PanTrac

Carbon Brushes

for Industrial
and Railway Technology

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Ver. 1e/7-03

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

The name “carbon 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 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 EN 60276 we subdivide our carbon brush grades into 5 main groups:

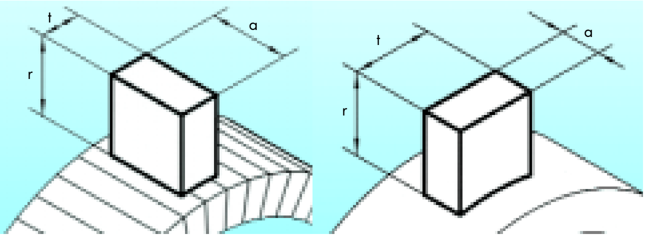
- Electrographite brushes
- Metal graphite brushes
- Resin bonded graphite brushes
- Carbon graphite brushes
- Graphite brushes

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



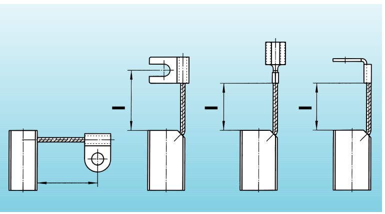
commutator brush slipring brush

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 to specify the dimensions in this sequence.
The cross section of the flexible is determined according to a. m. norm and DIN 46438.



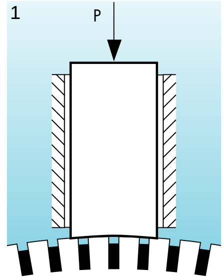
The length (l) of the flexible is the distance between the top of the brush and the center of the terminal (see sketch).
When ordering brushes with special terminals (e.g. plug-contact) the length (l) of the flexible should be measured in accordance to the sketch.
In standard DIN 46224 are given recommendations for basic types and standards for dimensioning of plug types.

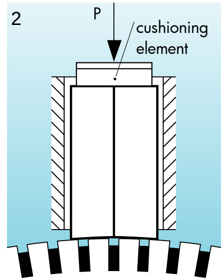
1. Solid brushes

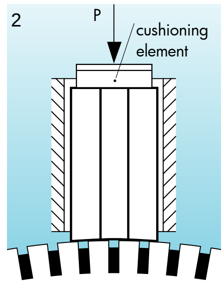
The simplest type of brush used on machines without electrical and/or mechanical problems.

2. Split brushes

The solid brushes which are relatively heavy and rigid are cut into 2 or 3 parts of equal size in order to create better electrical and mechanical contact conditions. First, the cutting 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.

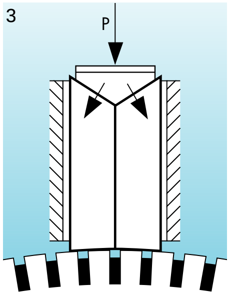






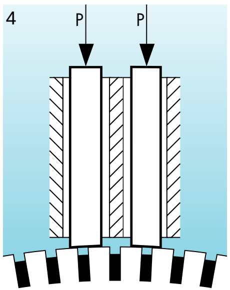
The tangential dimension of the brush parts has to be not less than 4 mm for mechanical reasons.

3. Spread brushes



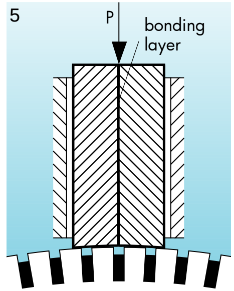
The spread brush is a special type of split brush the top of which are chamfered at a certain angle towards their dividing line. Pressure to the brush is applied via a top piece with accordingly chamfered bottom face. The top pieces are generally made from brush or insulation material that has a cushioning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

4. Tandem brushes



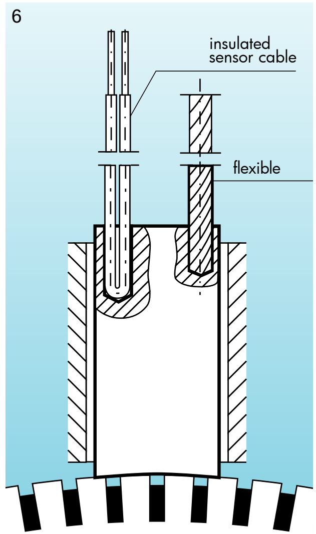
Tandem brushes are special pairs of brushes, where each brush has its own box within the tandem brush holder, pressed against the commutator by separate pressure fingers. The result is a symetrical brush pressure and current distribution.

