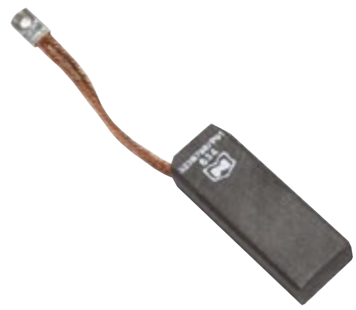
Sliprings and carbon brushes on turbo alternators



Morgan
Advanced Materials

Morgan Advanced Materials

Morgan Advanced Materials

Morgan Advanced Materials is a global materials engineering company which designs and manufactures a wide range of high specification products with extraordinary properties, across multiple sectors and geographies.

From an extensive range of advanced materials we produce components, assemblies and systems that deliver significantly enhanced performance for our customers' products and processes. Our engineered solutions are produced to very high tolerances and many are designed for use in extreme environments.

The Company thrives on breakthrough innovation. Our materials scientists and applications engineers work in close collaboration with customers to create outstanding, highly differentiated products that perform more efficiently, more reliably and for longer.

Morgan Advanced Materials has a global presence with more than 10,000 employees across 50 countries serving specialist markets in the energy, transport, healthcare, electronics, security and defence, petrochemical and industrial sectors. It is listed on the London Stock Exchange in the engineering sector.

Contents

Sliprings and carbon brushes on turbo-alternators

This brochure discusses the technical background of carbon brushes and sliprings of turbo-alternators; one of the more difficult applications of carbon brushes in electrical machines.

Morgan Advanced Materials is the world's largest manufacturer of carbon products for electrical applications. Within the Carbon Division, National and Morganite are world leaders in the manufacture of carbon brushes on sliprings of turbo-alternators.

The experience and knowledge of our team of application engineers was used in the preparation of this brochure.

We are the recognised number one supplier of carbon brushes into the power generation market and we offer quality high performance generator carbon brushes to support your applications. The optimum grade for turbo alternator applications is National 634 brush which we manufacture and supply and is recognised as the industry standard for this application.

The products we offer are:

- Carbon brushes
- Carbon brush holders
- Slip rings
- Commutators
- Diagnostics for motors and generators..
- Reliable and consistent performance
- Low wear of both brush and slip ring surface
- Minimal Polarity wear differences
- Low and stable friction
- Assists in Preventing ghosting on ring surfaces
- Proven long life capability
- Excellent current sharing capabilities
- Consistent contact drop
- Available to fit any generator
- Consistent material processing globally

634 grade is recognised globally as the best performance material in power generation

Introduction

A turbo-alternator is a turbine driven synchronous alternator which is used for power generation in either industry or by power companies.

The turbine runs at a constant speed of 3000 or 3600 RPM, depending on the required frequency of the alternator output (50 or 60 Hz).

The DC excitation current of the rotor is often supplied through two (sets of) sliprings on the alternator shaft.

The excitation current, depending on the size of the turbo alternator, could be as high as 5000 Amps.

At 3000 or 3600 RPM the surface speed of the sliprings is normally quite high. A speed of 80 m/sec (16,000 ft/min) is not exceptional.

The carbon brushes which are used on the sliprings provide a stable electrical contact, whilst carrying high currents, at a high surface speed exceeding 250 km/hr. This must be achieved without damaging the sliprings and with reasonably long brush life.

National grade 634, which is normally used for this application is a bonded natural graphite material.

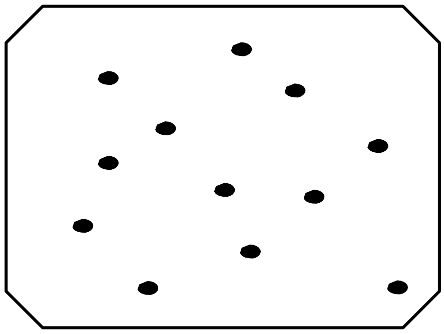
It sets the world standard for carbon brush performance on turbo alternators.

Surface film

During operation a protective film or patina is automatically formed on the surface of the slipring which plays a very important role in conducting the current and lowering the friction reducing brush wear to the lowest possible level. The film is essential to ensure optimum operation of the brushes.

This very thin film, only about 20 Å (2 x 10^{-7}cm) thickness consists of:

- oxide of the slipring material
- moisture (water)
- graphite



Conducting spots

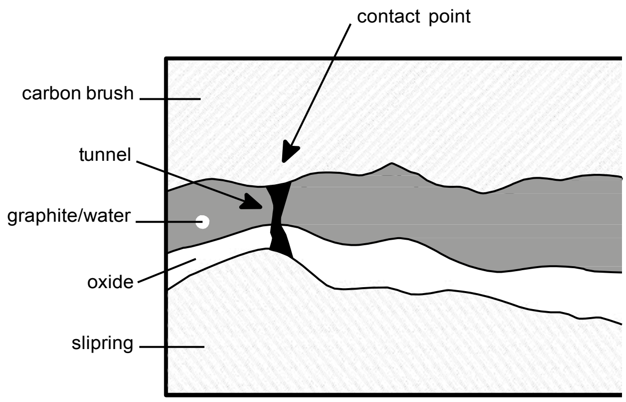
Current flow

The flow of the current from the carbon brush to the ring is through a small number of contact points which carry the full current load. The contact points are balanced by an equilibrium between the tendency of the brush and collector surface to oxidize and the abrasion of the brush against the slipring surface.

