TECHNICAL DATA SHEET

SURFACE CONDITION OF COMMUTATORS AND RINGS: ROUGHNESS

1. WHAT IS ROUGHNESS?

Most discussions on the quality of surface finish revolve around the measure of roughness, although many experts prefer to use “surface texture”. Several definitions of roughness exist. The ones that we use hereafter are the most commonly used, and defined in ISO 4287 (main definitions are specified in the end note of the present document).

Figure 1 represents a profile of a surface along a measurement length l, obtained after high-pass filtering of the primary profile. On this figure are indicated the dimensions used in this document.

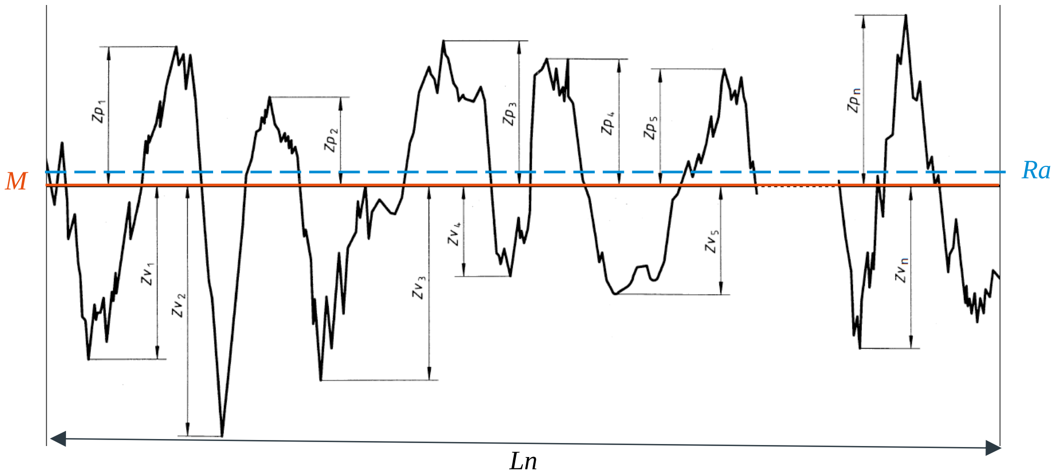


Figure 1 – Profile of a surface and determination of ordinate values [SOURCE: NF EN ISO 4287: 1998]

Roughness $\boldsymbol{Ra}$ is the most common roughness measurement for commutators and slip rings, expressed in microns (µm), completed by the **peak count** $\boldsymbol{RPc}$, in peaks per cm.

Both are measured using a **roughness meter**. All modern equipments comply with ISO 4287 and ISO 3274 and give simultaneously, after the profile measurement, all of the roughness specific values.

The roughness meter and its setup should be chosen according to the range of the values measured, in particular concerning the cut off to be used for the determination of the roughness profile. The setups are defined and explained in ISO 4288.

NOTE: ROUGHNESS DEFINITIONS

As represented on figure 1 the line M is the mean line, determined such that the sum of the peak areas between the profile and said mean line above and under M are equal.

The ordinate value Z(x) for each peak of abscissae x is the distance from the mean line M to the peak (on the figure 1, p corresponds to summits and v to the valleys).

Ra

It is the arithmetic mean of the absolute ordinate values Z(x) of a profile along the evaluation length Ln.

It is calculated from the formula hereafter:

$$Ra = \frac{1}{L} \times \int_{0}^{Ln} |Z(x)|dx$$

RPc

The peak count RPc is the number of profile elements per a unit length (generally cm) that rise above some predetermined line. The profile element is defined as consecutive summit and valley. In other words, the evaluation consists in counting the number of profile elements exceeding the upper intersection line (C1) and the lower intersection line (C2).

2. EFFECT OF ROUGHNESS ON OPERATION

The commutator / ring roughness will both **condition the film formation** (see *TDS-01*) and **ensure a good current transmission**, therefore the operating behavior of the carbon brush.

Not too polished…

It is often erroneously thought that after rectification, the surface should be as brightly polished as possible. On mirror-polished commutators, friction is higher, particularly at the beginning, and unstable. This difference in performance is due to two causes which are partly linked:

- When the friction surface tends to approach perfection (no defects, like on a glass sheet), the friction forces become much greater and uneven. This phenomenon is also called “slip-stick” effect.

- Graphite, one of the essential constituents of the film, is poorly abraded from the brush and fails to firmly adhere to the metal surface of the commutator / slip ring.

Both phenomena will cause vibrations and overheating.

In addition, a profile with a low roughness will generally exhibit a small number of peaks, in other words a low RPc, which reduces the number of contacts points for passing the current. It generates an additional overheating (see also *TDS-05* about losses) and possibly sparks, with burning marks (see figure 2).

