

INTERNATIONAL STANDARD

NORME INTERNATIONALE



Dimensions, marking and testing of carbon brushes and dimensions of brush-holders for electrical machinery

Dimensions, marquages et essais des balais et dimensions des porte-balais pour machines électriques



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2024 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

IEC Secretariat
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, ...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch

Discover our powerful search engine and read freely all the publications previews, graphical symbols and the glossary. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22 500 terminological entries in English and French, with equivalent terms in 25 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

A propos de l'IEC

La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC

Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Recherche de publications IEC -

webstore.iec.ch/advsearchform

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études, ...). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et une fois par mois par email.

Service Clients - webstore.iec.ch/csc

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch

Découvrez notre puissant moteur de recherche et consultez gratuitement tous les aperçus des publications, symboles graphiques et le glossaire. Avec un abonnement, vous aurez toujours accès à un contenu à jour adapté à vos besoins.

Electropedia - www.electropedia.org

Le premier dictionnaire d'électrotechnologie en ligne au monde, avec plus de 22 500 articles terminologiques en anglais et en français, ainsi que les termes équivalents dans 25 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

INTERNATIONAL STANDARD

NORME INTERNATIONALE



Dimensions, marking and testing of carbon brushes and dimensions of brush-holders for electrical machinery

Dimensions, marquages et essais des balais et dimensions des porte-balais pour machines électriques

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 29.160.10

ISBN 978-2-8322-8835-1

Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.

CONTENTS

FOREWORD.....	7
1 Scope.....	10
2 Normative references	10
3 Terms, definitions and symbols.....	11
3.1 Terms and definitions.....	11
3.2 Symbols.....	19
4 Units and marking.....	21
4.1 Units.....	21
4.2 Marking.....	21
4.2.1 Units.....	21
4.2.2 Additional marks on the brush.....	21
4.2.3 Additional marks for brush-holders	22
5 Principal dimensions and tolerances of brushes.....	22
5.1 Sequence	22
5.2 Standard dimensions	24
5.3 Tolerances on principal dimensions	24
5.3.1 General tolerances	24
5.3.2 Split brushes	25
5.3.3 Metal-graphite brushes	26
5.4 Recommended combinations of principal dimensions.....	26
5.4.1 Combination for t and a	26
5.4.2 Square brush.....	29
6 Complementary dimensions of brushes	30
6.1 Chamfers	30
6.1.1 Angle.....	30
6.1.2 Dimension	30
6.1.3 Non-reversing chamfer	31
6.2 Angles for contact and top bevels	32
6.2.1 Angles for contact bevel	32
6.2.2 Angles for top bevel.....	33
6.2.3 Combination of angles	34
6.3 Pressure area	34
6.4 Depth of insertion q_i of the flexible (shunt) in the brush.....	35
6.5 Residual material width adjacent to the flexible.....	36
6.6 Safe length of a worn brush r_m	37
7 Terminations of brushes: flexibles and terminals.....	38
7.1 Flexibles	38
7.1.1 General	38
7.1.2 Nominal area and maximum diameter of flexibles	39
7.1.3 Length of flexible	40
7.1.4 Flexible protection	40
7.2 Terminals.....	40
7.2.1 General	40
7.2.2 Axial spade terminals	41
7.2.3 Flag terminals.....	42
7.2.4 Double shoe terminals	43

7.2.5	Tubular terminals.....	44
7.2.6	Soldered terminals.....	45
7.2.7	Current capacity of terminals	46
8	Test procedures for determining physical properties of brushes.....	47
8.1	General.....	47
8.2	Measurement of electrical resistance of brush/flexible connection.....	47
8.2.1	General	47
8.2.2	Test equipment.....	48
8.2.3	Test procedure	50
8.2.4	Test procedure for method b) (mathematical).....	55
8.2.5	Calculation and report	56
8.3	Measurement of the pull strength of tamped or moulded connections.....	56
8.3.1	General	56
8.3.2	Principle	56
8.3.3	Test equipment.....	56
8.3.4	Test procedure	59
8.3.5	Calculation and report	59
9	Brush-holder dimensions and configuration	59
9.1	General.....	59
9.2	Dimensions of the inside of the brush-box.....	59
9.2.1	Main dimensions.....	59
9.2.2	Tolerances and clearances on brush-box t and a	59
9.2.3	Dimensions and tolerances on brush-box chamfer	60
9.3	Check of brush-box dimensions	61
9.3.1	General	61
9.3.2	Gauging of dimensions t and a	61
9.3.3	Gauging of chamfers	61
9.4	Serrations on fixing face of the brush-holder	61
9.4.1	General	61
9.4.2	Profile and dimensions of serrations	61
9.4.3	Location of serrations	62
9.5	Brush-holder mounting position.....	62
Annex A (normative)	Equivalent dimensions in inches.....	63
Annex B (normative)	Values of the principal dimensions of metal-graphite brushes.....	66
Annex C (informative)	Considerations relative to brush stability	67
C.1	General.....	67
C.2	Radial brush without top bevel angle operating in bidirectional rotation	68
C.3	Radial brush with top bevel angle operating in the forward direction	70
C.4	Radial brush with top bevel angle operating in the reverse direction	71
C.5	Trailing type brushes	72
C.6	Reaction type brush with top bevel angle	74
Annex D (informative)	Flexibles configuration	77
Annex E (informative)	Flexible location	78
Annex F (informative)	Recommended values of thickness for spade, flag and double shoe terminals	79
Annex G (informative)	Technical questionnaire for the definition of a carbon brush	80
Bibliography		82

