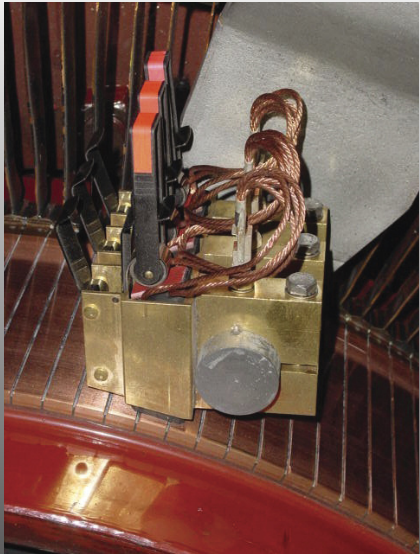
HELWIG CARBON PRODUCTS, INC.



Carbon Brushes

A Comprehensive Guide,
for Industrial and Railway Technology

Specifications • Installation • Troubleshooting

Carbon Brushes—Very Important Functional Parts of Carrying Current in Electrical Machines

The name “brushes” comes from bundles of tiny copper wires, which were used as elastic contacts at the starting period of the electrical engineering industry.

The term “carbon brush” appeared with the change to materials made out of graphite and carbon. Carbon brushes have been developed for several decades; they are also indispensable hardware for electrical machines in the microelectronic era.

The production parameters permit a wide variation of the physical characteristics and the application possibilities. Following DIN EN60276 we subdivide our carbon brush grades into 5 main groups:

- Electrographite brushes
- Metal graphite brushes
- Resin bonded graphite brushes
- Carbon graphite brushes
- Graphite brushes

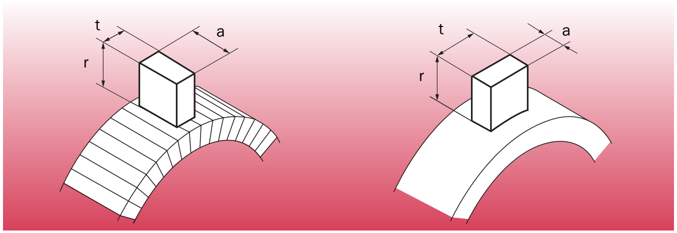
Information in this handbook courtesy of **E-Carbon** Partner **Pantrac GmbH**, Berlin, Germany

Standards for carbon brushes, material and accessories

Below are given the most important standards for industrial and traction carbon brushes.

DIN IEC 60136-3	Dimensions of brushes and brush holders for electrical machinery.
DIN EN 60276	Definitions and nomenclature for carbon brushes, brush holders, commutators and sliprings.
DIN IEC 60413	Test procedures for determining physical properties of brush materials used for electrical machines.
DIN IEC 60467	Test procedures for determining physical properties of carbon brushes for electrical machines.
DIN 43021	Carbon brushes for traction motors. Dimensions and tolerances.
DIN 46224	Stamped cable sockets for flexibles of carbon brushes.
DIN IEC 60760	Flat plug contacts.
DIN 46438	Copper flexibles.

Dimensions and Design of Carbon Brushes



commutator brush　　slipring brush

t = tangential Brush dimension in direction of rotation of commutator or slipring

a = axial Brush dimension parallel to the axis of rotation

r = radial Brush dimension perpendicular to the axis of rotation

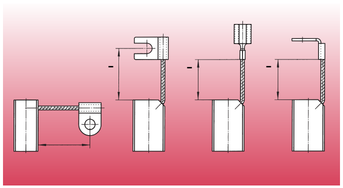
Dimensions of carbon brushes are specified according to DIN IEC 60136-3 in the sequence **t** x **a** x **r**. In order to avoid misinterpretation, we suggest specifying the dimensions in this sequence.

The cross section of the flexible is determined according to a.m. norm and DIN 46438.

The length (l) of the flexible is the distance between the top of the brush and the center of the terminal (see sketch).

When ordering brushes with special terminals (e.g., plug-contact) the length (l) of the flexible should be measured in the accordance to the sketch.