These disadvantages do not appear on unpolished commutators which are slightly rough: the skin forms normally and the brushes rapidly establish a stable condition.

But not too rough!

On the other hand, if the surface is too rough, the commutator acts rather like a grinding wheel. As a result, an excessive wear of the brushes occurs, so a higher amount of dust is released, together with a high and unstable friction, which generates overheating at contact. Generally, with a long operation time, the friction would finally reach a stable state and an equivalent level as for a correct roughness.

Experimental study

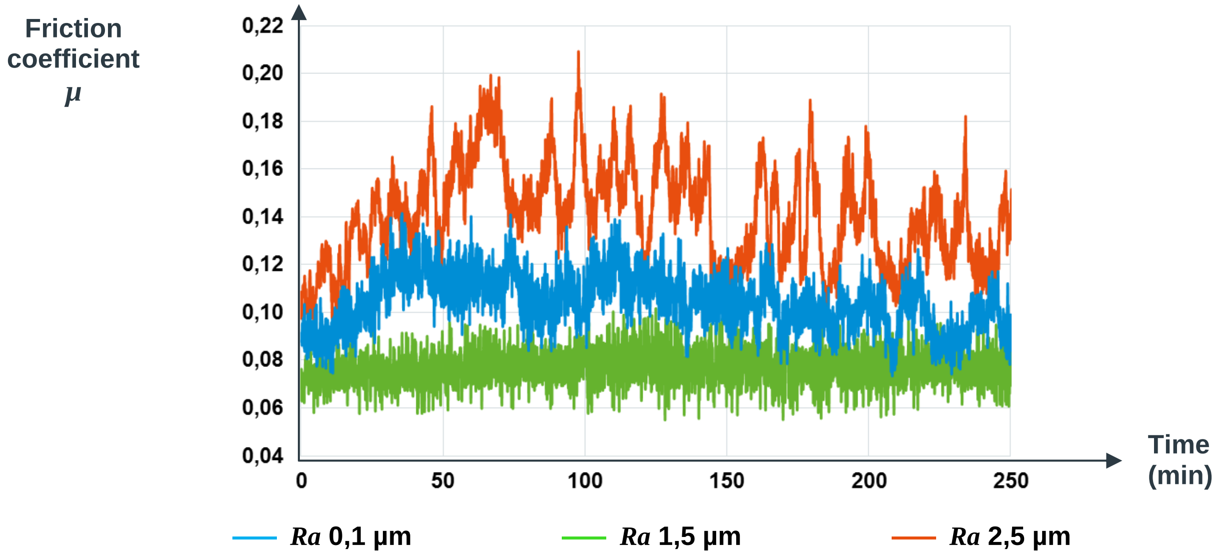
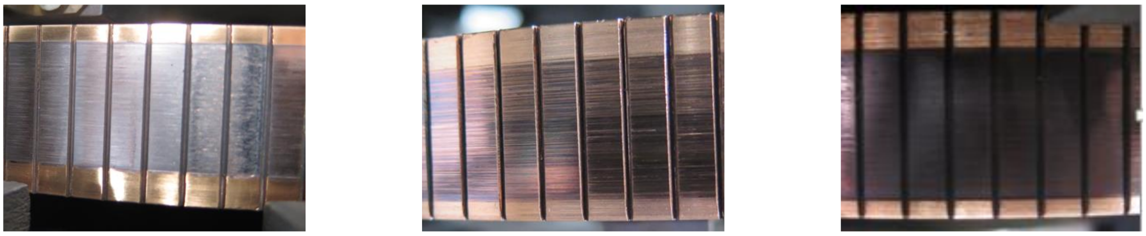


Figure 2a – Effect of initial roughness on brush operation: friction vs time

Ra 0,1 µm — Ra 1,5 µm — Ra 2,5 µm



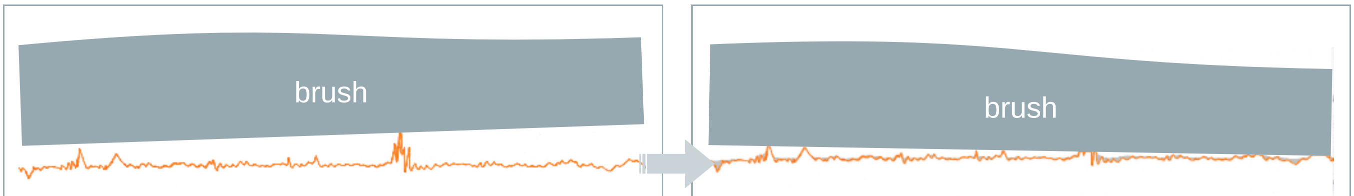
P6 + B6 — P3 — P6

Figure 2b – Effect of initial roughness on brush operation: film aspects after test

Figure 2a represents the evolution of friction coefficient over time when using a low (orange), a high (blue) or a correct (green) initial roughness. Figure 2b shows the film aspect at the end of the test. The test has been carried on a copper ring with bars, without commutation, and brushes made of electrographite (procedure derived from IEC 60773).

