Renown Electric motors & repair inc.

Renown Electric's Guide to Carbon Brushes for Motors & Generators

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Introduction

What is A Carbon Brush?

Also known as a motor brush, a carbon brush is a sliding contact that is used to transmit an electrical current from a static to a rotating part in a generator or motor. In DC machines, a carbon brush ensures a spark-free commutation.

They can be made of one or more carbon blocks, and come equipped with one or more shunts or terminals. In brush manufacturing, five brush-grade families are used, each of which has its own production process and corresponds with its own specific requirements.

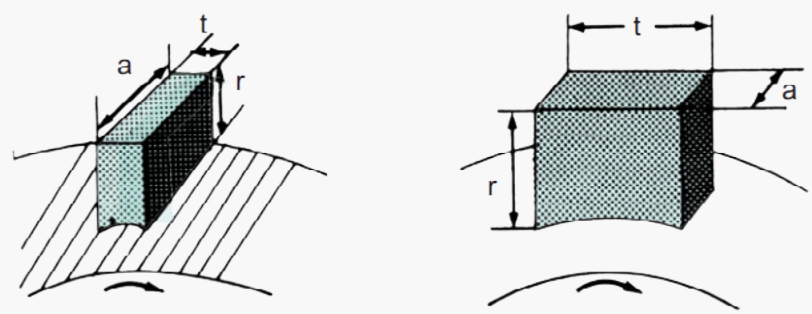
Carbon Brush Operation

As an essential part of the operation of electric motors, a carbon brush has three operating parameters: **mechanical**, **electrical** and **physical/chemical (a.k.a. environment)**. The selection of the right carbon brush grade for a specific application will depend on these parameters and ensure the best performance.

MECHANICAL

Slip Ring and Commutator Surface Conditions (Roughness) *(Fig. 1)*
Using the right slip ring or commutator provides an adequate seating base and good current transmission for the carbon brush. They should not be too smooth/glossy, nor too rough, in order to ensure the best carbon brush performance. Commutators must be checked for proper mica undercutting and the absence of burrs along the edges, and the bar edges must be properly chamfered. Also be sure the slip ring or commutator run out does not exceed acceptable limits.

Figure 1



NORMAL ORIENTATION OF A CARBON BRUSH ON A COMMUTATOR

NORMAL ORIENTATION OF A CARBON BRUSH ON A SLIP RING

Friction Coefficient
The friction coefficient of a carbon brush must be low and stable over time in order to prevent overheating. The friction coefficient ("μ") is the relationship between tangential force due to friction (T) and normal force (N), and depends on many factors, including the carbon brush's speed, grade, load, commutator/slip ring condition, and environment.

Vibration
Vibration can be caused by a number of factors, including incorrect balancing/alignment, deformed commutators, the machine's external components, moving machinery, and high or fluctuating friction (from a number of factors). Excessive vibration can damage the carbon brush as well as the brush holder and commutator/slip ring. Choosing the right brush and regularly maintaining it will help prevent this.

Carbon Brush Pressure on a Slip Ring or Commutator

No matter the machine speed, the spring pressure must ensure proper contact between the slip ring/commutator and the carbon brush. The spring pressure must remain equal for current distribution, which can be aided by regular pressure measurements with a scale or load cell. Recommended spring pressure is:

- For stationary electrical machines: 180 - 250 g/cm² (2.56 - 3.56 psi)
- For electrical machines under heavy vibration (e.g. traction motors): 350 - 500 g/cm² (5.00 - 7.11 psi)

Brush Holders

In order to avoid the brush getting stuck or rattling in the holder, it's necessary for the brush to be guided by a brush holder with the right height and clearance. The International Electrotechnical Committee (I.E.C.) sets tolerances and clearances.