Figure 1 – Examples of brush components.....	11
Figure 2 – Chamfer height	12
Figure 3 – Contact bevel angle α	12
Figure 4 – Top bevel angle β	13
Figure 5 – Pressure area width for commutator and for slip-ring	13
Figure 6 – Depth of insertion.....	14
Figure 7 – Residual material width	14
Figure 8 – Safe length of a worn brush	15
Figure 9 – Flexible dimensions l_S and d_S for different examples of brushes	16
Figure 10 – Definition of distance d_P for different types of brush connection	17
Figure 11 – Brush-holder box chamfer height.....	18
Figure 12 – Definition of serration location distance	19
Figure 13 – Safe remaining length mark for different brush designs	22
Figure 14 – Main dimensions for a wedge-edge brush.....	23
Figure 15 – Preferred orientation for anisotropic grades depending on the application	30
Figure 16 – Angle of chamfers	30
Figure 17 – Split brush.....	31
Figure 18 – Non-reversing chamfer height	31
Figure 19 – Sharp edge when a contact bevel angle α is applied	33
Figure 20 – Flat surface of edge when a top bevel angle β is applied.....	33
Figure 21 – Flexible configuration illustration	38
Figure 22 – Definition of shape and dimensions of axial spades terminals	41
Figure 23 – Definition of shape and dimensions of flag terminals	42
Figure 24 – Definition of shape and dimensions of double shoe terminals	43
Figure 25 – Definition of shape and dimensions of tubular terminals	44
Figure 26 – Definition of shape (example) and dimensions of formed spade terminal	45
Figure 27 – Definition of shape (examples) and dimensions of two types of pin terminals.....	46
Figure 28 – Examples of testing device for the measurement of the connection electrical resistance	48
Figure 29 – Example of contact probe for flexible.....	49
Figure 30 – Example of contact probe for brush	49
Figure 31 – Measurement of connection resistance for a moulded or tamped connection	51
Figure 32 – Measurement of connection resistance for a riveted connection	52
Figure 33 – Alternative method for the measurement of connection resistance in case of 2 rivets.....	53
Figure 34 – Connection with a metal top soldered or riveted to the block	54
Figure 35 – Iterated determination of location P of Probe 2.....	55
Figure 36 – Test equipment for the measurement of the pull out force	57
Figure 37 – Example of support device for brushes with inclined connection hole	58
Figure 38 – Profile of serrations – cross-sectional view.....	62
Figure C.1 – Illustration of rotational moments for a radial brush.....	69

Figure C.2 – Illustration of forces applied on a radial brush with top bevel angle operating in the forward rotation	70
Figure C.3 – Illustration of forces applied on a radial brush with top bevel angle operating in the reverse direction	72
Figure C.4 – Illustration of forces applied on a trailing brush with a top bevel angle operating in the forward direction	73
Figure C.5 – Illustration of forces applied on a reaction brush	75
Figure E.1 – Flexible location	78
Figure G.1 – Main dimensions	80
Figure G.2 – Brush operation	81
Table 1 – Symbols for each unit system	21
Table 2 – Standard dimensions of brush block	24
Table 3 – Tolerances on t , a and r	25
Table 4 – Recommended combination of t , a and r	27
Table 5 – Dimension of chamfer height c	31
Table 6 – Recommended values of non-reversing chamfer height	32
Table 7 – Preferred values for contact bevel angle α and top bevel angle β	33
Table 8 – Typical combination values for contact bevel angle α and top bevel angle β	34
Table 9 – Recommended minimum values of pressure area width w_p	35
Table 10 – Maximum values of depth of insertion q_i	35
Table 11 – Example of maximum values of q_i for an EG grade	36
Table 12 – Minimum width of residual material	37
Table 13 – Recommended nominal area for flexibles and their corresponding maximum diameter	39
Table 14 – Standard lengths of flexibles l_S and tolerances	40
Table 15 – Standard values of spades terminals dimensions	42
Table 16 – Standard values of flag terminals dimensions	43
Table 17 – Standard values of double shoe terminals dimensions	44
Table 18 – Standard values of tubular terminals dimensions	45
Table 19 – Standard values of formed spade terminals dimensions and tolerances	46
Table 20 – Minimum values of current capacity for terminals	47
Table 21 – Tolerances on brush box dimensions and clearances	60
Table 22 – Maximum value of the brush-box chamfer height c_H	60
Table A.1 – Standard dimensions and tolerances on brush dimensions $t \times a \times r$ in inch system	63
Table A.2 – Nominal and maximum dimensions of chamfer height c to be used in inch system	64
Table A.3 – Recommended minimum value of w_p to be used in inch system	64
Table A.4 – Maximum values of depth of insertion q_i	64
Table A.5 – Recommended nominal area for flexibles (shunts) and their corresponding maximum diameter	65
Table A.6 – Standard lengths of flexibles l_S and tolerances	65
Table B.1 – $t \times a \times r$ tolerances and clearance for metal graphite grades	66