Figures 3a, 3b and 3c below, with their comments, explain the influence of each of the respective initial surface condition.

- **When $Ra \approx 0{,}1$ µm:**



Ra = 0,1 µm - Rpc = 1 peak/cm	
Initial: smooth – few peaks ⇨ stuck surfaces – very few contact points – brush inclined	Final: poor skin – unstable brush ⇨ high friction, bad electrical contact + burning

Figure 3a – Profile compromising the skin formation and resulting in a malfuction (vibrations, burning…)

Both rotating element and brush surfaces are very smooth, so that they are sticked together. The friction is high and unstable at the beginning (see orange curve on figure 2). The current passes through few contact points. The brush tends to rotate in its box and to rub on a single contact point, leading to local heating, with a high risk of sparking, and therefore burning.

With time the surface remains smooth and the burning becomes visible, as it can be seen on the picture of the commutator.

- **When *Ra* ≈ 2,5 µm:**

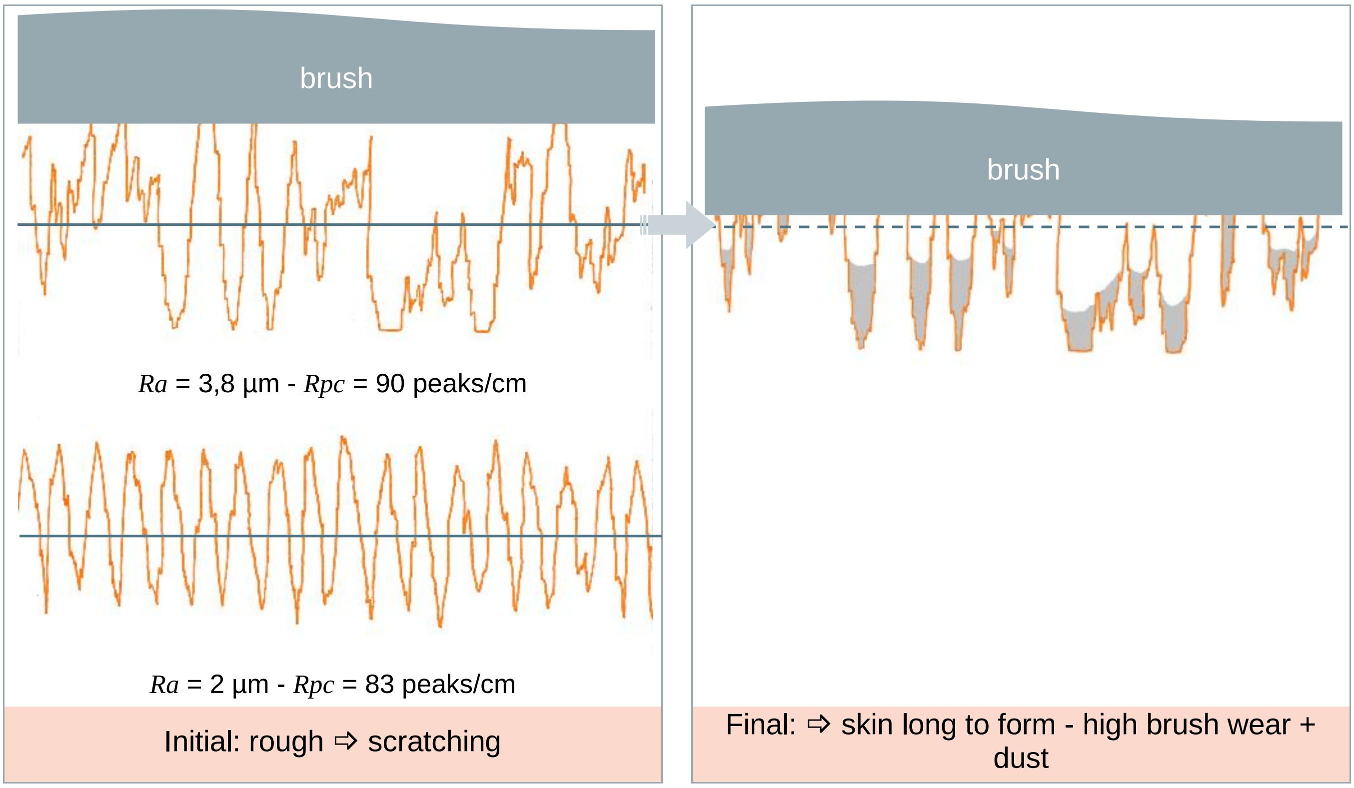


Figure 3b – Profiles leading to a long time required to form a suitable skin and a high brush wear

This initial profile is characterized by sharp and high peaks that will scratch the brush surface (peaks are even out of the scale of the roughness meter). The friction is quite high (see blue curve on Figure 2). Since the valleys are also deep, the skin takes a long time to form.