There is a thin layer of oxide and moisture between the sliding surfaces through which current passes by means of a 'tunnel' effect arising through metallic adhesion and film breakdown. Shear forces or oxidation result in eventual breakdown of these contact points. New contact points are constantly being formed and eroded across the brush face.

Thus we can say that the current flow between a carbon brush and slipring occurs through a constantly changing, small number of contact points.

The basic elements of the film, which are oxide, water and graphite, will now be further discussed.



Surface film (continued)

Oxide

An oxide film on steel is more porous, more abrasive, and forms faster than on copper.

The speed of oxide formation depends on the temperature, current and specific atmospheric contaminants.

Temperature

At a higher temperature the slipring material tends to oxidise faster than at a low temperature.

The best ring temperature during operation is 60 - 90 °C. It is also very important that the temperature is the same across the whole surface of the slipring.

Different temperatures not only cause different thickness of oxide layers, but also affects the current distribution between brushes.

Therefore the cooling air of the slipring compartment has to flow in such a way, that the same cooling properties are achieved across the slipring surface.

Sometimes air turbulence is created by obstacles in the airflow path. Because of this, part of the ring becomes less cooled than others. As a result ring wear, selective action, or even worse burnt cables can be the result.

The temperature rise of the slipring is approx. 90% caused by the friction and only 10% by electrical losses.

Current

The ionised metal gas that conducts the current in a conducting spot transforms into a little bit of oxide. This is how in general, oxide formation is improved when the current density is higher.

On cathodic or negative brushes this effect is much stronger due to electrolysis. On positive brushes the current causes a roughening of the slipring surface.

This will be further discussed in paragraph 3, polarity effect on the film.

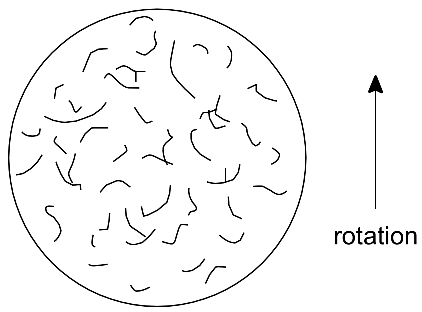
Contaminants

The presence of oil, dirt, dust, smoke, silicones in free form or oxidising gases can reduce or increase the formation of the oxide layer. More details are given in paragraph 9, inspections and maintenance.

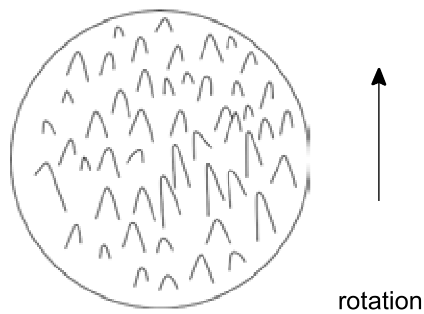
Graphite

Studies show that the graphite layer plays the major role in reducing friction and wear in addition to improving contact.

The graphite particles fill the recesses on the slipring surface, in a layered or shingled manner. They have a random oriented structure next to the metal and a cone pointing orientation 10 – 20 degrees in the direction of sliding on the sliding surface. The layers are held together by adhesive forces which are higher than the friction force between the brush and the ring, provided that there is enough moisture on the sliding surface.



Graphite near slipring



Graphite near sliding surface

Humidity

Another important ingredient in the film is water, which lowers friction. The humidity in the air normally provides this water which is needed to reduce the friction to an acceptable low level.

In very low temperature conditions the absolute humidity of the air will be too low.

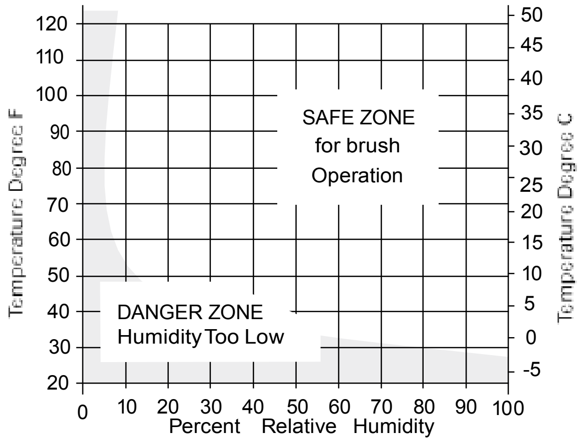
This will cause high brush wear and increase ring temperature.

If the absolute humidity drops below 4.5 g/m3 (grams/cubic metre) friction will increase, causing severe brush problems.

If humidity exceeds 25 g/m3 over filming may occur.

The absolute humidity can be found using the following chart.

HUMIDITY and Brush Life



The curved line represents 2 grains of water per cubic foot dry air or 4.6 grams per cubic meter.

In those cases where low humidity causes problems, humidifiers are used in the cooling air intake system.

Polarity effect on the film

The film on a positive low carbon steel slipring normally appears to be lighter, the ring temperature higher and the brush wear higher than on the negative low carbon steel slipring.