5. Sandwich brushes



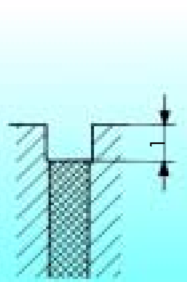
When the segments of split brushes are bonded together they are called sandwich brushes. The bonding layer can be of an insulating material. From a mechanical point of view this is now a block brush with an additional polishing effect caused by the bonding layer. From an electrical point of view the 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

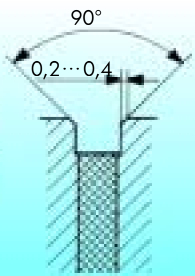


Carbon brushes with wear sensors signal when the wear limit is reached and enable a lower maintenance supervision. An insulated sensor cable is glued in the carbon brush and the warning occures when the insulation of the contact is worn down through the wear of the carbon brush.
The warning is electrically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

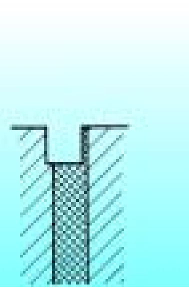
Directions for Installation and Operation



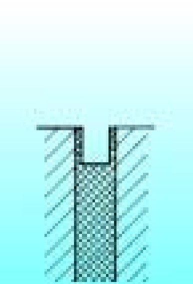
Undercut to the correct width and depth



Undercut and bevelled correctly



Offset undercut (wrong)



To thin an undercut (wrong)

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

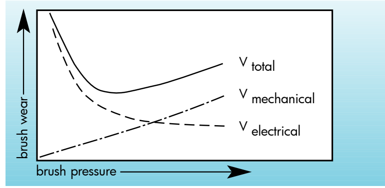
- good roundness of the commutator
- no lamination protrusions
- no flat points on the commutator
- a symmetrical undercutting of the commutator insulation, and chamfered laminate edges
- very slight roughness of the commutator or slipring surface
- uniform brush pressure
- good seating of the brushes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

Commutator and slipring machining

A new or reconditioned commutator should have an out of roundness of not more than 0,02 mm. Lamination protrusions between neighbouring laminates over 0,002 mm and the flat points must be eliminated. In dependence on the application conditions and the carbon brush material, the rotors should be reconditioned in case of long-wave unroundness of more than 0,30 mm and short-wave unroundness of more than 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 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 kPa mounting stable	Brush pressure in kPa mounting swing frame
DC machines up to 1500 r.p.m	15–20	20–30
DC machines over 1500 r.p.m	20–25	25–35
Three-phase commutator machines	18–20	25–30
Slipring motors	20–25	25–35
Turbo generators	15–25	–
Traction motors	–	30–50

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

Bedding in of carbon brushes

The interface of brushes to the slipring or commutator surface occures with the bedding in of the brushes. Herewith are several techniques used:

1. The carbon brushes are placed in the brush holder. A strip of abrasive linen (for instance a granulation 80-100) is pushed between the brush and the surface of the commutator or slipring: This strip is drawn in a tangential direction.
After that the running surface has approximately taken the shape of the commutator or slipring's surface the contact means 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

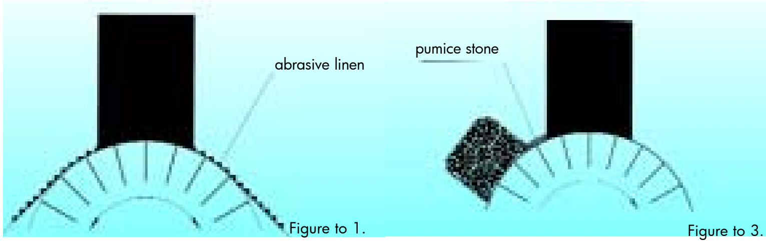


Figure to 1.
Figure to 3.

