Technical Information

Low load conditions

Beside brush vibrations, out-of-roundness and ambient influences, which were already discussed in previous editions, a wrong electrical loading of carbon brushes is the leader in the hit-list of possible causes for brush problems. With the latest edition we would like to highlight low load problems with carbon brushes. We will explain the reasons and comment on possible remedial actions. Problems caused by low load are regular topics in discussions and seminars and they are misinterpreted very often.

Our general rule is valid particularly for this issue :

"The carbon brush is an indicating instrument for the machine status"

A proper interpretation of the collector surface and the contact surface of the carbon brushes may help to recognize problems prematurely, to start actions and to prevent damages.

Definitions

An electrical machine is under loaded if it is working below the nominal range. One has to distinguish between temporary and permanent under load. Carbon brushes and commutators or slip rings are the only parts of a motor which are negatively influenced by a permanent under load situation. Even permanent damages can occur in extreme situations. The electrical load of carbon brushes is expressed as current per area, i.e. A/cm² or A/in².

Each group of carbon brush grades has got its own range of optimal load:

Grade Group	min. Continuous Current Density A/cm^2(A/in^2)	opt. Continuous Current Density A/cm^2 (A/in^2)	max. Continuous Current Density A/cm^2 (A/in^2)	Short Term Over-load A/cm^2(A/in^2)
Metal graphite (30 – 75%)	12 (77)	15-20 (97-129)	25 (161)	40 (258)
Metal graphite above (75%)	15 (97)	25-30 (161-193)	35 (226)	50 (322)
Electrographite	4 (25)	10-12 (64-77)	16 (103) (E105:20) (129)	30 (193)
Resin Bonded Graphite	1 (6)	6-8 (39-52)	10 (64)	14 (90)
Pitch Bonded Graphite	3 (19)	6-8 (39-52)	10 (64)	12 (77)

In case of high permanent current densities or overload the shunt diameter has to be adjusted accordingly. Calculation of current densities is done with the formulas already given in the Info 27.

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Formula	Example
Spec. Current Density DC Motors	
$$S = \frac{I}{(N/2) \times t \times a}$$ I = current [A] N = Number of Carbon Brush t = Tangential Brush Dimension [cm] a = Axial Brush Dimension [cm] S = Current Density [A/cm^2]	1000 A – 6 pole 5 cb's ea., i.e. 30 brushes, i.e. calculation with 15 brushes 20 x 32 x 50 mm³ $$\frac{1000\ A}{15 \times 2cm \times 3,2} = 10,4\ A/cm^2$$ 1000A - 4 pole 5 ea. **Tandem Brushes** , i.e. 20brushes, calculation with 10 brushes 12,5 x 32 x 50mm³Tandem Brushes i.e. total dimension - t – is 25mm
Spec. Current Density Slip Ring	
$$S = \frac{I}{(N/2) \times t \times a}$$ I = current [A] N = Number of Carbon Brush t = Tangential Brush Dimension [cm] a = Axial Brush Dimension [cm] S = Current Density [A/cm^2]	Turbogenerator 1000A - 2 rings with 10 cb's e.a. i.e. calculation with 10 brushes – 32 x32 x64mm³ $$\frac{1000\ A}{10 \times 3,2cm \times 3,2cm} = 9,7\ A/cm^2$$ Asynchronous-Slip-Ring Drive 500A - 3 rings 5 cb's, i.e. calculation with 5 brushes – 40 x 20 x 40 mm³ $$\frac{1000\ A}{10 \times 3,2cm \times 3,2cm} = 9,7\ A/cm^2$$

Causes and consequences

The following problems might come up in case of low electrical load or low surface temperature:

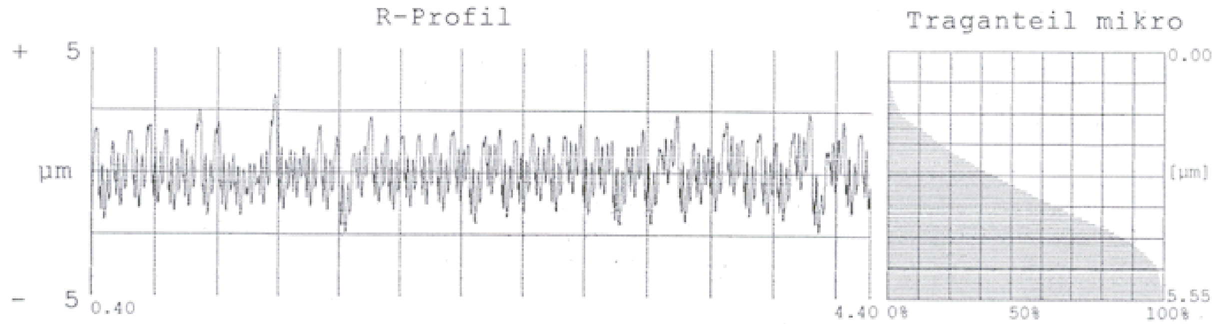
- Insufficient film formation
- Brush vibrations
- Groove formation
- Increased brush wear

There is a strong correlation of electrical load and surface temperature of a collector. The surface temperature is determined by the electrical losses in the contact surface between carbon brush and collector. So low load is tantamount to low electrical losses and low surface temperature.
Phenomena caused by low temperature due to excessive cooling have the same appearance like low load problems.

Bad film formation, brush chattering

The collector copper is permanently oxidized by the oxygen of the air. In the optimal temperature range (60 - 90°C - 140 - 195 °F) the commutator surface is roughened in the microscopic scale. It's easy to picture in ones mind, that carbon from the carbon brushes can be deposited in the "valleys" of this hilly landscape and a carbon containing film can be built up. The thickness and the colour of this film depend on the surface roughness and the grade in service.

TEXT	RmD	RzD	Ra	Pc/cm
9 Lam. 16 ,	5.56 ,	4.60 ,	0.84 ,	230 ,



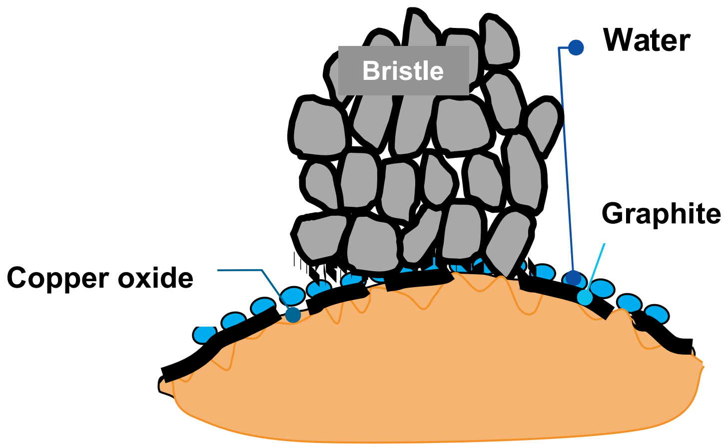
This "natural" oxidation is limited at low temperatures (<40°C). The surface becomes more and more smooth by the carbon brushes. The film will be going to be thin. In the extreme case it will totally disappear. .
Due to the low graphite content , the friction coefficient is increased, and brush vibrations with all known effects like breaking of the shunts, breaking of the brushes, brush sparking

and damages of holder components can arise. The higher friction coefficient will also cause an increased brush wear.

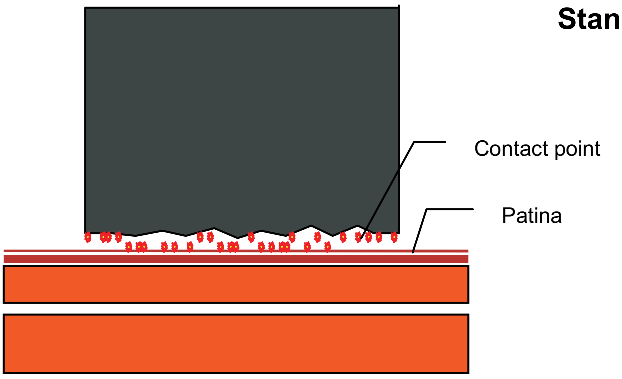
Groove formation

Groove formation by means of low load is a quite complicated process. So we try to explain the correlation as simple as possible. Experts may excuse the possibly scientific incorrect description.