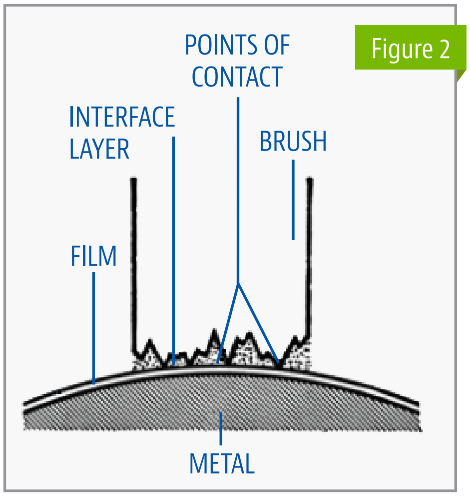
ELECTRICAL

Voltage or Contact Drop *(Fig. 2)*

To avoid overheating or electrical loss, which will damage the sliding contact, voltage drop must remain moderate. This also affects commutation and current distribution between the carbon brushes. This will depend on the carbon brush grade, electrical contact, and film (a mix of metal oxides, carbon and water, deposited on the slip ring or commutator).

Factors that affect the film include room temperature, pressure, and humidity; environmental impurities, pressure on the carbon brush; commutator/slip ring speed; and transverse current.

Figure 2



Commutation (DC Machines)

Commutation is the reversing of the direction of the flow of current in the armature coils located under the brush of an AC/DC commutator motor or generator.

Commutation sparking can occur due to incorrect adjustment of the brush position or asymmetrical brush arm adjustment. Commutation can be improved by a number of factors, including multi wafer carbon brushes, sandwich brushes, staggering carbon brushes, and more.

Distribution of Current in Brush Contact Surface

Current flows through a varying number of contact spots, which are very small areas of the brush that come in contact with the surface of the commutator or slip ring. These contact spots should be evenly distributed. If contact spots decrease or concentrate, balance could be disrupted and the film will show signs of bar marking, streaking, grooving, erosion and deterioration.

Current Density

Current density (JBrush) is the ratio of the current to the cross-sectional area of the brush, and significantly influences every aspect of the brush performance. Maximum densities vary based on the machine's characteristics and the ventilation method, and as a general rule, a low current density is more harmful to the carbon brush than a high current density.

Introduction *(Continued)*

Resistivity

Resistivity (rho (ρ)) refers to the resistance of a material to the flow of electrical current, and higher resistivity material improves commutation. It's an important factor in the choice of a carbon brush grade.

PHYSICAL/CHEMICAL (ENVIRONMENT)

Humidity

Water is a critical component of commutator/slip ring films, and is supplied by ambient air. For best performance, a humidity range of 8 to 15 g / m3 (0.008 to 0.015 oz/ft3) of air should exist. Therefore, dry air is unfavorable, and in applications such as aerospace/space, totally enclosed motors, desert/arctic environments, and machines in dry-gas enclosures, special treatments are recommended.

Corrosive Vapors or Gases

Corrosive vapors (whether in low concentration or in humid conditions) can damage and destroy the commutator and contact film, and therefore the brush itself. These gases include, but are not limited to, chlorine, ammonia, sulphur dioxide, and hydrogen sulphide. In these cases a protective surface on the brush can help prevent their effects on the brush.

Oils and Hydrocarbons

Leaks, vapor condensation, and drops of mist can contaminate carbon brushes and their commutators/slip rings. They lead to deterioration or immobilization of the brushes.

Dust

Dust leads to high brush wear, machine pollution, grooving of commutators/slip rings, and brush side gulling. The best way to prevent this is through the use of clean, filtered air and cleaning motors regularly.

P1

P2

P2a

P1 is a good example of streaky film, which contains lines of varying widths, alternating light and dark, without copper wear. Frequent causes include excessive humidity, aggressive gases or oil vapors in the atmosphere, underloaded carbon brushes.

P2 and P2a depict raw grooved film. This is a result of excessive exposure to humidity, aggressive gases or oil vapors in the atmosphere, for long periods of time. Additionally, the carbon brush grade may not be suitable.

The 5 Main Carbon Brush Grades

The choice of the right brush grade largely depends on the motor itself and the environment. There are five main brush grades, and working with an expert can help determine which is right for you.

The grades are broken down as follows:

1. Electrographitic Brushes (EG)

These are made of carbographitic materials that have been graphitized, transforming them into artificial graphite. These brushes have a medium contact drop and low to medium friction coefficient. They have low electrical loss and are well suited for high peripheral speeds. Characteristics include high strength, low resistance material, and resistance to high temperatures.