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.

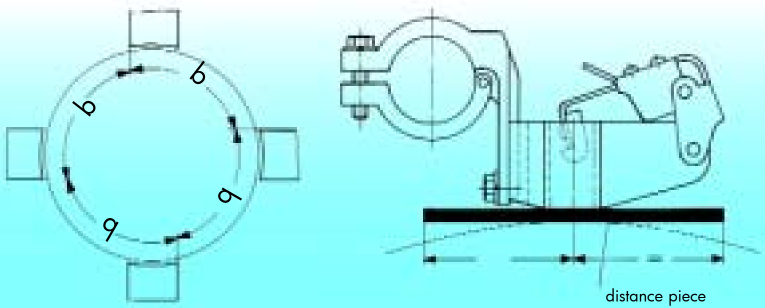
The bedding in can be finished when about 70% of the running surface has contacted with the commutator/slipring. After the bedding in the carbon brushes have to be taken away from the holder and the machine has to be cleaned by means of oilfree compressed air.

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

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

Mounting of 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 0.5 mm between the brushes of different polarities can cause considerable problems with regard to commutation and current distribution.



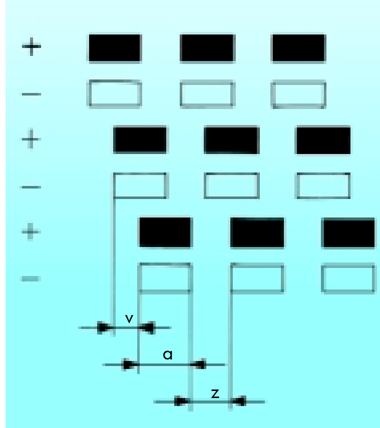
The distance between the commutator and the lower edge of the brush box should be set at between 1.5 and 2.0 mm. If the commutator has been remachined, the brush holders will have to be reset to maintain this distance. The setting of the brush holders should be done with a distance piece.

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 DC machines brushes should be installed in the same track for each pole pair. This ensures that the patina being built is not adversely affected by the brushes on the plus and on the minus poles. On machines with high number of

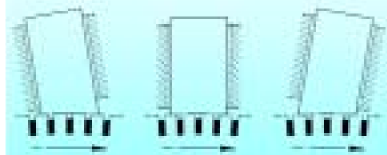
poles, the brushes will be staggered across the commutator axially so that there is even wear across the commutator.

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.

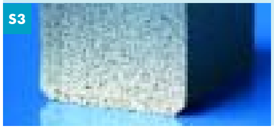
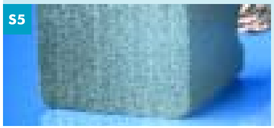
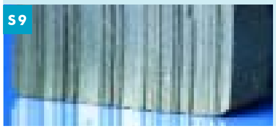


Assessment of Performance of Carbon Brushes

Appearance of the brush sliding face

The following pictures show typical brush-sliding faces. For easy identification we suggest you to 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 matt. If there is dust in the circulating air fine hairlining may occur as shown in S5.

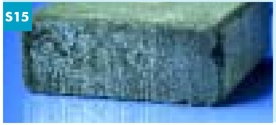
	S1 Dense, shining sliding face	Normal operation
	S3 Slight porous sliding face	Normal operation
	S5 Fine hairlining	Normal operation, slight dust influence
	S7 Hairlining	Causes: Underload, influence of dust, oil or grease
	S9 Tracking with hairlining and groves	Causes: Like S7, but stronger

S11 Ghostmarks, difficult commutation

Causes: Communication 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

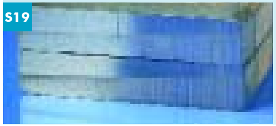


S15 Eroded brush face

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

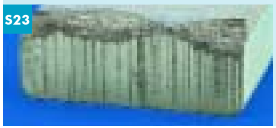


S19 Double facing here for a twin brush

Causes: Tilting of the brush in dual direction machine

S21 Copper nests

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

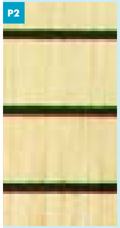


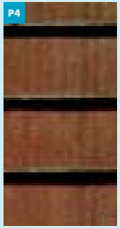
S23 Broken edges

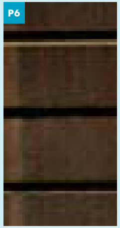
Causes: High raised lamination, commutator seriously out of round, brush chatter by low load and idle running