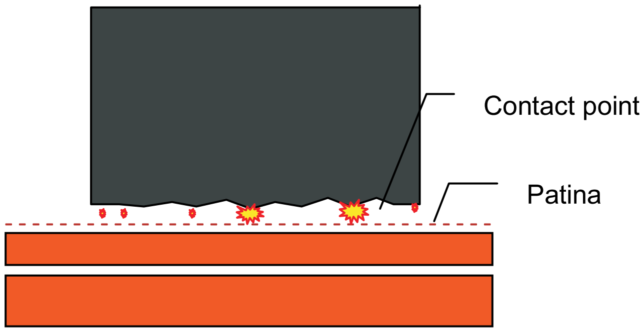
Beside carbon copper oxides are the main components of the surface film on commutators. In general these oxide layers on copper surfaces are called patina. Copper oxide Cu_2O is a semiconductor. With current flow metal bridges are formed within the layer, so called fritted spots. These spots take care for the current conduction.. As higher the temperature as more of those channels are formed. One estimation is, that there are approx. 20 fritted spots per cm² at normal load. . At low load there are only 5 of these contact points.



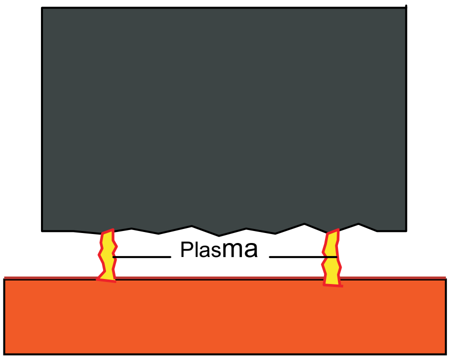
Standard consitions



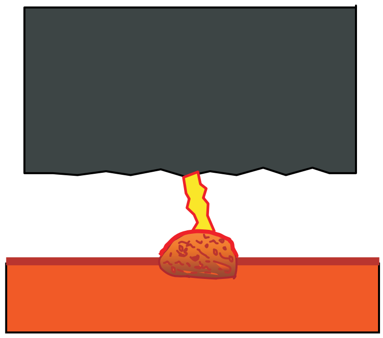
At low electrical load the number of fritted spots is less. So the current is distributed on some channels only.



Locally overloading and flashes in some of those channels are possible.



In the plasma the copper is molten.



Copper particles are loosened from the surface.

... single parts come underneath the contact surface and groove formation might occur.

The corresponding contact surface looks like this...

Remedial actions

All measures leading to an increase of the surface temperature of the commutator / slip ring may will make a contribution to the solution of the problems:

- Reduction of the number of brushes - de-brushing
- Preheating of the cooling air
- Change of the cooling direction -. cooling air via the winding first..
- Use of an alternative brush grade

De-Brushing

According to the a.m. formula a reduction of the number of brushes (N) leads to an increased current density (S) . So it should be checked as a first step, whether a reduction of the number of brushes is possible. Brush staggering must be considered. Full brush tracks should be removed only. Brushes on the bearing side should preferably be removed. That's because brushes on the winding side are a bit warmer by means of the radiation of the winding
.

Alternative grades

One of the main problems of low load conditions is the bad film formation on the collector surface. In case a reduction of the number of brushes is not successful one should start thinking about alternative brush grades, e.g. resin bonded brush grades.

On induction motors brush grades with a high metal content should be substituted by grades with a lower metal content

Compact
• Problems at low load conditions are: - Bad film formation - Brush vibrations - Groove formation - Increase of brush wear • Groove formation is caused by semiconductor phenomena • Measures increasing the surface temperature will help against the effects of low load conditions. • A reduction of the number of brushes gives an increase in current density. • The use of alternative grades depends on the application and the kind of the motor.