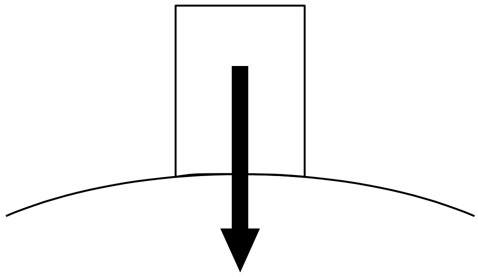
Brush wear differences between positive and negative brushes with a ratio of 5:1 are quite often found.

Most literature on carbon brush applications use different nomenclature for polarity or the direction of the current flowing into or out of a carbon brush.

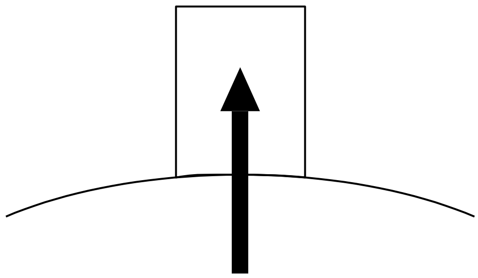
In order to describe the polarity effect we use the following definitions:

Positive brush: The current flows from the carbon brush into the current collector.

Negative brush: The flow from the current collector into the brush.

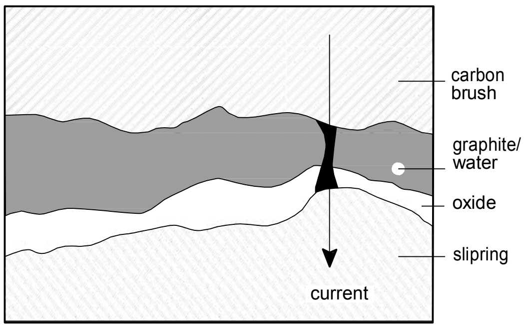


CURRENT
positive brush



CURRENT
negative brush

As discussed in paragraph 2, the current flows through a limited number of continuously changing spots, which occur where the film is the thinnest.



In DC motors the oxide part of the film plays an important role, as it controls the voltage drop in the film, and thereby the commutation properties.

If the oxide layer is thin, the voltage drop is low which has negative effects on the commutation properties.

Too thick an oxide layer will make the formation of conducting spots difficult, resulting in violent current flow, film stripping and high friction.

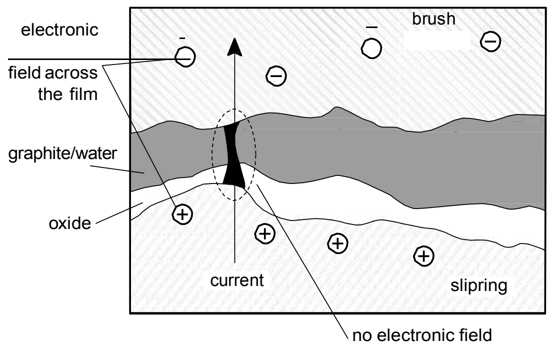
On a slipring, ideally the oxide layer should be thin and the graphite part of the film should be dominant (no commutation properties required).

This is because graphite reduces the friction and is a better current conductor than oxide.

Current direction and formation of oxide

If a current flows between the brush and the ring an electric field is created across the film.

This field does not exist where the actual current flows (tunnels or spots).



In the case of a ring with one polarity, such as in turbo alternators, the metal will continuously form ions and electrons under the negative brush.

For steel this means:

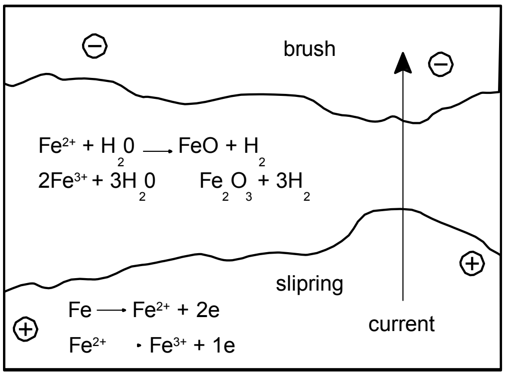
$Fe \rightarrow Fe^{2}+ + 2e$ or

$Fe^{2+} \rightarrow Fe^{3}+ + 1e$

The electric field under the negative brush will cause the positive $Fe^{2}+$ or $Fe^{3}+$ ions to move from the collector surface into the film where they will form Fe0 or $Fe_2 0_3$ with the moisture in the film.

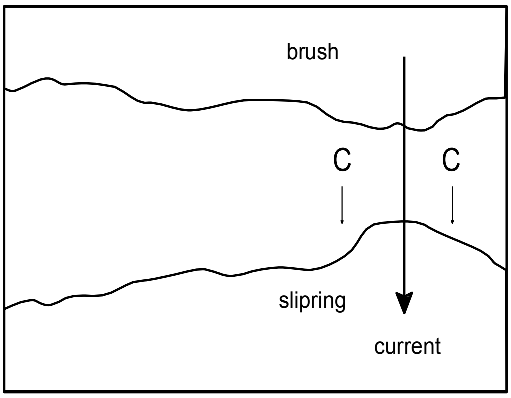
Polarity effect on the film (continued)

The electrons are pushed in the other direction.