Commutator appearance

In addition to the physical appearance of the surface of the commutator, the skin or patina is of equal importance for the good running of the carbon brushes. Each carbon brush builds a characteristic patina which is affected by operating and ambient conditions. The patina consists mainly of copper oxides, graphite deposits and absorbed water, and its appearance is of importance for the assessment of the running behaviour of the commutation set. The following pictures show typical appearances of commutation surfaces. The pictures are used by carbon brush manufacturers and users of brushes as a guide to assist in judging the operation of carbon brushes.



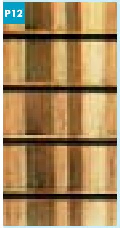


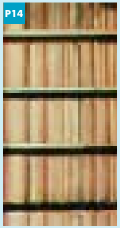


P2, P4 and P6 are examples of normal skin or patina formation. When a machine runs well, the patina or skin on a commutator will be even, slightly shiny and coppery brown to black in colour.

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

Electrical, mechanical and atmospheric influences on the patina appearance





P12 Streaky patina having some wide and narrow tracks of different colour. No commutator wear

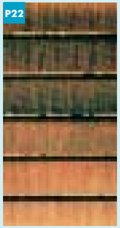
Causes: High humidity, oil vapour, aggressive gases in the atmosphere, low electrical load on the brushes

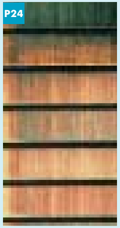
P14 Torn patina, general appearance as in P12, but with commutator wear

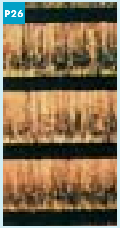
Causes: As in P12, but the conditions have been maintained for a longer period causing commutator damage

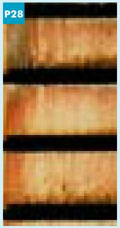
P16 Smutty patina, uneven skin having patchy colours and random spots

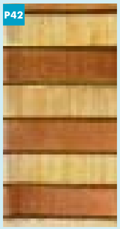
Causes: Uneven commutator or unclean operating conditions

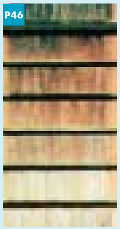




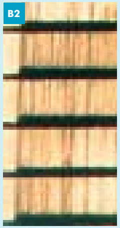


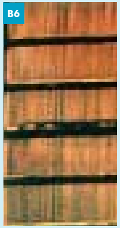






P22	Patina with dark areas, regular or irregular patches covering one or more commutator segments	Causes: Out of round commutator, vibrations of the motor caused by badly adjusted shaft or damaged bearings
P24	Dark patchy patina having definite edges as in T12 and T14	Causes: Raised segment or group 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 pitches	Causes: Usually by faulty soldering of the risers or segment connections

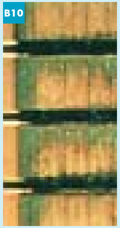




B2, B6, B8

Burning at the edge or in the middle of bar

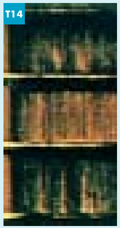
Causes: Sparking caused by commutation problems



B10

Perforated patina, light, dense or distributed build-up spots

Causes: Patina 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

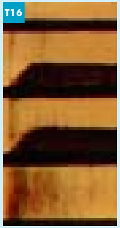
Burning of a trailing edge and the next leading edge of a bar

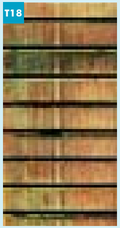
Causes: Caused by protruding segment as in L2

T14

Dark markings

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





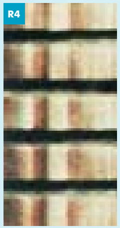
T16 Clearly defined dark markings together with segment edges burnt

Causes: Raised mica (see L6)