In standard DIN 46224 are given recommendations for basic types and standards for dimensioning of plug types.



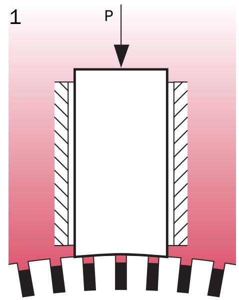
1. Solid brushes
The simplest type of brush used on basic machines without electrical and/or mechanical (challenges).

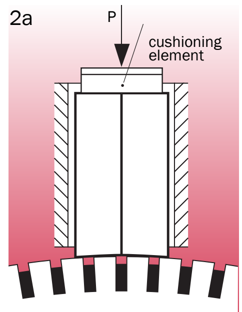
2. Split brushes
Split brushes are formed by assembling 2, 3, or more carbon sections into one unit to create better electrical and mechanical contact conditions.

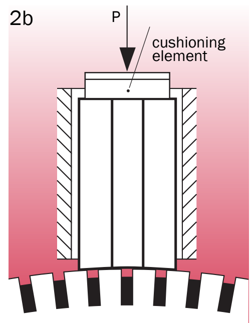
First, the (splitting) of the brush leads to a large number of electrical contact points between the brush surface and the commutator; it also increases the resistance in the transverse circuit of the brush because of the additional contact resistance between the brush parts. The cutting of the brush causes smaller acceleration forces over the brush parts which enables better dynamic properties.

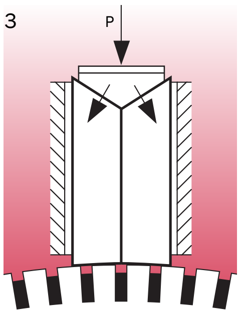
Split brushes give satisfactory results (mainly) on machines with reversing operations, since there is a faster adaptation to the running surface. In addition, tops made of rubber, laminate, or both cause a uniform pressure distribution, as well as a bigger damping ability.

The tangential dimension of the brush sections must not be less than 4 mm for mechanical reasons.



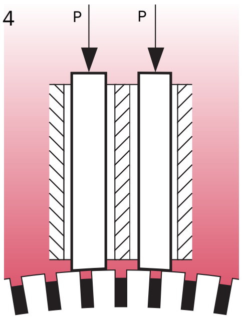






3. Spread brushes

The spread brush is a special type of split brush in which the tops of both sections are chamfered at a certain angle towards their dividing line. Pressure to the brush is applied via a top piece with an accordingly chamfered bottom face. The top pieces are generally made from brush or insulation material that has a cushioning effect.

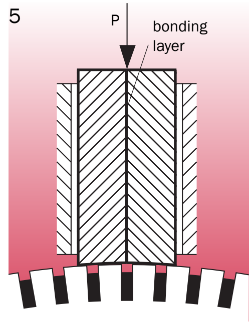


4. Tandem brushes

Tandem brushes are special pairs of brushes, where each brush has its own box within the tandem brush holder, pressed against the commutator by separate pressure fingers. The result is a symmetrical brush pressure and current distribution.

5. Sandwich brushes

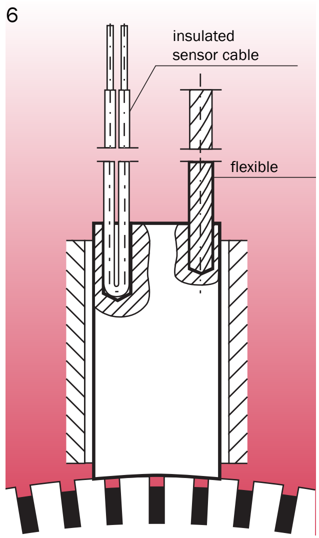
When the segments of split brushes are bonded together, they are called sandwich brushes. The bonding layer can be an insulating material. From a mechanical point of view this is now a solid brush with an additional polishing effect caused by the bonding layer. From an electrical point of view, the brush has an increased cross resistance. By using different brush materials for the single wafers, it is possible to influence the commutation properties of the carbon brush.