Applications include DC stationary or traction industrial motors operating with low, medium, or high voltage and constant or variable loads. Additionally, AC synchronous and asynchronous slip ring applications.

2. Carbographitic Brushes (A)

Made from a mixture of coke and graphite powders, these materials are not graphitic. These brushes commutate well as a result of their high resistance. They provide good polishing action and can withstand high temperatures and variable loads.

Applications include older motors (characterized by slow speed, low voltage, lack of interpoles), modern small motors (operating with permanent magnets, servomotors, and universal motors), and low-voltage battery-powered motors.

3. Soft Graphite Brushes (LFC)

Made of purified natural graphite and artificial graphite mixed with additives, these brushes have excellent shock absorption and low shore hardness. They are particularly well suited for high peripheral speeds.

Applications include steel and stainless steel slip rings for synchronous motors.

4. Resin-Bonded (Bakelite Graphite) Brushes (BG)

Made from either natural or artificial graphite that is mixed with thermo-setting resin, these brushes have high to very high electrical resistance, contact drop, mechanical strength, and electrical loss. This translates to good cleaning and commutating properties. They work at very low current densities.

Applications include AC Schrage-type commutator motors and medium-speed DC motors at medium voltage.

5. Metal Graphite Brushes (CG, MG, or CA)

Made from either natural or artificial graphite mixed with a thermo-setting resin, copper powder, and/or other metal powders, these brushes are dense to very dense with low friction and low contact drop. They operate with low losses and high currents. These brushes also include EG and A carbon brushes that are metal-impregnated.

Applications for copper-based brushes include low-speed, low-voltage DC motors; medium-speed, highly-loaded AC asynchronous motors (e.g. wind turbine generators); medium-speed AC synchronous motors slip rings; high-current collection systems; low-voltage current collection; special motors; and slip ring assemblies in rotary joints.

Applications for silver-based brushes include signal current transmission; pulse transmission to rotating devices; tachometer generators; aerospace and space applications; and shaft grounding in a dual-grade construction.

Installing Carbon Brushes in Motors

Installation Tips:

- In order to avoid serious problems, never mix different carbon brush grades on a motor.
- Be sure to remove the existing film before any carbon brush grade change.
- Check that the carbon brushes slide freely in their brush-holders without excess clearance.

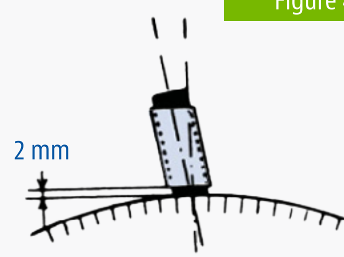
Figure 3

- Always check that the carbon brushes were not fitted (or re-fitted) in the wrong direction in the brush-holders. This is especially important for carbon brushes with a beveled contact surface or split brushes with a metal plate.
- Use brush-seating stones (pumice stones) while running at low or no load in order to precisely match the carbon brush contact surface to the slip ring/commutator radius. Always use the medium grade (M) grinding stone again after this operation. When removing carbon brush material, first rough-grind the surface with sandpaper by inserting the abrasive face up between the contact surface and the commutator and moving it back and forth (*Fig. 3*). Thoroughly clean the contact surface after brush seating.

For Brush-holders:

- Make sure that the brush-holder is in working condition and check the interior surface condition.
- Adjust the distance between the brush-holder and commutator to range from 2.5 to 3 mm (*Fig. 4*).
- Align the carbon brushes parallel to the commutator bars.
- Check with an appropriate gauge that the pressures are equal on all of the carbon brushes.

Figure 4



For Commutators and Slip Rings:

- Be sure there is no out-of-round above 3 mils or any surface defects. Grind or machine if necessary (*Fig. 5*).
- Chamfer the bar edges.
- Clean the surface with an "M" grade grinding stone, and do not use abrasive paper/cloth. Sufficient roughness is critical.

Figure 5

Putting the Motor into Service:

Make sure that all carbon brushes slide freely within the brush-holders and that the shunts are correctly routed and the terminals are tightened. Then start the motor at a low load, slowly increasing until the full load is reached.