Table C.1 – Overview of the different mechanical configurations (bevel angles) in operation	67
Table D.1 – Configuration of flexibles	77
Table F.1 – Recommended thickness for spade, flag and double shoe terminals corresponding to screws diameter.....	79
Table G.1 – Elements to be included in a form.....	80

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**DIMENSIONS, MARKING AND TESTING OF CARBON BRUSHES AND
DIMENSIONS OF BRUSH-HOLDERS FOR ELECTRICAL MACHINERY**

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

IEC 60136 has been prepared by IEC technical committee TC 2: Rotating machinery. It is an International Standard.

This third edition cancels and replaces the second edition published in 1986 and Amendment 1:1995. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

Title: modified.

Clause or subclause	Previous clause	Change
1	I-1	Clarification and extension of the scope.
2	None	New clause introduced.
3	None	New clause introduced.
4	I-4 and II-7.5	Addition of units and extension of marking.
5.1	I-2	Addition of cylindrical and wedge-shape brushes.
5.2	I-3	Distinction of dimensions between t , a and r .
6.1	II-7.1	Revision of the chamfer dimension table and addition of non-reversing chamfer.
6.2	II-7.2	Revision of angles dimensions and addition of typical combination of angles.
6.4	II-7.4	Clarification of the definition of the depth of insertion and modification of maximum values.
6.5	None	New subclause introducing the concept of residual material width.
7.1.2	II-8.7	Change of definition of flexibles area and diameter.
7.1.4	None	Addition of flexible protection.
7.2	II-8.1 to II-8.5	Clarification. Addition of other types of terminals.
8	Annex C	Clarification of the method of measurement of electrical resistance and addition of graphical method.
9.2 and 9.3	Clause A.3	Brush-holder: Separation of Dimensions and Control of brush box in two different subclauses.
Annex A	None	Compilation of tables with inches dimensions from the previous edition.
Annex B	None	Addition of recommended dimensions for metal-graphite grades.
Annex C	None	Explanation of stability of brushes (linked to 6.2).
Annex D	II-8.7	Addition of examples of configuration of flexibles.
Annex E	None	Addition of recommended standardization of flexibles' location
Annex F	Annex D and II-8.8	Link between the thickness of terminals and the screw diameter.
Annex G	Annex B	Simplification of the questionnaire, to include only elements defined in this document.

The text of this International Standard is based on the following documents:

Draft	Report on voting
2/2180/FDIS	2/2189/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

DIMENSIONS, MARKING AND TESTING OF CARBON BRUSHES AND DIMENSIONS OF BRUSH-HOLDERS FOR ELECTRICAL MACHINERY

1 Scope

This document applies primarily to brushes and brush-holders for cylindrical commutators and slip rings for electrical rotating machines. Some clauses of this document may cover other configurations, such as flat commutators or plain disks.

It defines the dimensions of brushes and their components, together with their tolerances:

- dimensions of brush block (t , a , r),
- angles α and β ,
- chamfer,
- flexibles (shunts),
- standard terminals.

It also covers the conventional designation of principal dimensions, the marking of brushes and the testing methods for the qualification of brushes after their manufacturing (except the brush grade material, covered by IEC 60413).