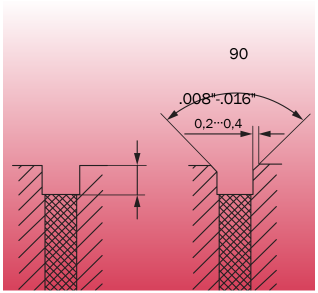


6. Carbon brushes with wear sensor

Carbon brushes with wear sensors signal when the wear limit is reached and enable a lower maintenance supervision. An insulated sensor cable is glued in the carbon brush and the warning occurs when the insulation of the contact is worn down through the wear of the carbon brush.

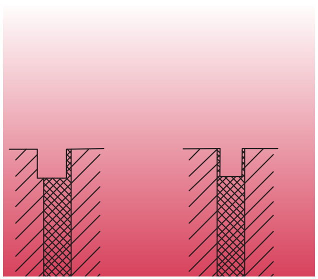
The warning is electrically evaluated and optically and acoustically recorded.





Undercut to the correct width and depth

Undercut and beveled correctly



Offset undercut (wrong)

Too thin an undercut (wrong)

Here are the required conditions for perfect carrying and for black commutation:

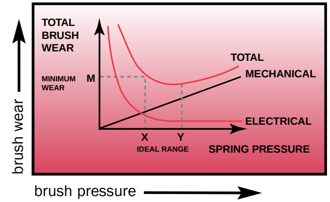
- good roundness of the commutator
- no lamination protrusions
- no flat points on the commutator
- a symmetrical undercutting of the commutator insulation, and chamfered laminate edges
- very slight roughness of the commutator or slipring surface
- uniform brush pressure
- good seating of the brushes to the commutator/slipring surface.

Commutator and slipring machining

A new or reconditioned commutator should have an out of roundness of not more than .001" (0.02 mm). Lamination protrusions between neighboring laminates over .0001" (0.002 mm) and the flat points must be eliminated. Depending on the application conditions and the carbon brush material, generally the rotors should be reconditioned if there is long-wave unroundness of more than .012" (0.30 mm) and short-wave roundness of more than .006" (0.15 mm).

Commutators with flush mica against the copper segments require very hard brush material with the consequence of high commutator wear. For a better lifetime, it is necessary to undercut the insulation (see sketches).

A new commutator should have a surface of roughness Rz between .0001" and .0003" (4 and 8 µm).



Brush pressure

The brush pressure must be set to the operating conditions. It must also represent a compromise between the mechanical and electrical wear.

Recommendations for brush pressure

Type of machine	Brush pressure in PSI (kPa) mounting	
	stable	swing frame
DC machines up to 1500 r.p.m.	2.0-3.0 (15-20)	3.0-4.5 (20-30)
DC machines over 1500 r.p.m.	3.0-4.0 (20-25)	3.5-5.0 (25-35)
Three-phase commutator machines	2.5-3.0 (18-20)	3.5-4.5 (25-30)
Slipring motors	3.0-3.5 (20-25)	3.5-5.0 (25-35)
Turbo generators	2.0-3.5 (15-25)	-
Traction motors	-	4.5-7.5 (30-50)

The tolerance of the brush should be limited to ± 10%

Seating in of the carbon brushes

The interface of brushes to the slipring or commutator surface occurs with the seating in the brushes. Here are several techniques used:

1. The carbon brushes are placed in the brush holder. A strip of abrasive linen (recommend garnet paper of 80-100 granulation) is pushed between the brush and the surface of the commutator or slipring. This strip is then drawn in a tangential direction.

After the running surface has approximately taken the shape of the commutator’s or slipring’s surface, the contact mean is drawn in the direction of rotation of the machine to finish the grinding. In order to withdraw the abrasive linen, the brushes have to be raised. In this way, it is guaranteed that the brushes take the same position in the brush holder as in the future operation of the machine.

2. A strip of abrasive linen is fitted around the commutator or slipring, and fixed with adhesive tape. Then, the brushes are placed in the holder and the rotor of the machine is turned over in the operating direction (particularly at smaller machines).