T18 Dark markings

Causes: Badly undercut segment edges (see L8)

Commutator wear

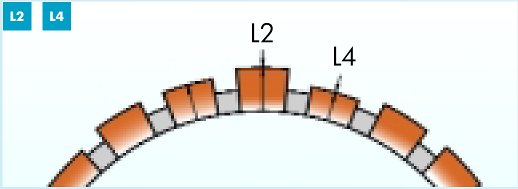


R2 Top view of a commutator

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

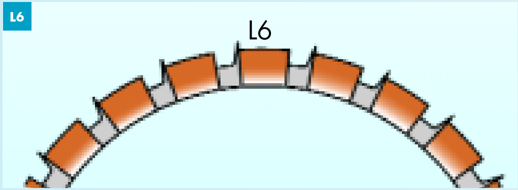
R4 Commutator bar showing abnormal metal abrasion

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

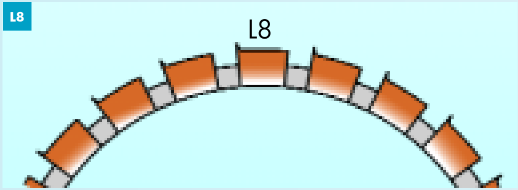


L2 Protruding segment

L4 Low segment

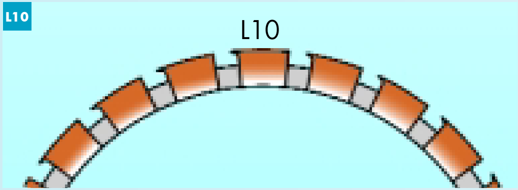


L6 Raised mica



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 page 9)
Carbon brushes are stuck in holder	Carefully remove foreign bodies and dust from brush and holder. Dust grooves are recommended
Oil or dirt between segments	Clean segments, filter cooling air, and possibly seal bearings
Carbon brushes badly bedded in	Repeat bedding in
Brush holder too far from the commutator or slipring	Adjust distance between holder and commutator to 2 mm
Protruding insulation segments	Undercut insulation and shamfer 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 fibre and rubber top
Wrong position 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 turning 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 desposit from brush to steel on stationary steel sliprings (galv. element)	In case of long standstill periods insert insulating strip under the carbon brush

Exessive 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 enviroment (P14)	Blow in clean air by installing a filter
Aggressive gases or vapours (P12)	Blow in clean air and use brushes with a stronger polishing effect
Grooving caused by low electrial 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 vapour
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 the cause, please contact our technical service
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 tail 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

Carbon Brush Grades and Typical Properties

SGL CARBON GmbH (Ringsdorff®, EKL)

	Grade designation	Resistivity µΩm	Density g/cm³	Flexural strength MPa	Hardness Rockwell B	Current density A/cm²	Peripheral speed m/s
Electrographite	**RE 28**	42	1,63	21	70 HR 10 / 100	12	50
	RE 50	9	1,40	7	-	10	80
	RE 54	18	1,58	28	65 HR 10 / 60	12	50
	RE 59	49	1,67	24	75 HR 10 / 150	12	56
	RE 60	50	1,67	20	70 HR 10 / 150	12	56
	RE 75	25	1,56	21	58 HR 10 / 60	12	50
	RE 76	25	1,57	25	68 HR 10 / 60	12	50
	RE 78	23	1,54	17	75 HR 10 / 40	12	50
	RE 80	15	1,50	9	30 HR 10 / 40	10	50
	RE 92	16	1,53	14	55 HR 10 / 40	12	50
	RE 98	61	1,41	12	50 HR 10 / 60	12	60
	RE 140	90	1,68	25	95 HR 10 / 150	10	50
	RE 170	74	1,68	27	92 HR 10 / 150	10	50

It is possible to improve the running properties of the grades by impregnation: in that case, numbers or letters are added to the basic grades, e.g. RE 59 N1

SGL CARBON GmbH (Ringsdorff®, EKL)

