BRUSHES FOR SLIP-RINGS

TECHNICAL NOTE ■ STA BE 16-42 GB

Slip-ring motors (synchronous and asynchronous) and all rotating systems using slip-rings, use technologies different from those used on DC motors. Technological requirements are also different.

Therefore, a study is carried out mainly dealing with temperature rises and the available means depending on the machine construction to reliably dissipate the heat generated by operation of the brushes on the slip-rings, in order to make a judicious choice of a grade of brushes for slip-rings.

Care shall be taken to choose grades containing a variable quantity of metal (usually copper) providing a "normal" service on slip-rings, and also that are incapable of switching on a DC motor, in order to carry high currents, reduce voltage drops at contact (resistive losses) and improve heat exchange. There is a very wide range of brush grades for slip-rings, and the metal content can vary from 0 to more than 90%.

The first necessary step in making sure that a grade is properly adapted to its function is to consider the slipring temperature after the assembly has reached a temperature equilibrium.
As the system temperature increases abnormally, in other words as the positive difference between the real slip-ring temperature and the maximum allowable temperature fixed by the manufacturer increases, the risks of fast wear of the slip-rings and the brushes also increase, including possible arcing between phases as a secondary effect. The diagram below shows how an increase in the slip-ring temperature affects the general condition of a machine, as a result of the various parameters involved.

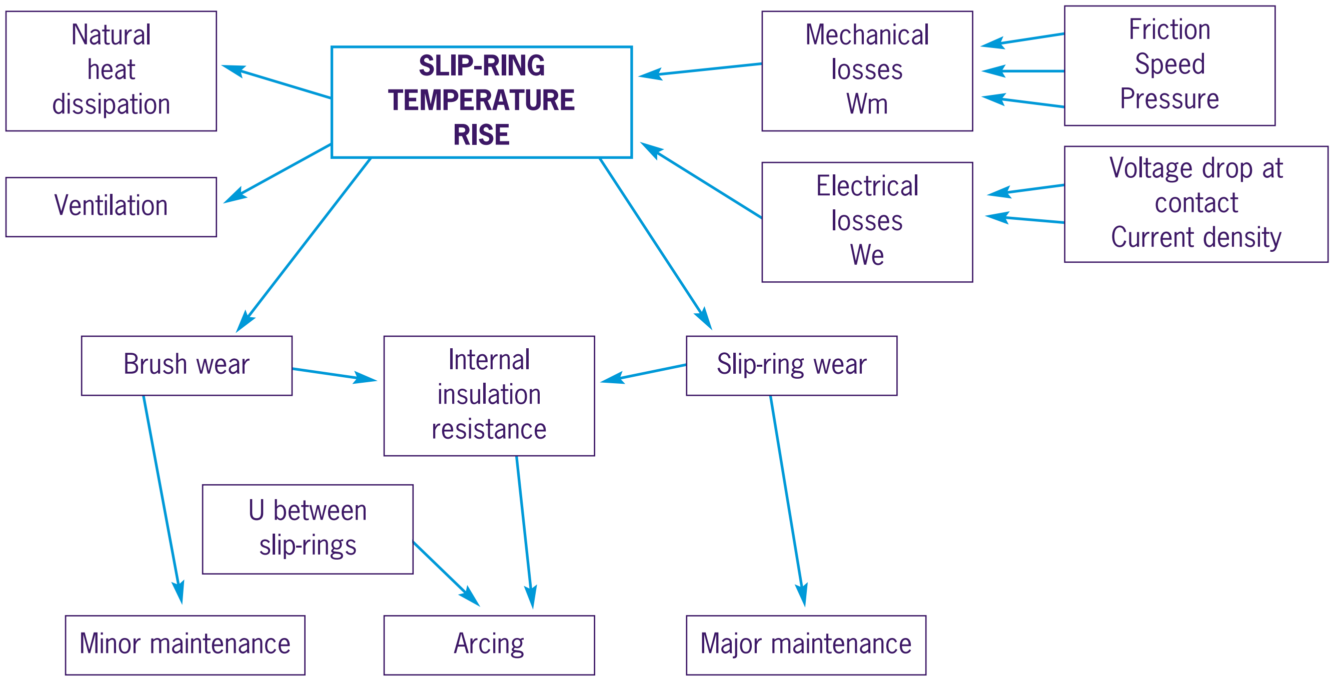


Figure 1

The brush grade only affects the evaluation of total losses (Wm+We) through its friction and its voltage drop at contact.