3. The machine is completely equipped with carbon brushes, and it is put into operation in idle running (possibly with a reduced speed of rotation). A pumice stone is pressed in front of the brushes on the commutator. The dust of the pumice stone which results reaches the brushes and grinds them in.This method of grinding is particularly suited to large DC machines.

The seating in can be finished when about 70% of the running surface has contacted with the commutator/slipring. After the seating in, the carbon brushes have to be taken away from the holder, and the machine has to be cleaned by means of oil free compressed air.

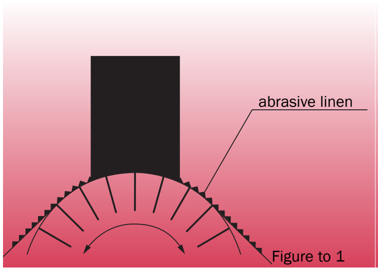


Figure to 1

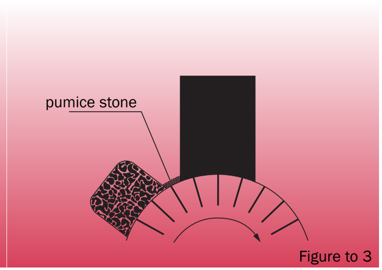


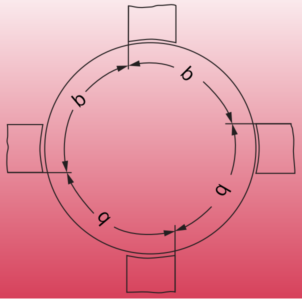
Figure to 3

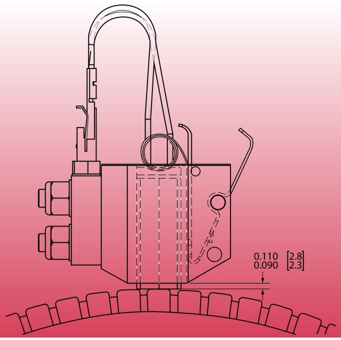
Attention, the dust must not reach the coils or the machine bearing.

The carbon brushes have to be cleaned with a clean rag (without oil or fat), and their running surface must be cleaned by means of a glass brush in order to avoid infiltrated grains.

Mounting of the brush holders and brushes

To ensure correct operation of brushes, the holders and brushes must be fitted exactly geometrically on the commutator in accordance with the design of armature and windings. For instance, the distance between brushes of different polarities must be equal. To make certain that this is the case, a strip of paper is put around the commutator under the brushes, and the distance between the impressions of the brushes of each pole can then be measured correctly. This strip of paper can be used as a record for checking the positions at a later stage. A variation of as little as .020" (0.5 mm) between the brushes of different polarities can cause considerable problems with regard to commutation and current distribution.





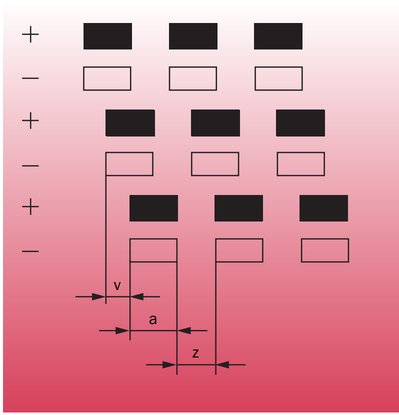
The distance between the commutator and the lower edge of the brush box should be set at between .090" - .110" (2.3 and 2.8 mm). If the commutator has been remachined, the brush holders will have to be reset to maintain this distance. The setting of the brush holders should be done with a distance piece.

If the distance between the brush holder and commutator is too high, this can lead to brush vibration, because the brush will be tilted at a greater angle. On the DC machines, brushes should be installed in the same track for each pole pair. This insures that the patina/film being built is not adversely affected by the brushes on the plus and on the minus poles.

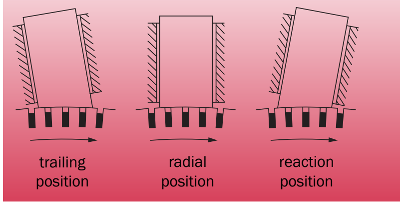
On machines with high number of poles, the brushes will be staggered across the commutator axially so that there is even wear across the commutator.