And finally, it specifies dimensions of the brush-holders that are linked to brushes.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60276:2018, *Carbon brushes, brush holders, commutators and slip-rings – Definitions and nomenclature*

IEC 60560, *Definitions and terminology of brush-holders for electrical machines*

ISO 129-1, *Technical product documentation (TPD) – Presentation of dimensions and tolerances – Part 1: General principles*

ISO 197-1:1983, *Copper and copper alloys – Terms and definitions – Part 1: Materials*

ISO 286-2:2010, *Geometrical product specifications (GPS) – ISO code system for tolerances on linear sizes – Part 2: Tables of standard tolerance classes and limit deviations for holes and shafts*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60276:2018 and IEC 60560, and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

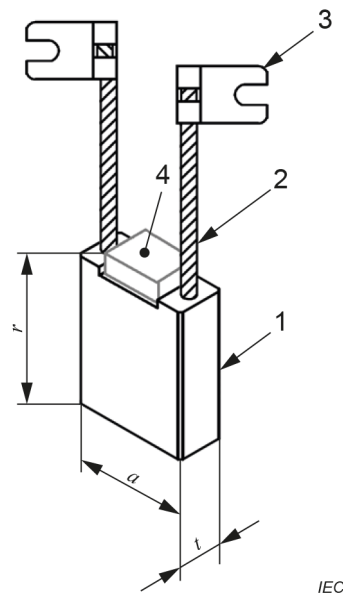
- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

3.1.1

component

<of the brush> element assembled onto the brush block and having a specific feature

Note 1 to entry: Figure 1 shows an example of a carbon brush designed for a DC machine, comprising the following components: two flexibles, two terminals and one top plate.



Key

- 1 block
- 2 flexible
- 3 terminal
- 4 top plate
- t tangential dimension of the brush
- a axial dimension of the brush
- r radial dimension of the brush

Figure 1 – Examples of brush components

3.1.2

chamfer height

c

smaller side of the isosceles rectangle triangle formed by the chamfer, as illustrated by Figure 2

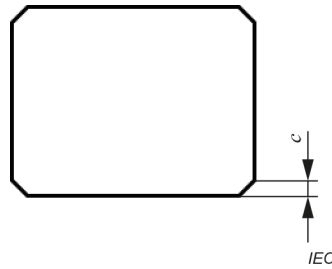


Figure 2 – Chamfer height

Note 1 to entry: c is expressed in millimetres (mm).

Note 2 to entry: In USA, c is also named depth of chamfer.

Note 3 to entry: The source of Figure 2 is IEC 60276:2018, item 147.

3.1.3

contact bevel angle

bottom bevel angle

α

angle between the centre line of the brush and the radial axis of the commutator or slip-ring, as shown in Figure 3

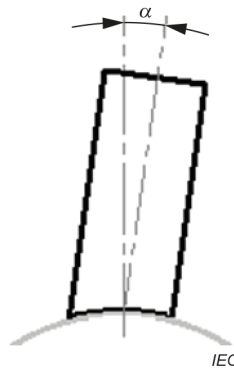


Figure 3 – Contact bevel angle α

Note 1 to entry: α is expressed in degrees (°).

[SOURCE: IEC 60276:2018, item 106]

3.1.4

top bevel angle

β

angle between the centre line and the top surface of the carbon brush, as shown in Figure 4

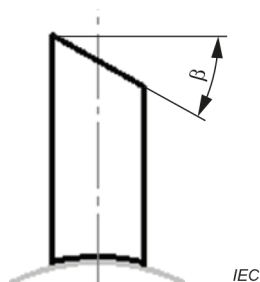


Figure 4 – Top bevel angle β

Note 1 to entry: β is expressed in degrees ($^{\circ}$).

Note 2 to entry: The source of Figure 4 is IEC 60276:2018, item 110.

3.1.5

pressure area width

w_p

width of the area on the top of the brush where the pressure system applies, as shown in Figure 5