	Grade designation	Resistivity µΩm	Density g/cm³	Flexural strength MPa	Hardness Rockwell B	Current density A/cm²	Peripheral speed m/s
Electrographite	**E 33**	57	1,62	22	105 HR 10 / 100	12	60
	E 33T	57	1,65	25	108 HR 10 / 100	12	60
	E 33U	57	1,65	27	110 HR 10 / 100	12	60
	E 34	48	1,58	25	90 HR 10 / 100	12	60
	E 34T	48	1,60	25	90 HR 10 / 100	12	60
Metal graphite	**RC 53**	1,3	3,2	30	84 HR 10 / 60	18	40
	RC 67	0,4	3,8	35	83 HR 10 / 60	18	35
	RC 73	0,20	4,2	44	85 HR 10 / 60	20	30
	RC 87	0,10	5,2	55	60 HR 10 / 60	22	25
	RC 90	0,09	5,3	36	74 HR 10 / 40	22	25
	RC 95	0,12	6,2	115	75 HR 10 / 60	25	20
	RS 70	0,8	4,3	30	90 HR 10 / 60		20
Resin bonded graphite	**RX 88**	140	1,68	32	85 HR 10 / 60	10	35
	RX 91	330	1,41	18	80 HR 10 / 40	10	40

It is possible to improve the running properties of the grades by impregnation: in that case, numbers or letters are added to the basic grades, e.g. RE 59 N1.

SGL CARBON Corporation, St. Marys (USA), (C/G bzw. AIRCO Speer Carbon)

	Metal %	Grade designation	Resistivity µΩm	Density g/cm³	Flexural strength MPa	Hardness Rockwell B	Current density A/cm²	Peripheral speed m/s
Electrographite		**E 3**	8	1,69	21	30	12	45
		E 31	48	1,60	28	70	12	40
		E 37	43	1,60	34	75	10	40
		E 41	58	1,55	21	60	12	45
		E 44	43	1,72	38	80	10	35
		E 45	58	1,55	23	55	12	45
		E 49	43	1,64	21	70	12	50
		E 57	53	1,53	18	50	12	45
		E 60	48	1,66	37	75	12	50
		E 61	15	1,45	10	30	12	45
		E 63	14	1,58	14	30	12	50
		4029	64	1,46	14	45	12	40
		4041	76	1,49	9	50	12	37
		6677	76	1,60	17	65	12	50
Natur Graphite		**702**	25	1,43	5	15	10	70
Copper Graphite	15	**626**	12,7	2,04	17,2	35	14	40
	30	**661**	6,6	2,35	18,6	35	16	40
	40	**672**	3,1	2,69	25,5	35	17	40
	50	**673**	2,03	2,95	22,1	30	18	35

Identical grade names have historical backgrounds. However properties and applications are not similar.

SGL ANGRAPH SP. Z O.O., Nowy Sacz, Polen

	Grade designation	Resistivity µΩm	Density g/cm³	Flexural strength MPa	Hardness Rockwell B	Current density A/cm²	Peripheral speed m/s
Electrographite	**E 13**	10–16	1,70	5	29	12	40
	E 13S	10–17	1,75	11	33	12	40
	E 17	15–22	1,55	6	34	12	40
	E 17S	15–25	1,60	10	36	12	40
	E 28	22–35	1,60	10	56	10	40
	E 28S	20–34	1,70	18	64	10	40
	E 30	28–42	1,69	8	55	10	40
	E 30K	26–41	1,65	12	55	10	40
	E 33S	27–42	1,68	16	58	10	50
	E 35	32–48	1,70	10	59	10	40
	E 35S	30–47	1,72	16	63	10	40
	E 40K	27–42	1,65	12	56	10	50
	E 44S	37–52	1,68	18	62	10	50
Natur Graphite	**G 12**	9–15	1,55	5	25	11	25
	G 20	17–26	1,66	5	32	11	25
	G 20S	15–26	1,68	10	35	11	25

It is possible to improve the running properties of the grades by impregnation: in that case, numbers or letters are added to the basic grades, e.g. E 28S. Identical grade names have historical backgrounds.

However properties and applications are not similar.

