TECHNICAL DATA SHEET

TANGENTIAL BRUSH COVERAGE CIRCUMFERENTIAL BRUSH STAGGERING

1. DEFINITIONS

The brush tangential coverage, T, is the arc **covered tangentially by one brush**.

- If the brush is **radial** (see *Figure 1.a)*, then the coverage of one brush is equal to the tangential dimension of the brush: $T = t$.
- If the brush is **inclined at an angle** α to the contact surface (*figure 1.b*): $T = t / \sin \alpha$.

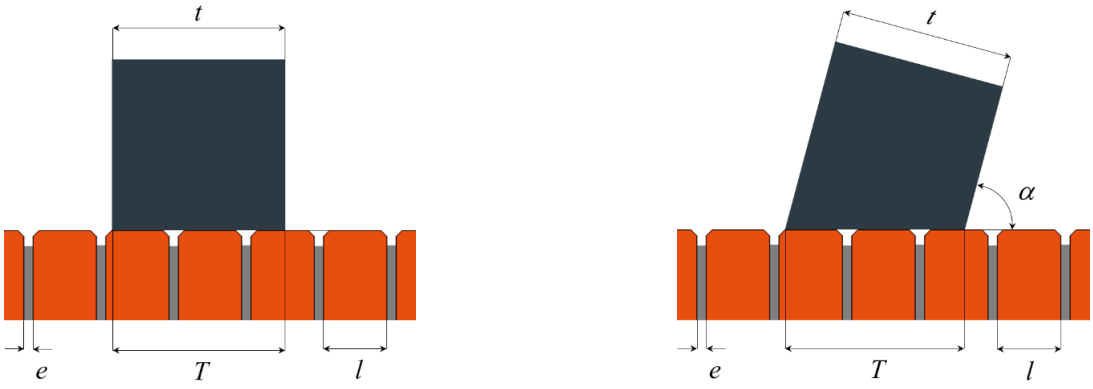


Figure 1 - Coverage of one brush T

Circumferential brush staggering on a commutator is a **method for mitigating the commutation difficulties** of a DC machine, mainly with variable or excessive load. It consists in increasing the commutator arc covered by the brushes by staggering tangentially one or more brushes on each arm.

On *Figure 2*, the drawing illustrates this concept, and the picture is an example of a DC motor with staggered brushes.



Figure 2 – Illustration of total tangential brush coverage and circumferential staggering

MERSEN PROPERTY

The total brush tangential coverage C corresponds then to the **commutator arc covered by the brushes** of one pole (i.e. of a given brush arm), as shown on *Figure 2*. It shall not be confused with T[1].

2. TANGENTIAL BRUSH COVERAGE

Both T and C shall be properly adjusted according to electrical and mechanical considerations.

Electrical considerations

For a satisfactory commutation, the reversal of current shall be complete during the commutation in the commutated coil section.

- If C is too low: the commutation time is reduced and, consequently, the reversal of current may not be complete before the end of the commutation time.
- If C is too large, the voltage difference over the covered arc may be too high, increasing the risk of sparking at brush edges. In addition, the risk of circulating currents under the brush contact face is increased.

Therefore, C shall lay between two limit conditions stated below, with reference to *Figure 3*.

Minimum arc of commutator

The **minimum arc of commutator**, C_{min}, is defined so that brushes overlap the bars corresponding to one armature slot with addition of one interbar gap:

$$C_{min} = z \times (l + e) + e$$

Where:

l is the bar width, in mm

e is the interbar width (mica), in mm

z is the number of conductors per armature slot (integer)

Figure 2 shows an example with z = 3.

Maximum arc of a commutator

The **maximum arc of a commutator**, C_{max}, is quite commonly calculated by using the following formula :

$$C_{max} = 2 \times z \times (l + e) - e$$

Note: C_{max} is limited by the zone of action of the auxiliary poles and by circulating currents developed between bars and brushes.

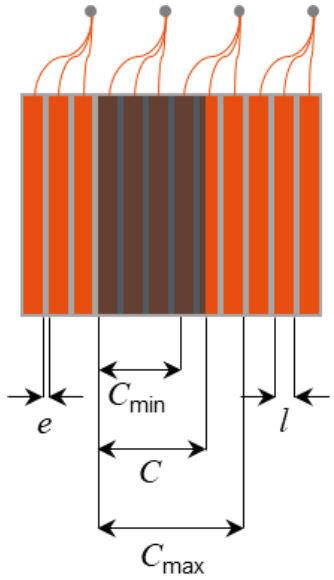


Figure 3 – Definitions of minimum and maximum arc for z = 3

Mechanical considerations

When T is a multiple of commutator bar pitch (l + e), **there is a risk of resonance** linked with the procession of bars under the brush. It would lead to an **instability** of the brush, causing vibrations; and it may result in sparks and, after a certain time, out of round.