Negative brush

For the positive brush the electric field is in the opposite direction. Under the brush no metal ions are pulled into the film and therefore there will be no additional oxidation under this brush.



Positive brush

On low carbon steel rings the brush wear on positive rings is caused by other effects.

The positive brushes riding on a low carbon steel slipring deposit carbon, which, at point contact temperature, lowers the melting point of steel. This results in minute pools of molten steel existing over an extremely short time span, but ever changing under the brush, producing a rougher surface than normal, a lower voltage drop and a higher friction.

A low carbon content steel normally contains 0.15 to 0.20% carbon. The melting point of low carbon steel is approx. 400°C lower than normal when an additive carbon content has reached 4.3%. Thus as the carbon content increases from original 0.20% to 4.3%, the melting point gradually reduces over the 400°C drop.

The phenomenon of “Case Hardening” of low carbon steel involves increasing the carbon content at the surface. This is achieved by heating the steel to a temperature below its melting point in the presence of carbon (in our case ions from the brush), which gradually penetrates, diffuses or absorbs into the steel thus increasing the carbon content at the surface. The hardness is due to a chemical reaction between the iron and manganese elements and carbon to form carbides which are very hard (similar to cutting tools). The carbon brush usage is therefore both chemical and physical (surface roughness).

Also a shiny surface and not a black graphite surface of the ring is normally seen under the positive brush being evidence of a definite change in ring composition at the surface.

The above described effects will only occur on low carbon steel rings. All other ring materials will not show this effect. In these cases the brush and ring wear will be higher on the negative side due to the oxide formation as described previously.

Conclusion for low carbon steel rings only

The negative brush (cathodic)

Under the negative brush additional metal oxide will be formed.

The film on the negative slipring contains therefore more oxide and less graphite and has a higher voltage drop.

The oxide film, which is abrasive, creates friction for the brush and therefore brush wear.

The positive brush (anodic)

The rough spots are created by carbon deposited onto the steel surface, lowering the melting point, creating miniature melting pools and “case hardening”.

Due to this hard, rough surface and metal picked up in the brush face, friction is higher.

Therefore brush wear is higher on the positive ring than on the negative ring.

Summary:

Low carbon steel rings:
Positive ring:

- higher brush wear
- lower voltage drop
- higher friction

Brass or other rings:
Negative ring:

- higher brush wear
- higher voltage drop
- higher friction

As mentioned earlier for steel rings, a difference in wear rate of 5: 1 is no exception.

The difference in wear rate can be reduced considerably by frequently changing the polarity.

Once a graphite film is formed on a ring the graphite layer stays intact for quite a while when polarity is changed.

A well accepted procedure, starting with new or recently ground sliprings is to change polarity with increasing time intervals such as:

Interval

2 weeks

4 weeks

8 weeks

16 weeks

32 weeks

After this total period of 32 weeks the polarity should be changed at an interval of one year.

Slipring materials

Some of the materials used for sliprings in general are:

Bronze

88% Cu, 10% Sn, 2% Zn

Phosphor-Bronze

90% Cu, 10% Sn, 0.4% P

Cupronickel

96% Cu, 4% Ni

Used in corrosive atmospheres

Cast iron, steel

Lower surface speeds used in hydropower generators

Alloyed steel

High speed applications

Materials like brass (Cu+Zn) and aluminium are not suitable for sliprings.

The alloyed steel used for turbo alternators usually contains:

0.15 - 0.2%	C
0.1 - 0.4%	Si
0.5 - 0.8%	Mn
1.2 - 1.6%	Cr
1.2 - 1.6%	Ni
0.1 - 0.3%	Mo
Traces of	P
Traces of	S

This composition is proven. It gives good wear resistance and strength against the strong centrifugal forces due to the high speed.

Helical grooving of sliprings

Helical grooving arose from the need for more even current distribution between brushes. When many are operating in parallel at high speed an air cushion is formed underneath the brush affecting the current distribution.

It was established about 1924 that a definite improvement could be obtained in cases of uneven current distribution, or “selective action”, by cutting axial slots across the contact face of each brush. The success of this arrangement was attributed to the removal of the gas layer between brush and ring which can give rise to unstable conditions and a variable contact voltage drop. With the removal of this gas layer the contact voltage drop becomes much more uniform and a great improvement is obtained in the distribution of the current between brushes operating on the one ring.

Some years later an application was made, and duly granted, for a British Patent for spiral, “helical”, grooving of rings and commutators. This was a new concept on the problem and it achieved an improvement in current distribution by rendering each part of the brush conducting surface inoperative for a certain period of time during each revolution of the ring. Thus in the case of “selective action” where a particular brush collects more then its theoretical share of current, the brush is forced to shed its current and equilibrium is restored. With axial slotted brushes there is a risk that the selective action condition will persist as there is no forced shedding of current.

The presence of helical grooving gives the added advantage of precluding a gas layer under the contact surface of the brushes and thereby gives the same beneficial effect as that of cutting axial slots in the contact surface of each brush.