Variation of the voltage drop at contact

Δu as a function of the copper content

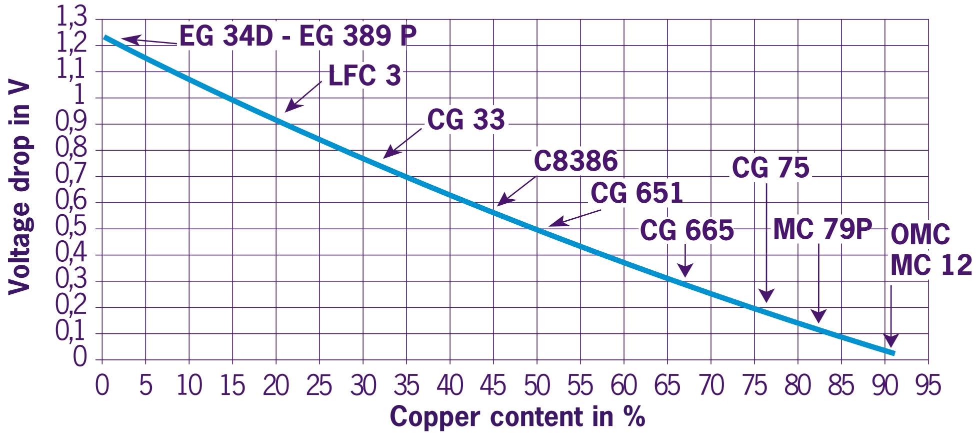


Figure 2

Voltage drop at contact (Δu in V) as a function of the metal content of brush grades for a current density J_B equal to 10 A/cm^2, peripheral speed V equal to 15 m/sec and a pressure P of 17.5 kPa.
Under normal conditions of use, friction varies little from one grade to another (proportion about 2 to 1), unlike voltage drops at contact that vary with ratios of 25 to 1.

The above curve shows the proportions by which the electrical losses of a motor with metallic grades can theoretically be reduced. Nevertheless, this advantage is only valid for slow machines with high loads, since metallized materials do not resist high speeds or prolonged underloads (the peripheral speed of the machine has to be reduced if the metal content is to be increased). Furthermore, since wear dust is a very good conductor, these grades should not be used on high voltage and/or completely closed machines due to the danger of a short circuit between slip-rings as a result of continuous recycling of dust between the slip-rings and brushes.

In practice, the choice of a grade of brushes for slip-rings must take account of:

- usage limits indicated for each grade in Technical Guide BE 2 (pages 6 & 7). For example, the following graph (figure 3) expresses these limits generally, giving a comparison of the capabilities of our brush grades as a function of their metal content,
- the type (open or closed) and the insulation class of the motor (A, E, B, F, H),
- total losses for the normal load and speed of the motor, calculated as described in technical note STA BE 16-8.

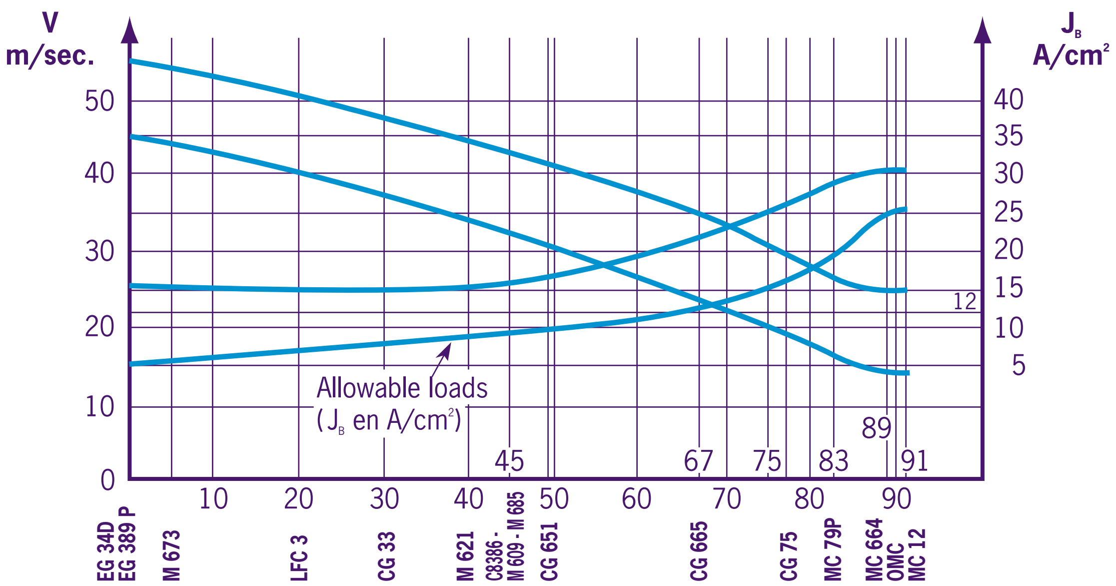


Figure 3

The following two rules should also be taken into account wherever possible:

- For closed motors, total losses on brushes (We+Wm) per unit surface area of the slip-rings must be less than 1 W/cm^2,
- For open ventilated motors, the limit naturally depends very much on the ventilation mode and its efficiency; as a first approximation, it can be fixed at 1.5 W/cm^2,
- Especially for closed motors, the most suitable brush is the brush that produces the least amount of conducting dust (with the lowest metal content) due to wear, provided that its total losses remain less than 1 W/cm^2.