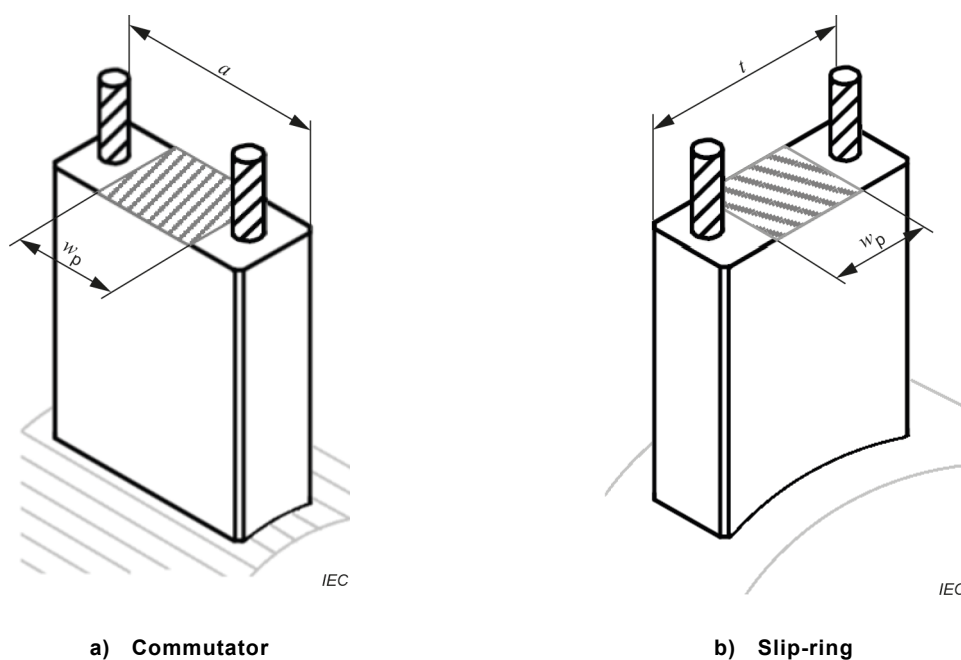


Figure 5 – Pressure area width for commutator and for slip-ring

Note 1 to entry: w_p is expressed in millimetres (mm).

3.1.6

depth of insertion

q_i

distance between the extremity of flexible inside the brush and its insertion location onto the top of the brush, along the flexible direction axis, as illustrated by Figure 6

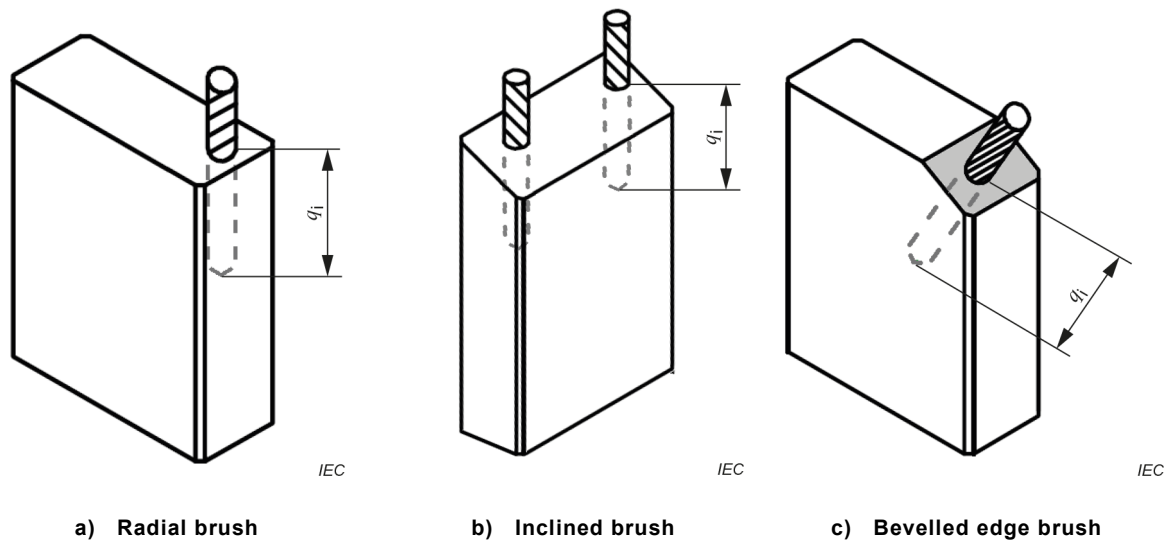


Figure 6 – Depth of insertion

Note 1 to entry: q_i is expressed in millimetres (mm).

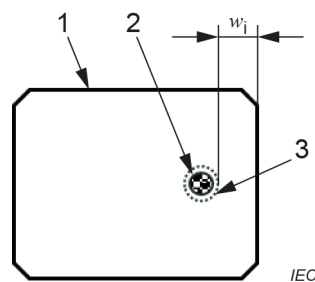
3.1.7

residual material width

w_i

width of the residual material adjacent to the flexible (see Figure 7), defined by the distance between:

- the closest side of the brush block, and
- the periphery of the hole drilled for the insertion of the flexible



Key

- 1 brush
- 2 flexible
- 3 hole (for the flexible insertion)

Figure 7 – Residual material width

Note 1 to entry: w_i is expressed in millimetres (mm).