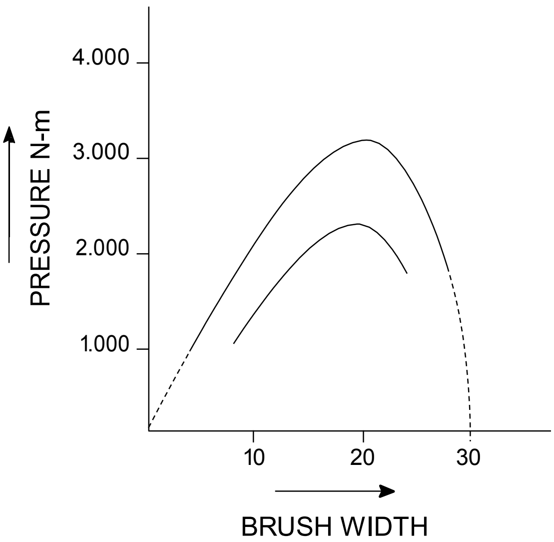
There is no general consensus of opinion as to the optimum dimensions and spacing of the grooving, but grooves in use have widths ringing between 2 and 4.3 mm and depths approximately equal to the widths. Pitches of the grooves vary from a single-start groove of about 9.5mm pitch to a 4-start groove having a pitch equal to the width of the ring, i.e. 4 equally spaced grooves each making a single complete circuit of the ring.

It is desirable, however, that the area of the brush in contact with the ring should not fluctuate widely during the traverse of the groove under the brush. This suggests that the pitch of the groove should be related to the brush "a" (axial) dimension rather than to the width of the ring, i.e. the brush "a" dimension should be an exact multiple of the groove pitch.

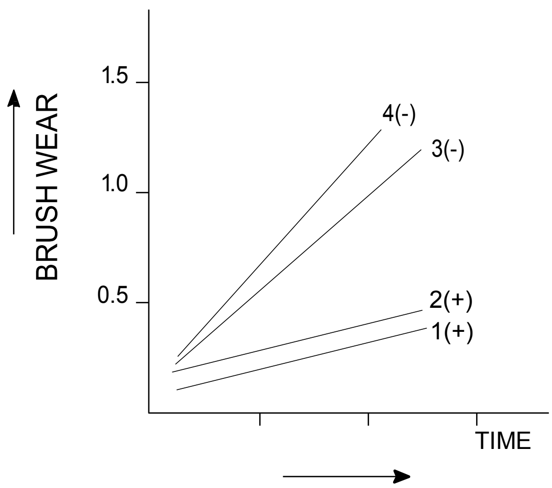
When a ring is helically grooved, there is an apparent reduction in the contact area between brush and ring and therefore it would be reasonable to calculate the contact force on the apparent contact area between brush and ring, i.e., the cross sectional area of the brush less the area of the groove under the brush. However, the second effect of the grooving must be taken into account, i.e. the absence of a gas layer between brush and ring. As a result of the absence of this gas layer, the brush seats down more closely to the ring surface to give a lower contact voltage drop but a higher coefficient of friction.

In general the lower electrical heat loss counter balances the higher mechanical heat loss and therefore the contact force on the brush should be calculated on the full cross sectional area of brush. Furthermore, it is preferable to apply the full contact force to give more mechanical stability to the brush.

Conversely for slower speed, non-turbo applications where the pitch of a helically grooved slipring can effectively remove up to 40% of the brush face area, a reduction in spring pressure maybe beneficial in preserving brush or slipring longevity. In these lower surface speed applications there is likely to be no air cushion and therefore the losses remain the same. The reduction in effective area can sometimes lead to an increase in brush pressure to levels in excess of carbon brush manufacturers specifications.



Slotted brush face reduces pressure to ½



1 & 3 slotted brush
2 & 4 not slotted

Electrical contact

With often more then 50 carbon brushes working in parallel, the electrical contact and thereby the uniform distribution of current is extremely important.

Some of the elements that affect the electrical contact are:

Slipring

If the slipring is out of round (more then 0.05 mm) or has any disturbances such as ghost marks on the surface, the electrical contact between brush and ring is compromised, causing sparking and spark erosion.

Because of this erosion the surface of the ring will be attacked even more causing heavier sparking.

Brush holder

The brush pocket of the holders must be square and smooth, enabling the brush to move freely in the radial direction.

A build up of dust, or any disturbance of the brush holder pocket, could cause the brush to stick in the holder, reducing the contact pressure with the ring and increasing the brush wear (electrical wear or sparking).

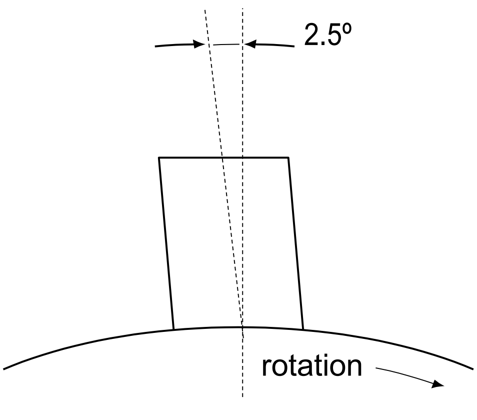
The brush holder and gear must be mechanically very stable.

The distance between brush pocket (holder) and ring should be between 2 and 3 mm.