If the commutator is long enough, the best stagger arrangement would be as follows:
v = z = a/(p-1)

v = Stagger
z = Distance between brush pair of same polarity
a = Axial brush dimension
p = Number of brush pole pairs, i.e., half the number of poles of the machines



The fitting of brushes on the commutator must be carried out either exactly radial or at a certain angle, which is then called either a trailing or a reaction position, according to the direction in which the commutator rotates.
The trailing and reaction position are used in order to reduce vibrations.



Assessment of Performance of Carbon Brushes

Appearance of the brush sliding face

The following pictures show typical brush-sliding faces. For easy identification, we suggest you use the symbols **S1**, **S3** etc. **S1**, **S3** and **S5** are satisfactory sliding faces, indicating that there are no mechanical or electrical problems. Depending on the carbon material, the sliding surface appears dense or porous, and shiny, dull or matte. If there is dust in the circulating air, fine hairlining may occur, as shown in **S5**.

S1 - Dense, shining sliding face

Normal operation

S3 - Slight porous sliding face

Normal operation

S5 - Fine hairlining

Normal operation, slight dust influence

S7 - Hairlining

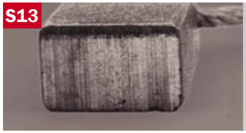
Causes: Underload, influence of dust, oil, or grease, weak spring pressure

S9 - Tracking with hairlining and grooves

Causes: Like S7, but stronger

S11 - Ghostmarks, difficult commutation

Causes: Commutation problems, e.g., false or incorrect position of the neutral zone or interpole

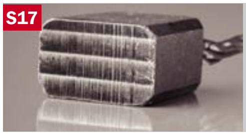


S13 - Burning edge of the leaving or trailing edge

Causes: Difficult commutation, heavy sparking, interruption of contact due to out of round of commutator or insufficient brush holder spring pressure

S15 - Eroded brush face

Causes: Electrical overload, interruption of contact

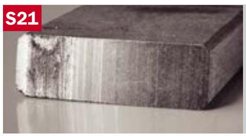


S17 - Lamination of sliding face

Causes: Burned segments of the sliding face, caused by a winding fault giving voltage surge during commutation

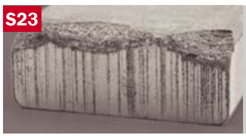
S19 - Double facing here for a twin brush

Causes: Tilting of the brush in dual direction machine



S21 - Copper nests

Causes: Pick up of copper particles, often following copper drag



S23 - Broken edges

Causes: High raised lamination, commutator seriously out of round, brush chatter by low load and idle running

Commutator appearance

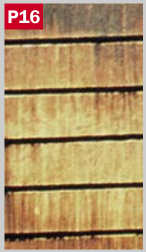
In addition to the physical appearance of the surface of the commutator, the skin or patina/(film) is of equal importance for the good running of the carbon brushes. Each carbon brush builds a characteristic patina/(film) which is affected by operating and ambient conditions.

The patina/(film) consists mainly of copper oxides, graphite deposits and absorbed water, and its appearance is of importance for the assessment of the running behavior of the commutation set. The following pictures are used by carbon brush manufacturers and users of brushes as a guide to assist in judging the operation of carbon brushes.

P2, **P4** and **P6** are examples of normal skin or patina/film formation. When a machine runs well, the patina/film or skin on a commutator will be even, slightly shiny and coppery brown to black in color.

There may be appearance of greyish, blueish and reddish hues, but of importance is the evenness of the skin formation and not its color.

Electrical, mechanical and atmospheric influences on the patina/film appearance.



P12 - Streaky patina/film having some wide and narrow tracks of different color. No commutator wear.

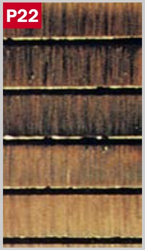
Causes: High humidity, oil vapor, aggressive gases in the atmosphere, low electrical load on the brushes

P14 - Torn patina/film, general appearance as in P12, but with commutator wear.