3.1.8

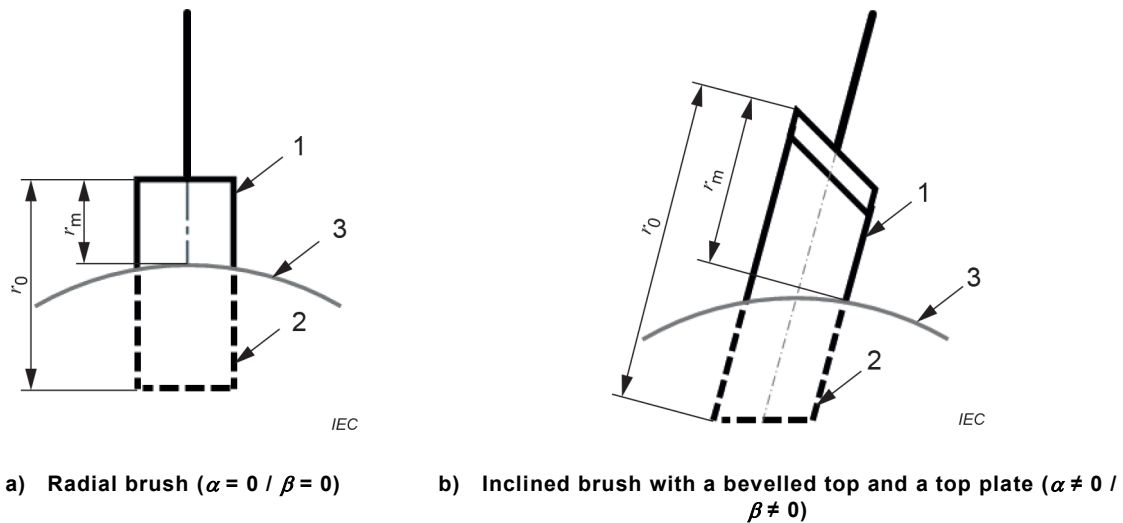
safe length of a worn brush

r_m

distance between two planes perpendicular to the centre line, passing over the extremities of:

- the contact surface at its minimum safe wear limit, and
- the elements of brush or parts of elements, which take part in the pressure application

Note 1 to entry: Figure 8 illustrates the definition of r_m for two examples.



Key

- 1 worn brush
- 2 initial brush
- 3 rotating surface

r_0 initial radial dimension

r_m safe length of the worn brush

NOTE Dash lines represent the worn part of the brush.

Figure 8 – Safe length of a worn brush

Note 2 to entry: r_m is expressed in millimetres (mm).

3.1.9 length of flexible

l_s

distance of the flexible between the brush-flexible connection (onto the brush top) and the screw connection axis of the terminal, as illustrated by Figure 9

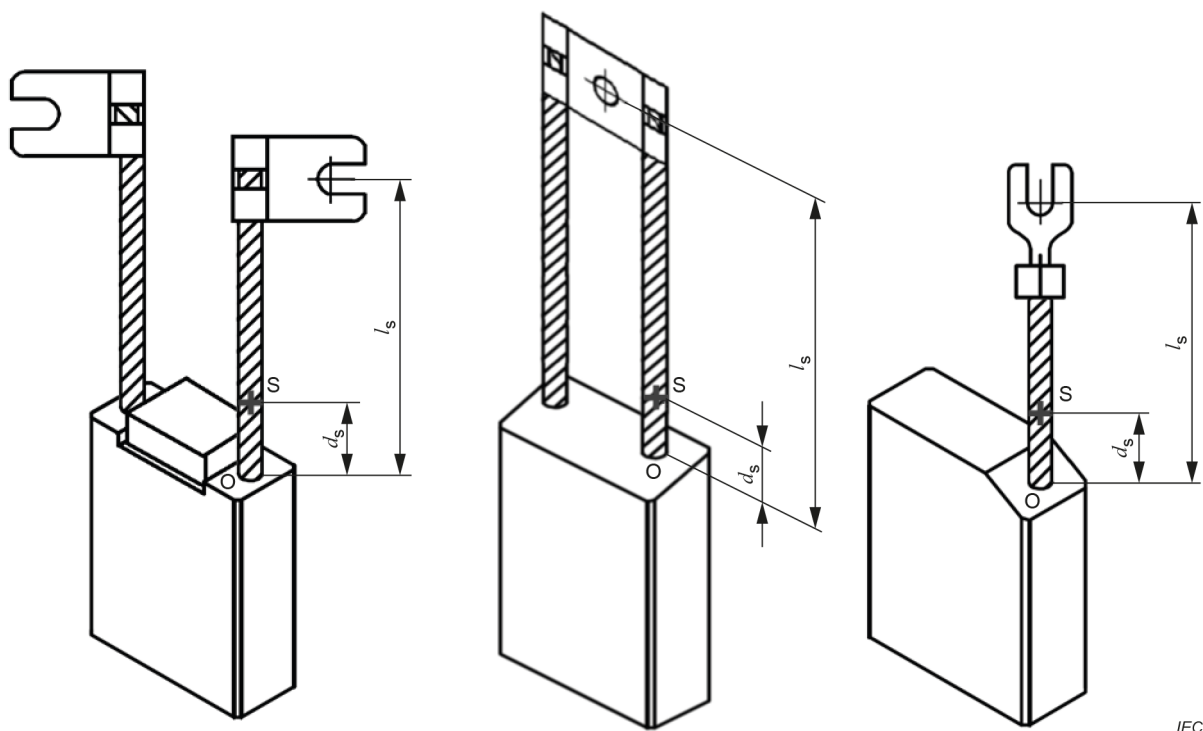
Note 1 to entry: l_s is expressed in millimetres (mm).