It has been found that brushes perform better when operating in a slightly trailing position.

An angle of approx. 2.5° is enough.

A stubbing position must be avoided as it increases the tendency to vibrate.

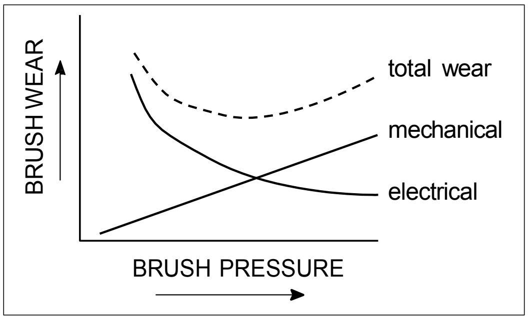


Brush pressure

Brush pressure plays an important role in the brush performance of turbo alternators.

In order to keep the current distribution between the brushes as equal as possible all brushes should have equal and correct pressure.

Too low brush pressure will increase the electrical wear (sparking) whilst too high pressure increases the friction and therefore the mechanical wear.



It has been found that in general a brush pressure of 160-180 g/cm² is the optimum for grade 634 on turbo alternator applications.

The brush pressure should be checked regularly.

The maximum allowable difference between individual brushes should be below 10%.

Other electrical connections

All electrical connections between main busbar and brush body must have a low resistivity and should be equal for parallel conductors.

A critical electrical connection is the one between brush and cable.

Two of the most common connection technologies are riveted connections or tamped connections.

Studies have shown that a modern tamped connection is thermally more stable than the riveted one.

Ghosting

One effect frequently seen on sliprings of turbo alternators is called ghosting, also called ghost marks.

A ghost mark can best be described as an imprint of the brush on the slipring. The imprint, with the same dimensions of the brush has a somewhat rougher surface. It appears as if material is etched away – see photograph showing "Ghosting" on rings back cover.

These are two causes for ghost marks which are:

1. During operation of the turbo alternator a momentary extreme high current peak occurs in the excitation current (high dI/dt).

The number of contact points at the brush surface are insufficient to carry this sudden high current load. The effect is a violent current flow with heavy ionisation and arcing. The result is a burnt spot with the exact brush width and thickness.

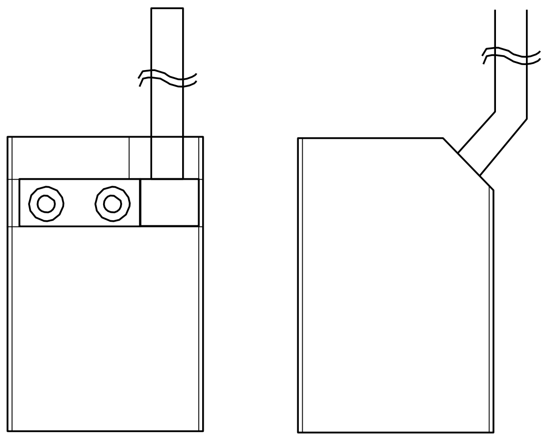
This instantaneous current surge can occur when:

- There has been a short circuit in the AC system.
- a large asynchronous motor was started in the power plant with a high starting current.
- alternators were switched without being quite synchronised.

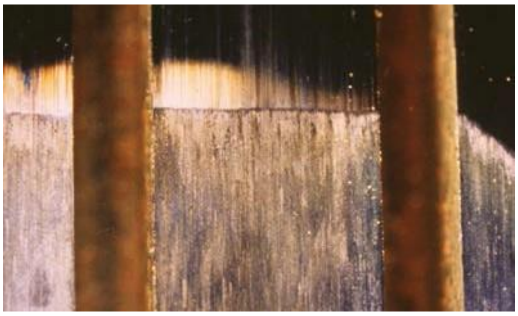
2. Another type of ghost marking can occur after a turbo alternator has been standing still for a number of weeks.

Different metals in the alternator circuit create a galvanic cell, that can cause closed loop currents to flow.

Electrolysis as discussed in section 3, polarity effect, will then oxidise the ring under the brush with the exact brush dimensions.



Riveted connection   Tamped connection

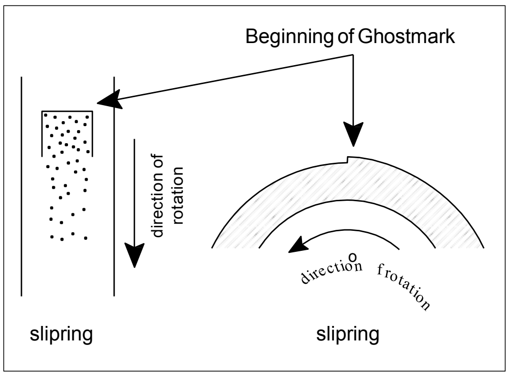


It is therefore recommended that, when a machine is stopped for a longer period of time, brushes are removed from the holders or lifted away from the slipring surface.

In most cases turbo alternators, when not in use, are turned at very low speed. In this case brushes do not have to be removed.

When ghost marks have developed on a slipring they tend to develop into larger rough spots because of spark erosion. Every time the spot passes a brush some sparking will be seen.

This phenomena will not automatically improve and the slipring has to be reground to restore performance.