Based on our experience, we have defined and used a coefficient S that can be defined as the heat dissipation capacity index of a machine.

This coefficient S can be used to quickly evaluate the degree of difficulty of a motor and choose a brush grade for the application considered, without needing to calculate the losses:

$$S = \pi \frac{DL}{I}$$

In this formula:
S is expressed in cm^2/A,
D is the slip-ring diameter in cm,
L is the slip-ring width in cm, and
I is the current intensity per slip-ring (I rotor or I excitation) in A.

As S reduces and the risks of overheating become more severe, total losses should be restricted by a judicious choice of the brush grade.

The following table contains limiting values of the coefficient S for our main grades of slip-ring brushes depending on the motor type considered.

GRADE	Motor	
	Ventilated	Closed
EG34D-EG389P-M673	> 1	> 1,2
CG651-CG45	0,9	1,1
CG665	0,8	1
CG75	0,6	0,8
MC79P-MC664-MC12	0,5	0,7
OMC-	0,4	0,6

Notes:
The values of parameters are determined in observations and practical tests on bronze slip-rings (good emission power).
Losses on ordinary steel or stainless steel slip-rings are always higher than on bronze slip-rings. Thus, values of S should be increased by 10 to 20% for brushes that are not metallized or are only slightly metallized.

COVERAGE RATE

It will be seen from the above discussion that the main concern with these motors is heat exchange or dissipation of heat due to losses.

The result is that we need to consider two other parameters to give a fairly precise idea of the capacity of the machine design to dissipate losses at brushes.

The coverage rate concept is complementary to the concept of the coefficient S and these two parameters are indissociable.

Obviously, if the coefficient S is too small in the beginning, in other words < 0.4, no other calculations are necessary to realize that no brush grade will operate properly. In this case, the slip-rings will have to be redefined and resized, since there is no other solution to the problem.

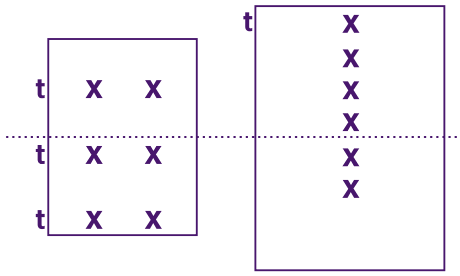
But if the coefficient S is within the values given in the table above, the positions of the brushes still need to be determined such that the patina can be continuously regenerated, ventilated and aerated, so that the brushes continue to operate smoothly.

Peripheral coverage ratio τp :

This value defines the area of the slip-ring covered by the brushes along the tangential direction, as a fraction of the slip-ring periphery.

Example: 6 brushes are necessary to transfer the required current: a good choice will be to provide brushes over two tracks of three brushes. This will increase the coefficient S (wider slip-ring) and improve the peripheral coverage ratio.

$$\tau p = \varepsilon \text{ “t”} / \pi D \quad \text{per track}$$



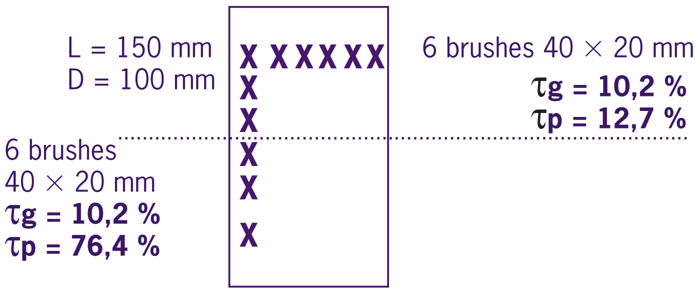
$\tau p = 3t / \pi D$ $\qquad$ $\tau p = 6t / \pi D$

Global coverage ratio τg :

This ratio defines the area of the slip-ring covered by the brushes, as a proportion of the total surface area of the slip-ring.

Example: 6 brushes are necessary to transfer the required current:

$$\tau g = \varepsilon \text{ s brush} / \pi DL = \varepsilon \text{ (txa)} / \pi DL$$



This ratio is invariable for a given slip-ring dimension and number of brushes, since the important value is the sum of the areas of all the brushes.

Our experience has shown that:

If $\tau p < 15$ % there will be no problems.

If τp est 15 % < τp < 20 % there is a risk of abnormal temperature rise.

If $\tau p > 20$ % there will be problems and operation of the slip-rings, brushes and the entire assembly will be difficult.

The same type of problem will occur if $\tau g > 15$ %.

This approach may seem to be new, but it is actually old and very important: problems still arise because it is too often forgotten, and it is impossible to solve these problems once the machine has already been built since there are no brushes that can resist the resulting conditions.

Therefore, these simple and fast parameters should be taken into account when designing slip-ring holders to make sure that the dimensions enable satisfactory operation.

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