Recommended Applications of Carbon Brushes for Stationary Machines

Application	Manufacturer **Semi-finished products:** SGL CARBON GmbH (Ringsdorff®, EKL) **Final products:** PanTrac GmbH, Berlin
DC machines until 110 V, Fork lift motors	RE 75, RE 76, RE 78, RE 54, VM 81
Large DC machines > 110 V	
Rolling mill and mine hoist motors	RE 60, RE 92N1, RE 98N1
Control generators	RE 92N1, RE 98N1, RE 60
Exciters	RE 60, RE 75
Steel mill auxiliary motors	RE 75, RE 54
Small and medium DC machines	RE 603, RE 753, RE 60N5, RX 91, RE 98, RE 170
3-phase commutator motors	RX 88, RX 91
Sliprings until 40 ms^{-1}	
Bronze and copper rings	RC 53, RC 73, RE 54, RE 92
Remanite, perlite- and spheroidal cast iron rings	RC 53, RC 73, RE 92, RE 54
Sliprings until 80 ms^{-1}	
Steel rings (Turbo generators)	RE 50
Earthing contacts	RE 50, RS 70

stationary machines

Recommended Applications of Carbon Brushes for Railway Technology

Application	Manufacturer	
	Semi-finished products: SGL CARBON GmbH (Ringsdorff®, EKL) **Final products:** PanTrac GmbH, Berlin	
Traction motors (railway)		
16 $^{2}/_{3}$-Hz-AC traction motors	E 33, E 33U	RE 59, RE 60N7
Thyristor controlled motors	E 34D	RE 59N1
DC traction motors	E 34T	RE 59N1
Traction motors (local traffic)		
DC without chopper control	E 33T, E 34T	RE 59, RE 59N1, RE 92N7, RE 76
DC with chopper control	E 34T	
Trolleybus	E 34T	RE 59N1
Diesel electric trains		
DC motors	E 33, E 33T, E 34T	RE 59N1
Train generators	E 33, E 33D	RE 59N1
Traction motors for mining and industrial railways	E 34D	RE 76, RE 59N1
Auxiliary motors	E 33, E 33D	RE 54, RE 59, RX 91
Railway Earthing Devices		RC 87, RC 90

Recommended Applications of Carbon Brushes for Stationary Machines

Application	Manufacturer	
	Semi-finished products: SGL CARBON Corporation St. Marys, USA	**Semi-finished products:** SGL ANGRAPH SP. Z O.O. Nowy Sacz, Poland
DC machines until 110 V, Fork lift motors		E 30
Large DC machines > 110 V		
Rolling mill and mine hoist motors	E 45, E 41, E 57, 4029	E 30, E 30K, E 28
Control generators	E 45, E 61	E 30, E 35S
Exciters	E 35, E 61	
Steel mill auxiliary motors	E 45, 4029	E 28, E 28S, E 40K
Small and medium DC machines	E 45, E 61, 4029	E 17, E 28, E 28S, E 40K
3-phase commutator motors		
Sliprings until 40 ms^{-1}		
Bronze and copper rings	E 3	E 13, E 13S
Remanite, perlite- and spheroidal cast iron rings	E 61	G 12, G 20S
Sliprings until 80 ms^{-1}		
Steel rings (Turbo generators)	702	E 17

stationary machines

Recommended Applications of Carbon Brushes for Railway Technology

Application	Manufacturer	
	Semi-finished products: SGL CARBON Corporation St. Marys, USA	**Semi-finished products:** SGL ANGRAPH SP. Z O.O. Nowy Sacz, Poland
Traction motors (railway)		
16 $^{2}/_{3}$-Hz-AC traction motors	E 31	E 40K, E 28S
Thyristor controlled motors	6677	E 28S
DC traction motors	6677, E 45	E 28S, E 40K
Traction motors (local traffic)		
DC without chopper control	E 45, 6677, E 37	E 28
DC with chopper control	6677, E 37	
Trolleybus	E 45, E 37	E 28S
Diesel electric trains		
DC motors	E 37, E 45, E 49	E 28S
Train generators	E 45, E 49	E 28
Traction motors for mining and industrial railways	E 45, E 49	E 28S, E 35
Auxiliary motors	E 45, 4029, E 51	E 28, E 35

railway technology