Brushwear

The brush wear of grade 634 on turbo alternators depends on various conditions such as:

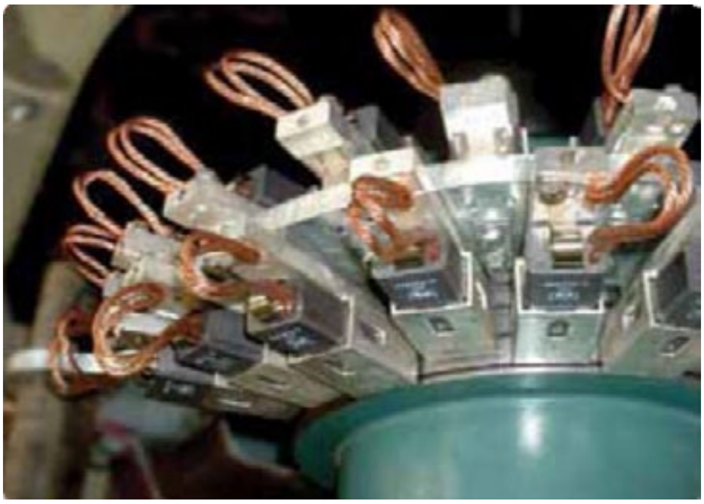
- current load
- surface speed
- brush pressure
- temperature
- contamination
- condition of the ring

As a general rule we can say that:

<5 mm/1000 hrs	is very good
5-10 mm/1000 hrs	is good
11-20 mm/1000 hrs	is acceptable
>20 mm/l000 hrs	needs attention

Optimum operating conditions for grade 634 are:

Current density:	5.5 - 8 A/cm^2
Surface speed:	45 - 80 m/sec
Abs humidity:	8 - 13 g/m^3
Slipring temp.:	60 - 90°C
Brush pressure:	160 - 200 g/cm^2



Inspections and maintenance

Brushes, holders and sliprings need to be inspected regularly. A problem found at an early stage can often be corrected easily. At a later stage it can lead to severe damage and expensive repairs.

Inspection checklist

Brushes

Brush length

Make sure there are no brushes in operation which are too short.

Cables

Check cables for discolouration or broken wires due to vibration or other types of wear.

If some brushes are found with discoloured cables this could be a sign of selective action. The current density in the discoloured cables has been much too high. It is recommended that the complete set of brushes are changed if severe selective action has taken place as the brush connections may have been damaged by the high currents.

Sometimes groups of wires in the flexible cables break due to vibrations or the continuous motion due to strong cooling air flow.

If more than 10% of the cable is affected the brush should be replaced.

Vibration marks

If the brush shows highly polished areas on the sides, this is an indication of excessive movement in the holder pocket.

This phenomena is caused by eccentric rings or high friction.

Also check the sides of the brush for erosion due to current flowing between brush and holder. (If this is suspected then the brush connections might be damaged and new brushes are recommended)

Brush face

Check the brush face for:

- Chips: caused by handling or other mechanical impact.
- Rough surface: probably caused by spark erosion due to too low brush pressure or bad electrical contact between the brush and ring in general.

Brushholders

Periodically the brush holders have to be checked.

Important points are:

Brush pocket

Make sure the brush pocket is not damaged and brushes can move freely.

Electrical connections, such as the brush terminal

Make sure this connection is clean and as tight as possible.

Holders designed for on-load brush changing need extra attention. The connection surfaces must be very clean and undamaged.

Note: Brush holders should never be cleaned using sand blasting or similar methods.

Sand blasting creates a rough surface inside the brush pocket which has a negative effect on the free movement of the brush.

Brush springs

Check the springs periodically and replace those which deviate more than 10% from the correct force.

Distance between holder pocket and slipring

Brush holders should ideally be set at 2-3mm from the slipring surface. Distances greater than this could lead to brush instability and possible damage.

Sliprings

Frequently check for any type of damage which could affect the electrical contact.

When the machine is running this could be done with a stroboscope adjusted to a frequency not exactly the same as the turbine speed.

This makes it easier for the human eye to inspect.

Inspections and maintenance (continued)

Slipring compartment

Inspect the whole compartment, looking for traces of oil.

If oil, leaking from a bearing gets into the slipring film, a highly polished layer is formed, causing high friction and high brush wear and possible jamming of the brushes in the brush holders.

Grey streaky spots on the slipring are a sign of this.

Carbon brushes are porous and will therefore soak up oil. If an oil leak developed and the brush gear was exposed to it, it is recommended to replace all brushes, and to thoroughly clean down all brush holders, springs and connection points.

Signs of sparking

Heavy sparking could result in a flashover between different polarity.

Signs of heavy sparking can be found on brush holders, brush gear or other places in the slipring compartment, then further checks should be made to determine and correct the cause.

Dust

Carbon dust is a good conductor of electricity.

Excessive buildup of carbon dust could lead to a flashover between rings of different polarity.

It is therefore recommended to clean the slipring compartment regularly, using a soft bristle brush to loosen the dust and then a vacuum cleaner to remove the dust.

Brush temperature

It is important to check the brush temperatures regularly. Too a high differential indicates possible selective action leading to different brush wear, or worse, burnt cables or connections.