Installing Carbon Brushes in Motors *(Cont.)*

Film Monitoring:

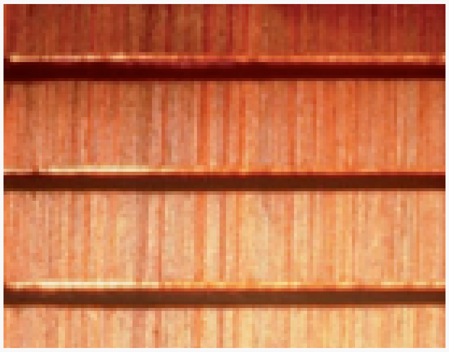
Look out for:

- Film deposits (streaky, patchy, and/or raw grooved film).
- Patchiness from mechanical causes (uneven film, dark patches in middle or edges, park patches followed by lighter fading, etc.).
- Bar marking from electrical causes (alternate bars of light and dark, pitting/spark marks, etc.).
- Oil/grease deposits from pollution/contamination.
- Burning (spark burns, burning at center or edges, pitted film).
- Marking (brush images on commutator/slip ring, dark fringes.
- Commutator bar faults.
- Commutator bar wear.

Normal Films:

Uniform, light brown (P3) to dark browner (P5). These images show normal films, where the machine and carbon brushes work well.


P3


P4


P5

Carbon Brush Maintenance

In general, always be aware of vibration or noise on the motor frame, on the bearings or bearing housings, or on the carbon brushes themselves. Once the motor has stopped, measure the commutator/slip ring temperature.

Checklist for carbon brush maintenance includes:

- ☐ Be sure to check for carbon brush stability, checking the clearance between brush holders and carbon brushes.
- ☐ If the carbon brush does not slide properly, check the brush-holder interior surface condition.
- ☐ Check the distance between the brush-holder and the commutator/slip ring, making sure it's adjusted correctly.
- ☐ Check spring pressure with a spring scale, making sure pressures are the same on all carbon brushes.
- ☐ Be sure brush-holders are adjusted at the correct angle.
- ☐ Check for signs of commutator wear and for the presence of copper dust.
- ☐ Measure/compare lengths of all brushes for any abnormal wear.
- ☐ Be sure brush edges are intact and have no chips or burn marks, and there are no signs of vibration, sparking, or sticking.
- ☐ Check that shunts are not oxidized, loose, frayed, or discolored.
- ☐ Following re-installation, be sure carbon brushes slide freely, their pressure devices are correctly centered, shock absorber pads are in good condition, and shunts are correctly located for minimal interference.
- ☐ Be sure carbon brushes are installed in the right direction in the brush-holders (especially important for carbon brushes with a beveled contact surface or split brushes with a metal plate).
- ☐ Remove the existing film before changing carbon brushes.
- ☐ Never mix different carbon brushes or brush grades on the same motor.
- ☐ Always maintain an equal number of positive and negative brushes per track.
- ☐ Be sure brush arm spacing is equidistant around the commutator.

Commutators/slips rings must be maintained/checked for:

- ☐ Degreasing
- ☐ Run-out
- ☐ Surface roughness
- ☐ Control of commutator bars
- ☐ Cleaning: Remove dust with a vacuum cleaner and blow dry air through the rotor and stator in both directions, blowing the dust out of the machine, no through it. Maintain filters regularly.

Precautions to take include:

- ☐ Protect commutators/slip rings against oil and dust using non-porous insulating materials.
- ☐ Lift all carbon brushes or insert a sheet of non-porous insulating material between carbon brushes and commutators/slip rings.

Troubleshooting & Repair Guide

SYMPTOMS

A=Sparking at the Leaving Edge
B=Sparking at the Entering Edge
C=Excessive Brush Vibration
D=Sparking Vicious and Trailing Around Commutator
E=Commutator - Slip Ring - Too Hot
F=Brushes and Brush Holders Too Hot
G=Shunts Burned Out or Discolored
H=Rapid Brush Wear - While Commutation Good
I=Unequal Brush Wear
J=Excessive Commutator or Slip Ring Wear - Bright Surface / Film Stripping
K=Cooper Dragging
L=Excessive Commutator or Slip Ring Wear - Bright Surface / Film Stripping
M=Threading and Grooving of Commutator or Slip Ring