Causes: As in P12, but the conditions have been maintained for a longer period, causing commutator damage

P16 - Smutty patina/film, uneven skin having patchy colors and random spots.

Causes: Uneven commutator or unclean operating conditions

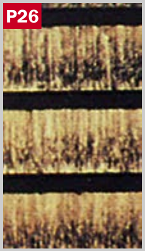


P22 - Patina/film with dark areas, regular or irregular patches covering one or more commutator segments.

Causes: Out of round commutator, vibrations of the motor caused by badly adjusted shaft or damaged bearings

P24 - Dark patchy patina/film having definite edges as in T12 and T14.

Causes: Raised segment or group of segment causing the brush to bounce



P26/P28 - Commutator segments having patches in the middle or at the edges.

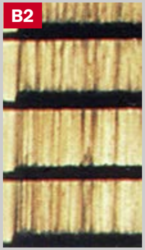
Causes: Often due to faulty grinding of the commutator or commutating problems

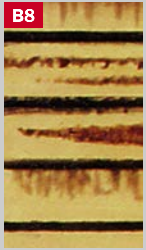
P42 - Alternating light and dark bar markings.

Causes: Uneven current distribution over two parallel windings caused by double windings crossing in the same slot

P46 - Mat patches in double pole patches.

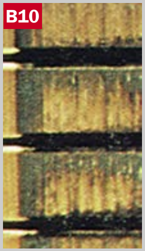
Causes: Usually by faulty soldering of the risers or segment connections





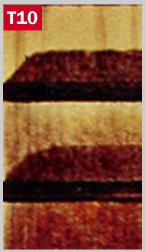
B2, B6, B8 - Burning at the edge or in the middle of bar.

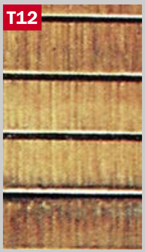
Causes: Sparking caused by commutation problems

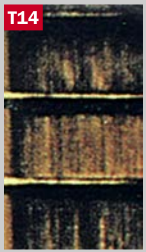


B10 - Perforated patina/film, light, dense or distributed build-up spots.

Causes: Patina/film destruction caused by too large electrical resistance







T10 - Dark patches at edges of bars in direction of rotation.

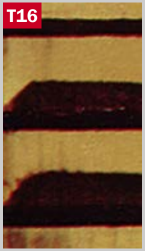
Causes: Frequently caused by long periods with the motor being stationary without power or short stationary periods under load

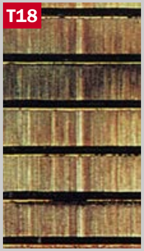
T12 - Burning of a trailing edge and the next leading edge of a bar.

Causes: Caused by protruding segment, as in L2

T14 - Dark markings.

Causes: Sign of a low segment, could also be caused by a flat spot on the commutator





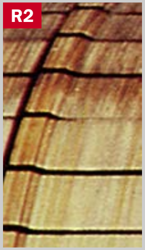
T16 - Clearly defined dark markings together with segment edges burnt.

Causes: Raised mica (see L6)

T18 - Dark markings.

Causes: Badly undercut segment edges (see L8)

Commutator wear

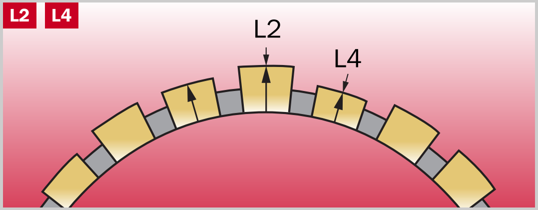


R2 - Top view of a commutator.

Causes: Trackwise normal metal abrasion after long period of operation with correctly positioned brushes

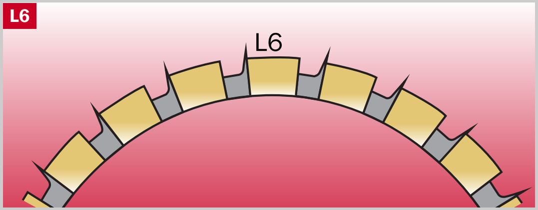
R4 - Commutator bar showing abnormal metal abrasion.