Modern infra red thermometers are accurate and quite safe to operate.

Humidity

Especially in areas where low humidity can be expected such as a higher altitude or at places with cold winters, humidity must be checked regularly. If low humidity (below 4.5 g/m^3) and high friction is found, excitation power and therefore the output power of the alternator has to be reduced to compensate for the high friction heat build-up.

A medium to long term solution to improve the situation is to inject some steam into the cooling air inlet system. This will increase the humidity and therefore reduce the friction again.

Steam injection must be stopped when humidity reaches a normal level again. In places where low humidity regularly causes friction problems, automatically controlled humidifiers are placed in the cooling air inlet system.

Slipring roundness

When vibration marks are found on the brushes and some sparking is noticed, the roundness of the rings must be checked.

Both manual devices such as dial indicators, as well as electronic slipring profiling units are capable of providing accurate indications of ring concentricity.

A sensor is placed in the brush pocket which is connected to the microprocessor based meter.

After the shaft is turned, a print-out can be made of the slipring profile.

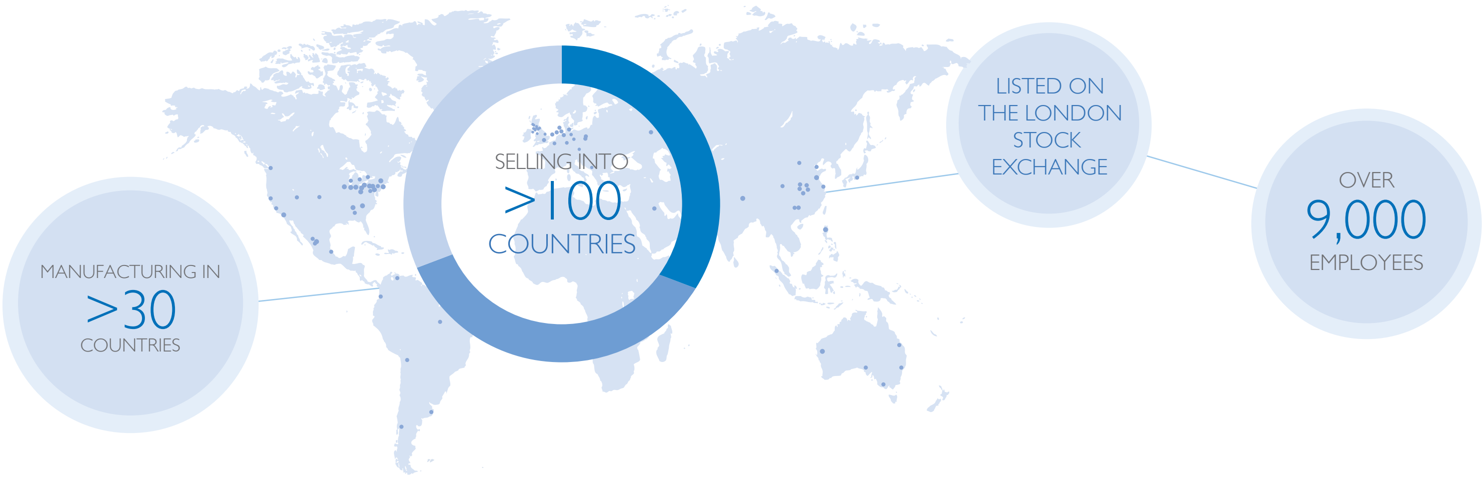
If the slipring is more than 0.05 mm out of round the ring should be ground.

Grinding is a specialists job using special grinding stones and a support.

Grinding by hand will likely make the problem worse.

Morgan
Advanced Materials

ABOUT MORGAN ADVANCED MATERIALS



Morgan Advanced Materials is a global engineering company offering world-leading competencies in materials science, specialist manufacturing and applications engineering.

We focus our resources on the delivery of products that help our customers to solve technically challenging Problems, enabling them to address global trends such as energy demand, advances in healthcare and environmental sustainability.

What differentiates us?

- Advanced material science and processing capabilities
- Extensive applications engineering experience
- A strong history of innovation and reinvention
- Consistent and reliable performance
- A truly global footprint
- We find and invest in the best people

For all enquiries, please contact our specialist sales and manufacturing sites:

UK

Morgan Advanced Materials
Upper Fforest Way
Swansea SA6 8PP
UK

T +44 1792 763000
F +44 1792 763167
meclsales@morganplc.com

Hungary

Morgan Advanced Materials
Csillagvirág utca 7.
H-1106, Budapest
Hungary

T +36 1 265 2206
F +36 1 265 1219
customerservice.hungary
@morganplc.com

Italy

Morgan Advanced Materials
Via Roma 338 - 64014
Martinsicuro TE

T +39-0861-7981
F +39-0861-760165
vendite.elettrico
@morganplc.com

Germany

Morgan Advanced Materials
Zeppelinstrasse 26
53424 Remagen

T + 49 2642 9040-0
F + 49 2642 9040-251
salesde@morganplc.com

Morgan Advanced Materials plc
Quadrant, 55-57 High Street,
Windsor, Berkshire, SL4 1LP United Kingdom

Designed and Produced by Inspiration Ltd

www.morganadvancedmaterials.com