With time the brush dust becomes important, which may be dispersed in the brush compartment, and finally friction stabilizes.

A particular case is illustrated by the bottom profile, when the surface is not grinded after machining.

- **When *Ra* = 1,5 µm:**

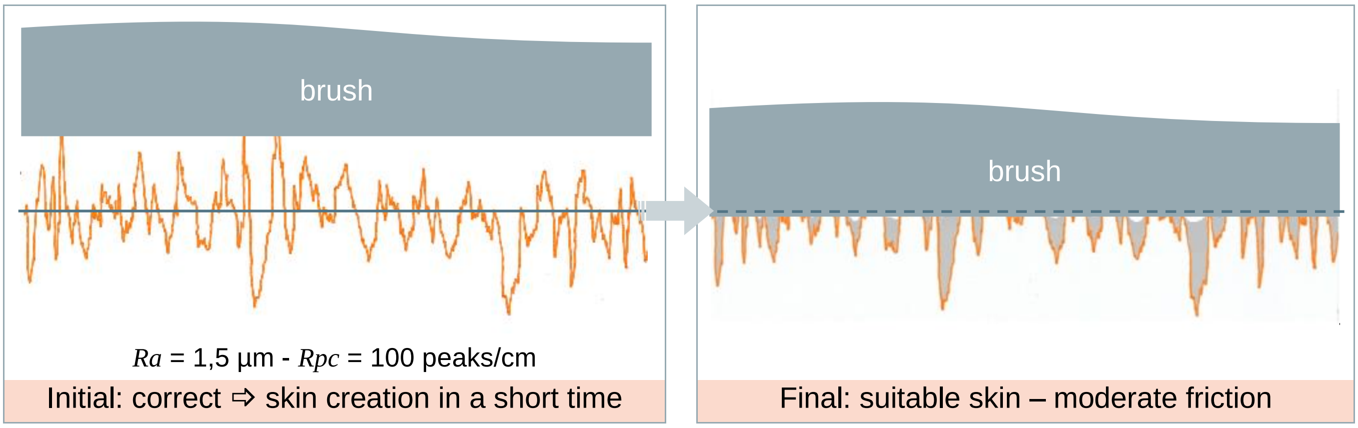


Figure 3c – Profile for an optimum brush operation in a very short time

With a high number of peaks and a correct value of peaks height, the skin will form very quickly.

It can be seen from the green curve of Figure 2 that a correct initial state, unpolished but not too rough, will provide almost immediately a stabilized friction.

3. RECOMMENDED VALUES OF ROUGHNESS

Recommended ranges

From the considerations above, it is seen that the roughness of commutators and rings must be restrained to certain limits.

For a new or refurbished machine, from our experience, we recommend a roughness ***Ra*** range of:

- **0,9 to 2,0 µm for commutators of industrial machines;**
- **0,5 to 1 µm for small commutators of machines with a power lower than 1 kW;**
- **0,75 to 1,8 µm for bronze slip rings;**
- **0,75 to 1,5 µm for steel or stainless steel slip rings.**

and a ***Rpc*** target of **100 peaks per cm**.

A roughness beyond the limit **may be acceptable** for some application, but it shall be kept in mind that it comes with an excessive wear of the brushes while the patina creation is under process.

In operation, brush may be able to operate under extended values of roughness *Ra*, depending on the application and operational parameters. Experience shows that below 0,4 µm machines may be subject to problems. We strongly recommend a corrective action.

Corrective action

In all cases you should not hesitate to grind the surface! This corrective action is achieved by applying a grinding stone on the surface when rotating, with a trailing angle. It is recommended to use a corundum grain of medium size (M). For small machines, if necessary, a finer grain size (F) may be applied.

Mersen can offer you grinding stones in various shapes, dimensions and grain sizes (see our catalogue).

Mersen experts may help you either to define and train you on this procedure or achieve this operation on your site – please contact us. E-mail: info.ptt@mersen.com

Cited documents:

Mersen Brochures:
Mersen Technical Guide: Brushes for motors and generators.
Tools & Services for the maintenance of electric machines

Mersen PTT Technical data sheets:
TDS-01: The functions of a good brush
TDS-05: Losses in brushes
TDS-15: Brush wear
TDS-24: Dust arising from brush wear

Norms / standards:
ISO 3274: GPS- Surface texture: Profile method – Nominal characteristics of contact (stylus) instruments
ISO 4287: GPS- Surface texture: Profile method – Terms, definitions and surface texture parameters
ISO 4288: GPS- Surface texture: Profile method – Rules and procedures for the assessment of surface texture
IEC 60773: Test methods and apparatus for the measurement of operational characteristics of brushes