commutator bars. Rough seating can be done with 60 or 100 grit sandpaper. Final seating should be done with finer sandpaper.

Commutation and brush life

In a DC motor, commutation periodically reverses the current in individual armature coils to maintain unidirectional torque as the armature coils move under alternate field poles. The commutator reverses current through armature coils leaving the influence of one field pole and approaching the influence of an another. The motor brush contacts more than one commutator segment and an armature loop is momentarily shorted.

If the short has a potential difference across its ends, severe sparking occurs between the brush and the commutator. The commutator burns and pits and reduces brush life. Ensure no voltage is induced in the commutator loop at the time of the momentary short.

A short occurring when the active conductors in the armature loop are moving in parallel to the field does not allow magnetic lines of force to be cut. No voltage will be induced in the armature loop. This vertical axis occupied by the shorted armature loop is the geometric neutral plane. In theory, this is where sparkles or black commutation takes place. But life is not that simple! Due to the self induced EMF and changes in load, the situation is somewhat more involved and beyond the scope of this article. In the end however, electrical neutral must be properly set to assure good commutation and good brush life.

When we talk of a motor's ability to commutate we are also referring to the armature's current handling capability. Standard industrial DC motors must successfully commutate 150% of the nameplate full load current for one minute at any speed within the motor's nameplate speed range. There is no exact definition of successful commutation.

Commutation can be considered successful even if sparking occurs provided that it does not result in excessive maintenance. Intermittent sparking or a slight amount of sparking does not necessarily indicate poor commutation. However, determine and correct the cause of excessive sparking.

It is common to refer to the amount of sparking as the *degree of sparking* with a reference number such as 1, 1-1/4, 1-1/2, 2 and so forth. Figure 1 is an example of a degree of sparking numbering system. Numbering systems vary with motor manufacturer.

The lower numbers represent a few small sparks, the higher numbers indicate more and larger sparks that do the most damage to the brushes and commutator. Black commutation — no visible sparking — is most desirable.

A wear rate factor is sometimes assigned to the degree of sparking reference number. The wear rate factor is 1.00 for a *given motor on a given application when commutation is in the black*. Assume this condition provides 7,000 hours brush life. If the degree of sparking changes to two with a corresponding 1.75 wear rate factor, the new expected brush life would be 4,000 hours (7,000 hours divided by 1.75).

What is normal brush life

As an estimate, 7,500 hours brush life is normal for general purpose, medium horsepower DC motors with good commutator film with commutator surface speeds in the range of 2,500 to 4,000 feet per minute. The minimum life might be 2,000 to 5,000 hours with 10,000 hours being about maximum. It is not uncommon however, for motors with light or variable loads to have a brush life that is less than 2,000 hours. Brush life is even further reduced at higher commutator surface speeds. As a rule of thumb, brush life at 3,600 rpm is half that at 1,800 rpm.

Load also affects brush life. The life of a 50 hp, 1,750 rpm, motor with a commutator surface speed of 2,620 fpm, might look like Table 3.

Better grades of brushes have three wear lines for monitoring brush life. Replace the brushes when the brushes wear to the third line.

Brush life is then dependent on the following:

- Application and duty cycle
- Atmospheric conditions
- Commutator condition including film, runout, quality of the undercut and so forth
- Brush assembly design including brush grade, brush length, holder design, spring pressure and the like
- Motor building practices including the accuracy to which neutral is set
- Power supply and motor design

Achieve better brush life

Identifying the variables and determining brush life gets to be quite a job, especially since some variables constantly change. What we can do is identify the current problems and take corrective action. A maintenance program that monitors the conditions affecting brush life yields information that alerts us to potential or developing brush and commutator problems. Just as commutator filming is a continuous process, so is the monitoring and corrective action process. Monitoring and corrective action reduces downtime and achieves longer, trouble free motor life.

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