PROBABLE CAUSE OF TROUBLE	A	B	C	D	E	F	G	H	I	J	K	L	M
Interpole Field Too Strong		●	●				●						
Interpole Field Too Weak	●		●				●				●		
Interpole Air Gap Too Small		●	●				●						
Interpole Air Gap Too Large	●		●				●				●		
Air Gaps Uneven (Bearings Worn)	●	●							●				
Overload Of Machine	●				●	●	●		●	●			
Vibration From External Causes, i.e., Prime Mover: Nearby Forge Hammer, etc.	●								●		●		
Vibration From Internal Causes, i.e., Out Of Balance, Poor Alignment, etc.	●								●		●		
Oil and Dirt on Commutator or Slip Ring	●							●	●				●
Resistance Between Brushes And Brush Arms Not Uniform						●	●		●				
Grains of Abrasive in the Brush Contact Face									●	●			●
Faults in Armature Winding or Equalizer Connections	●			●		●							
High MICA	●		●	●								●	
Commutator or Slip Ring Eccentric	●	●	●	●				●				●	
Commutator Riser Connections Open Circuited	●	●											
High or Low Commutator Segments	●		●	●								●	
Commutator Loose	●		●	●								●	
Flats on Commutator or Slip Ring	●		●	●								●	
Brush Pressure Too Low	●				●	●	●	●	●	●	●	●	●
Brush Pressure Too High					●	●		●		●	●		●

NOTE: The time factor is important. If consulting a National Application Engineer, state whether the trouble is new, or of long standing.

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PROBABLE CAUSE OF TROUBLE	A	B	C	D	E	F	G	H	I	J	K	L	M
Spring Pressure Unequal	●					●	●						
Brush Grade Unsuitable for Machine and Duty	●			●	●	●		●	●	●	●	●	●
Brush Arc of Contact Excessive	●	●	●										
Brush Arc of Contact Insufficient	●	●	●										
Brush Shunt Connection Faulty							●		●				
Brush Shunt Too Short or Too Stiff	●				●		●		●				
Imperfect Brush Bedding	●	●			●				●				
Radial Brush Holders Mounted At Small Reaction Angle	●				●				●		●		
Brush Sticking or Sluggish in Brush Holder	●				●		●	●	●			●	
Brushes Too Loose in Brush Holder (Holders Worn)	●					●			●				
Terminal Connections Loose or Dirty					●	●	●		●				
Brush Holder Mounted Too Far From Commutator or Slip Ring	●								●				
Incorrect Brush Position	●	●	●									●	
Unequal Brush Holder Spacing or Alignment	●	●	●	●			●		●				
Humidity of Atmosphere Low								●		●			
Humidity of Atmosphere Excessive											●		●
Dusty Atmosphere								●		●			●
Gas or Acid Fumes in Atmosphere	●						●	●					●
Long Periods at Low or Steady Loads											●		●
Silicone Contamination								●					
Fumes From Oils with High Pressure Additives											●		

Troubleshooting & Repair Guide

SYMPTOMS

N=Wear of Slip Ring on One Polarity
O=Copper Picking in Brush Face
P=Brush Chatter
Q=Commutator Surface Streaky
R=Commutator Has Unsymmetrical Burn Marks
S=Commutator Has Symmetrical Burn Marks
T=Commutator Has Wavy Pattern
U=Ghost Marks on Steel Still Rings
V=Pitted Contact Surface of Brush
W=Chipping of Brush Edges or Brush Breakage
X=Failure to Develop A Protective Skin