This condition also applies to the single blocks (wafers), in case of split and tandem brushes.

[1] Exception: when there is no circumferential brush staggering, $C = T$.

MERSEN PROPERTY

Choice of T

The tangential dimension t of the brush is chosen among the standard dimensions of carbon brushes (see *TDS-04*), so that :

T shall be between C_{min} and C_{max} and shall not be a multiple of the bar pitch ($l + e$).

In practical, two common methods are commonly applied:

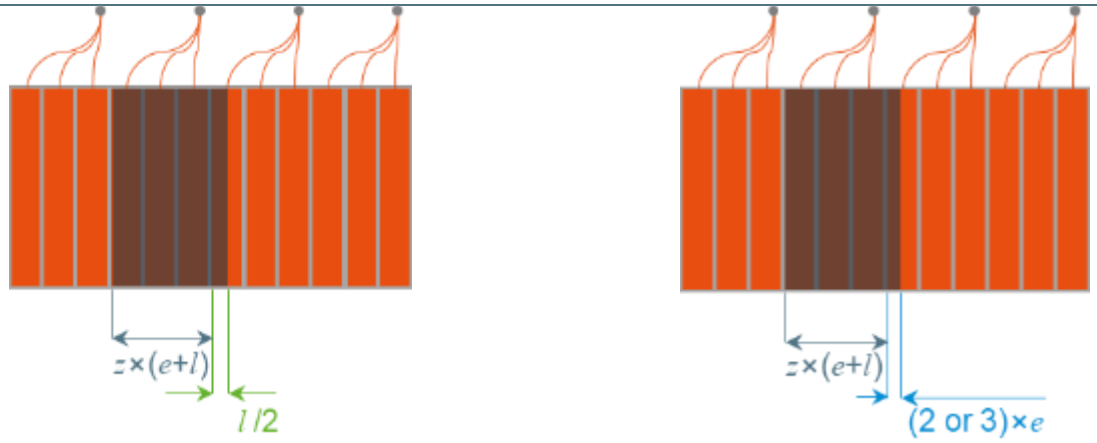
a) the brush covers a number of bars approximatively equal to the **number of coils (conductors) per armature slots plus a half of bar width**:

$$T \approx z \times (l + e) + l / 2$$

b) the brush covers a number of bars approximatively equal to the **number of coils (conductors) per armature slots plus 2 or 3 time the interbar gap** (mica):

$$T \approx z \times (l + e) + (2 \text{ or } 3) \times e$$

Figure 4 illustrates these methods.



Method a) *Method 3.b)*

Figure 4 – Practical methods for determination of T

When proper dimension *t* cannot be found (low current implying thinner brushes for example), or **when the DC machine operates with a variable load, with underload[2] and/or overload**, **then staggering should be implemented**.

3. CIRCUMFERENTIAL BRUSH STAGGERING

Staggering types and arrangements

Staggering will **increase *C* without changing *t*** (and thus T).

The determination of C will follow one of the methods exposed above for T.

[2] The effects on the Neutral Line and machine operation are explained in *TDS-06* and *TDS-25*.

MERSEN PROPERTY

There are two types of staggering, represented on *Figure 5*.

– **Symetrical** according to the neutral line (cases *b* and *c*), for reversing machines.

– **Dissymetrical** according to the neutral line (cases *d* or *e*), for unidirectional machines, by staggering in the direction of rotation (the name "advanced brushes" is sometimes given to the staggered brushes).

These two arrangements can be obtained from the initial situation represented on case *a*:

- by "all or nothing", as shown on arrangements *b*, *c* or *d*, or
- by progressive stagger, as shown on arrangement *e*.

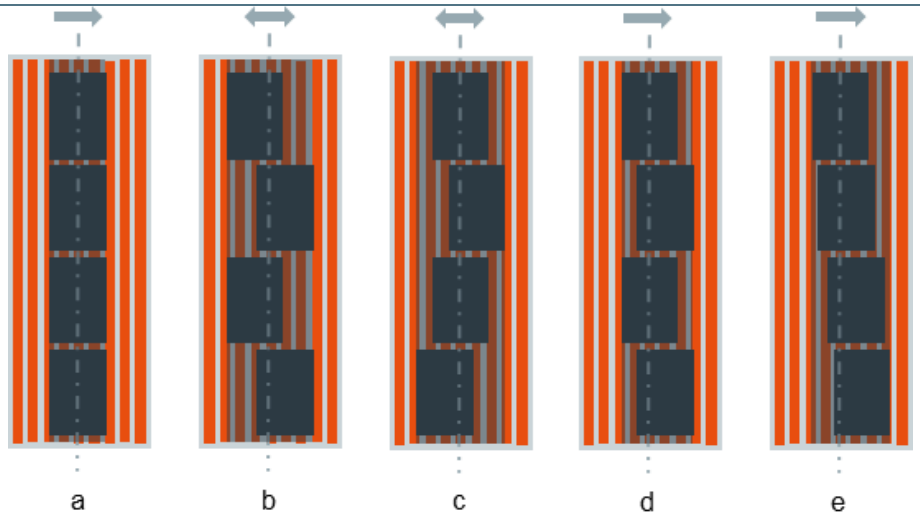


Figure 5 – Different arrangements of brush staggering (grey mixt line: neutral line)

Note: An example of arrangement d is shown on the picture of *Figure 2*.