Causes: Abnormal abrasion is caused by incorrect brush alignment, incorrect brush material or contamination, etc.

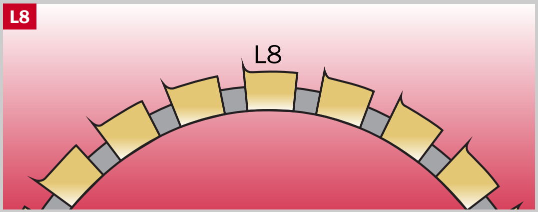


L2 - Protruding segment

L4 - Low segment

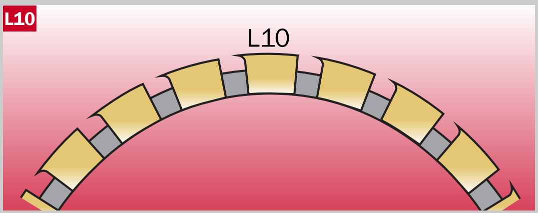


L6 - Raised mica



L8 - Ridge on the segment edge

Causes: Faulty commutator segments



L10 - Copper drag

Causes: Bumps or vibrations with various causes

Instructions in Case of Operating Difficulties

Strong brush sparking

Cause	Corrective measures
Out of round commutator or slipring	Turning or grinding (see "Directions for Installation and Operation")
Insufficient brush pressure	Increase brush pressure (see recommendations for brush pressure, page 9)
Carbon brushes are stuck in holder	Carefully remove foreign bodies and dust from brush holder. Dust grooves are recommended
Oil or dirt between segments	Clean segments, filter cooling air, and possibly seal bearings
Carbon brushes (not seated in)	Repeat the seating in process
Brush holder too far from the commutator or slipring	Adjust distance between holder and commutator to 2 mm
Protruding insulation segments	Undercut insulation and chamfer segments
Machine vibrating or chattering	If it is not possible to reduce the vibration of the machine, increase brush pressures or use a brush design fitted with fiber and rubber top
Wrong positioning of brush bridge	Establish neutral position and adjust brush arms accordingly
Faulty installation of brush arms	Adjust brush arms correctly
Interpole too strong or too weak	Machine manufacturer to correct fault, or install another brush grade to compensate
Incorrect brush grade	Please, contact our technical service

Patches or burn marks

Cause	Corrective measures
Producing or low segments (L2,L4)	Retighten and turn the commutator
Raised mica insulation (T16, P24)	Turning the commutator, undercut mica and possibly retighten commutator
Out of round commutator or sliprings, i.e., badly out of balance (P16)	Rebalance and/or remachine commutator or slipring
Bad soldering of risers (P42, P46)	Resolder risers
Electrolytic deposit from brush to steel on stationary steel sliprings (galv. element)	In case of long standstill periods, insert insulating strip under the carbon brush

Excessive wear of commutator and sliprings

Cause	Corrective measures
Overload on brush track due to uneven current distribution	Adjust brush pressures to the correct level. Possibly use brushes with a higher polishing effect
Dusty environment (P14)	Blow in clean air by installing a filter
Aggressive gases or vapors (P12)	Blow in clean air and use brushes with a stronger polishing effect
Grooving caused by low electrical load on brushes (P14)	Reduce number of brushes per pole or change brush grade
Grooving caused by oil film on commutator or sliprings	Seal bearings and avoid oil vapor
Material loss by anodic when using sliprings with DC current	Change polarity of sliprings from time to time
Copper drag (L10)	Because of complex nature of potential causes, please contact our Technical Service Department
Development of flat spots	Install starting current limits

Uneven brush wear

Cause	Corrective measures
Uneven current distribution	Adjust brush pressure to correct level
Bad connection of wire to brush	Change carbon brushes
Mixed brush grades	Use only one brush grade
Brushes stuck in holder	Clean holder, brushes and check tolerances, use dust grooves eventually

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