REMEDY	N	O	P	Q	R	S	T	U	V	W	X
Weaken Interpole Fields by Diverting or by Increasing Gap		●				●			●		
Strengthen Interpole Fields by Reducing Air Gap		●				●			●		
Enlarge Air Gap to Decrease Effective Interpole Flux		●				●			●		
Reduce Air Gap to Increase Effective Interpole Flux		●				●			●		
Renew Bearings and Realign Machine		●				●			●		
Reduce Limit Load on Machine		●					●		●		
Locate and Remove Cause of Vibration	●	●	●			●	●	●	●	●	●
Balance Armature and Check for Bearing Wear	●	●				●	●	●	●		●
Reverse the Polarity of Rings Periodically	●							●			
Clean Commutator or Slip Ring				●	●						●
Clean and Tighten the Connections						●			●		
Rebed and Clean the Brush Face											●
Locate and Cure Fault or Consult Manufacturer					●	●			●		
Recess MICA, or Use More Abrasive Brush		●	●		●				●	●	●
Turn or Regrind Preferably at Near Rated Speed	●	●		●	●		●		●		
Repair Riser and Equalizer Connection						●					
Tighten Commutator, Turn, or Regrind			●		●				●		
Rebuild or Replace Commutator if Necessary		●	●	●	●		●			●	
Locate and Remove Cause of Flatting, Turn or Regrind		●	●						●	●	
Adjust Brush Pressure (For Spring Force) To that Recommended for the Machine	●	●	●	●	●	●		●	●	●	●

Troubleshooting & Repair Guide

REMEDY	SYMPTOMS										
	N=Wear of Slip Ring on One Polarity **O**=Copper Picking in Brush Face **P**=Brush Chatter **Q**=Commutator Surface Streaky **R**=Commutator Has Unsymmetrical Burn Marks **S**=Commutator Has Symmetrical Burn Marks **T**=Commutator Has Wavy Pattern **U**=Ghost Marks on Steel Still Rings **V**=Pitted Contact Surface of Brush **W**=Chipping of Brush Edges or Brush Breakage **X**=Failure to Develop A Protective Skin										
	N	O	P	Q	R	S	T	U	V	W	X
Select One of Our Alternative Grades or Ask for Our Recommendation	●		●			●			●	●	●
Apply A Suitable Circumferential Stagger, Preferably Consult Manufacturer		●				●					
Fit A New Brush With A Sound Flexible Connection											
Use Brushes With Flexible of Correct Length and Flexibility						●					
Bed Brushes by Our Recommended Method				●							●
Adjust Holders To A Radial Position, and Correct Distance From Commutators See * Below	●		●		●	●			●		●
Reverse Holders or Direction of Rotation	●		●		●	●			●		
Check that Brush Size is Correct, Clean Brushes and Holders, Remove Any Burrs		●		●	●		●			●	
If Holders Worn, Replace with New Ones, Order brushes of Correct Dimensions			●			●			●		●
Clean Terminal and Terminal Block, Tighten Screws			●								
*Adjust Holder to be 3/32 in. or 2m.m From Commutator	●		●	●	●	●			●		●
Adjust Holders to Correct Position		●				●		●		●	
Correct Spacing and Alignment of Holders		●				●				●	
Humidify the Cooling Air or Draw Air From Normal Humidity Source			●						●		●
Enclose Machine or Draw Cooling Air From Normal Humidity Source				●				●			
Remove Cause if Possible or Install Filter											●
Arrange Clean Air Cooling				●	●			●		●	●
Change Brush Grade, Ask for Our Recommendation		●	●						●		●

About Renown Electric

Renown Electric is a privately-owned company based out of Concord, Ontario specializing in motor management and supply. Founded in 1984, all aspects of electric motor repair, re-manufacture, overhaul, field service, and engineering support are provided by experts 24 hours a day, 7 days a week, 365 day a year.

Renown is an authorized dealer and service representative of most major manufacturers, and can re-manufacture all major AC and DC motors up to 5000 hp. Renown has CSA qualification for the repair and service of motors and generators in hazardous locations as well as ISO 9001 certification. All repairs use the latest computerized testing techniques, and the service offerings include predictive maintenance, vibration analysis, infrared thermography, oil analysis, and non destructive testing.

Visit our website at www.renown-electric.com, or contact us with any questions or for more information any time.

ENGINEERING SUPPORT PROVIDED 24 HOURS A DAY, 7 DAYS A WEEK, 365 DAY A YEAR

CSA QUALIFIED ISO 9001

ALL REPAIRS USE THE LATEST COMPUTERIZED TESTING TECHNIQUES

SOURCES
1. Mersen. Technical Guide: Carbon Brushes for Motors and Generators.
2. Mersen. Maintenance of Carbon Brushes, Brush-Holders, Commutators and Slip Rings.