Effect

By increasing the number of bars covered by the brushes, the commutating difficulties of the machine are reduced accordingly.

The effect of circumferential stagger is especially **sensitive when**:

– the number of commutator bars is great,

– the speed of the machine is high,

– the t dimension of the brush is small (thin brush), i.e. the number of bars spanned by a line of brushes is small.

Limitations

We must bear in mind that the minimum arc of commutator that must be covered by an arm shall respect the formula of C_{min} given above.

The calculations above provide theoretical and approximative values. For a better accuracy, it is recommended to install the machine on a test bench and proceed to an adjustment of the staggering.

Generally, staggering range is from 3 mm to 10 mm.

It is evident that the circumferential staggering shall be applied **only if the neutral line is known or previously set** (refer to our *TDS-06*).

MERSEN PROPERTY

NOTE: Circumferential staggering shall not be confused with **axial staggering**, which consist in arranging brushes so as to cover the whole commutator width. One example is shown on the pictures of *figure 6* (large DC motors for rolling mills). This disposal is usually not recommended, because the tracks may not be covered by the same number of brushes (leading to an uneven wear of the commutator) and the film assessment becomes complex.

If in use, then the **machining of the commutator shall always be done before installing new brushes**, by the usual ways of grinding.

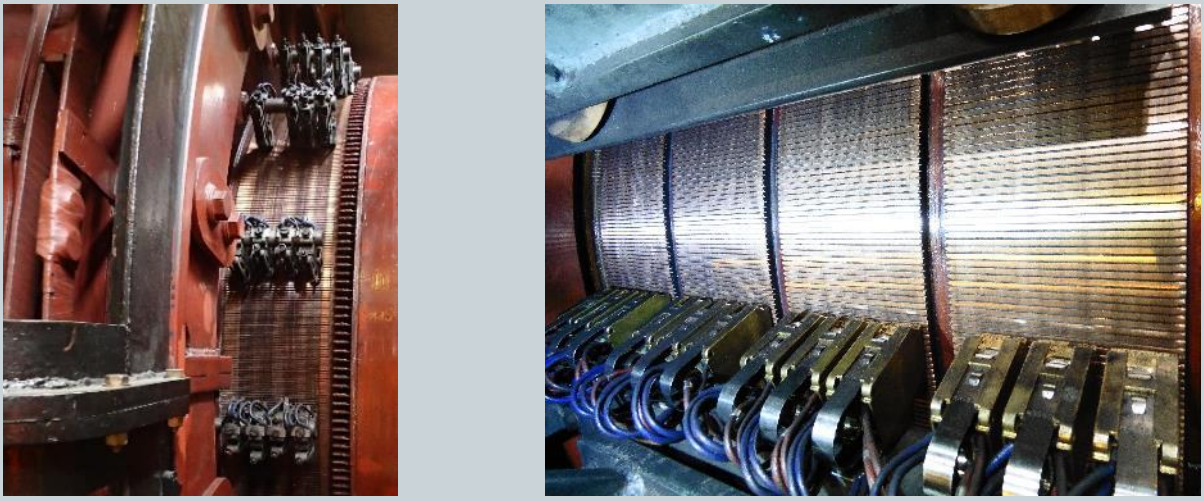


Figure 6 – Axial staggering examples

Cited documents (available from our website www.mersen.com):
Mersen PTT Technical Data Sheets:

- *TDS-04: Dimensions of carbon brushes and brush-holders*
- *TDS-06: Setting the neutral line*
- *TDS-25: Underloaded machines*

MERSEN SERVICES

Mersen's experts provide on-site machine inspections, maintenance and trainings:

- Machine inspection (measurements, operating assessment, diagnosis).
- In-situ machining and renovation of your rings / commutators.
- Technical advices.
- Retrofit solutions
- Trainings, in our facilities or at your site.

The specifications or data contained in present document are only given for information and do not create any undertakings whatsoever. Any copy, reproduction or translation, either partially or fully, of these information is subject to the Mersen's prior written consent. In addition, due to the continuing improvement of techniques and change of applicable standards, Mersen is entitled to modify at any time the characteristics and specifications of its products as described in present catalogue.
Contact: info.ptt@mersen.com

PTT-TDS-09-EN-2411

MERSEN PROPERTY