Note 2 to entry: When there is no terminal, the screw connection axis in the definition above is naturally replaced by the free extremity of the flexible.

3.1.10 distance for the application of the flexible probe

d_s

distance, along the flexible direction axis, from a location S onto the flexible to the brush-flexible connection (location O), as shown in Figure 9



IEC

Key

O brush-flexible connection location on the top of the brush

S location onto the flexible

d_s distance for the application of the flexible probe

l_s length of the flexible

Figure 9 – Flexible dimensions l_s and d_s for different examples of brushes

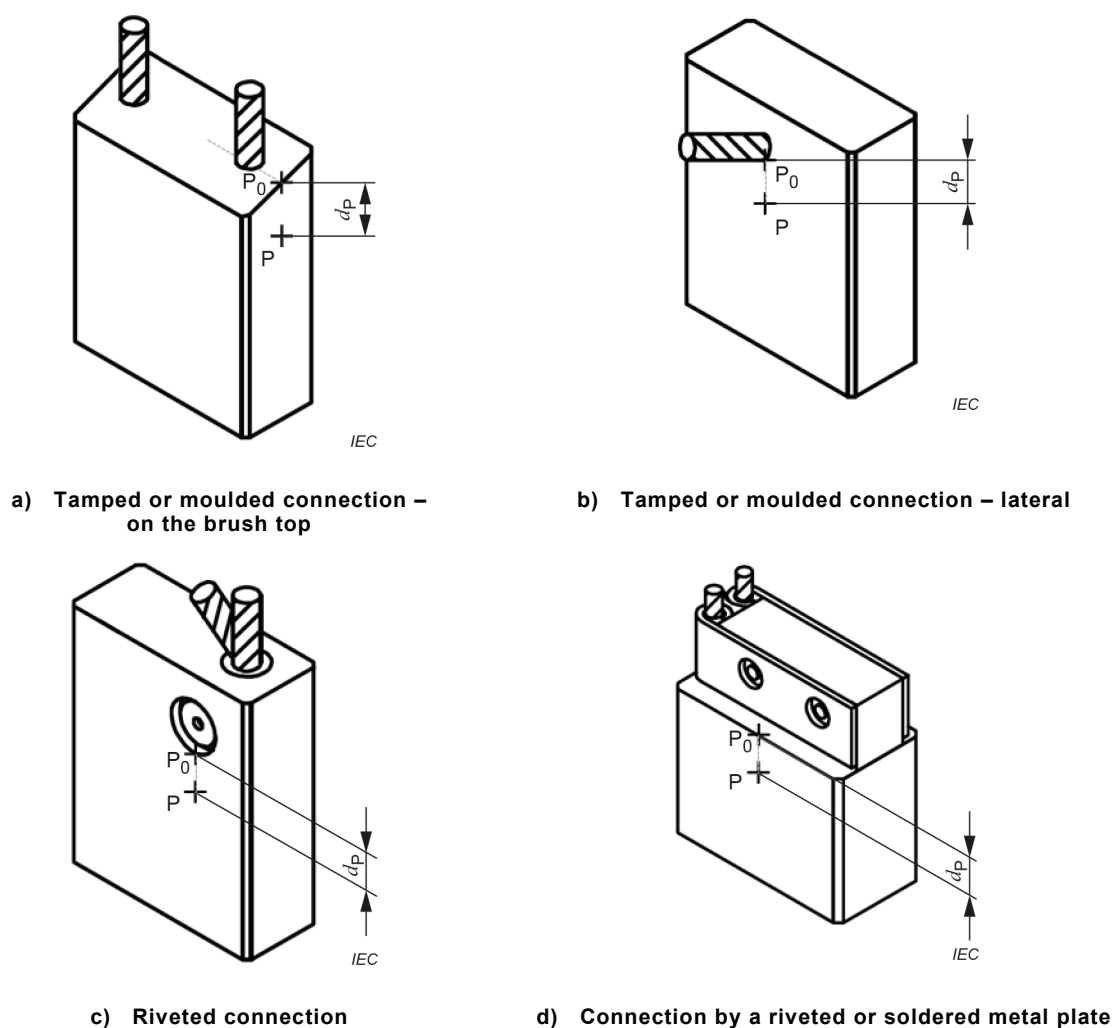
Note 1 to entry: d_s is expressed in millimetres (mm).

3.1.11

distance for application of the block probe

d_p

distance from a point P of a side of the block to a point P_0 of the same side, which is the closest to the outside of the connection mean, as shown in Figure 10



Key

P location onto the side of the brush block

P_0 location onto the same side of the brush block as P and closed to the brush-flexible connection

d_P distance for the application of the brush block probe

Figure 10 – Definition of distance d_P for different types of brush connection

Note 1 to entry: For any type of brush, the axis passing through both points P and P_0 is parallel to its centre line. The side of the block is chosen so that the distance from the axis (P; P_0) and the centre line is minimum.

Note 2 to entry: d_P is expressed in millimetres (mm).

3.1.12 electrical resistance of the brush-flexible connection

R_f

electrical resistance measured between a point S onto the flexible (see Figure 9) and a point P onto the brush body (see Figure 10)

Note 1 to entry: R_f is expressed in milliohms (mΩ).

3.1.13 pull-out force of the brush-flexible connection

F_f

force required to pull out the flexible from the brush in the direction of the flexible axis

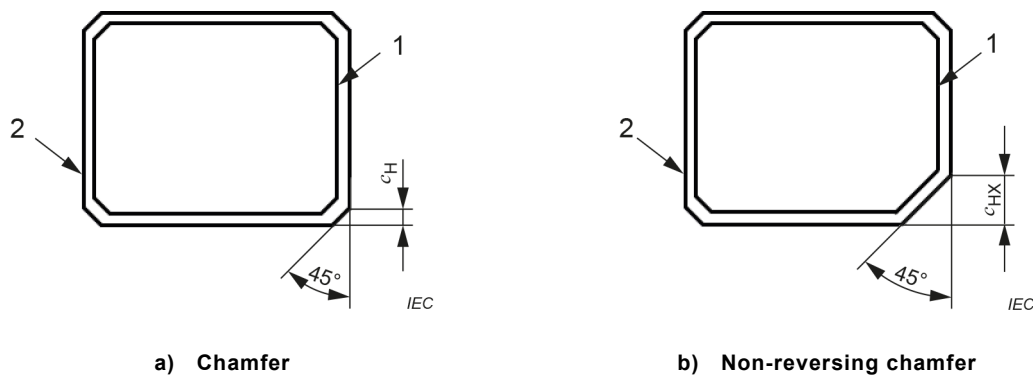
Note 1 to entry: F_f is expressed in newtons (N).

3.1.14 brush-holder box chamfer height

c_H

smaller side of the isosceles rectangle triangle formed by the chamfer of the brush-box

Note 1 to entry: By extension, the height of the brush box non-reversing chamfer c_{HX} can be defined. Figure 11 illustrates the definitions.



Key

- 1 brush
- 2 brush-box
- c_H height of the brush box chamfer
- c_{HX} height of the brush box non-reversing chamfer

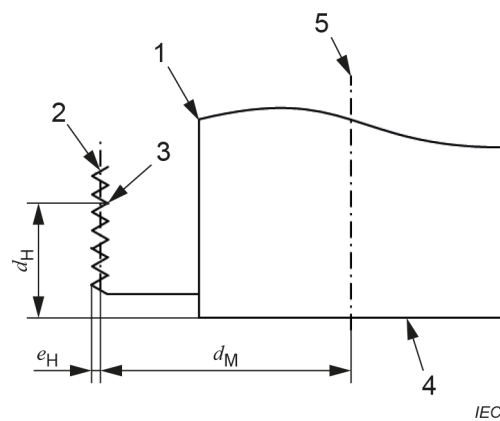
Figure 11 – Brush-holder box chamfer height

Note 2 to entry: c_H is expressed in millimetres (mm).

3.1.15 serration location distance

d_H

distance from any tooth root of the serrated side of the brush-holder to the bottom of the brush box, in vertical direction, as illustrated by Figure 12

**Key**

- 1 brush-holder box
- 2 serrated face of the fixation of the brush-holder
- 3 any tooth root of the serrated face
- 4 bottom of the brush box
- 5 brush centre line
- d_H serration location distance
- d_M mounting distance
- e_H distance between the tip of the tooth and the axis of application of the mounting distance

Figure 12 – Definition of serration location distance

Note 1 to entry: d_H is an integer and is expressed in millimetres (mm).

Note 2 to entry: The profile and dimensions of the serrations of the fixation are specified in 9.4.

3.1.16**mounting distance** **d_M**

distance from the axis of the fixation face to the centre line of the brush along the tangential direction (in the case of a DC machine), as illustrated by Figure 12

Note 1 to entry: d_M is expressed in millimetres (mm).

3.2 Symbols

- A sharp edge at contact bevel angle
- a axial dimension of the brush, in mm
- B sharp edge at top bevel angle
- c chamfer height (of the brush), in mm
- c_H brush-box chamfer height, in mm
- c_{HX} brush-box non-reversing chamfer height, in mm
- c_X non-reversing chamfer height (of the brush), in mm
- D_S flexible diameter, in mm
- D_T screw diameter, in mm
- d_H serration location distance, in mm
- d_M mounting distance, from the mounting interface of the brush-holder to the brush centre line in tangential direction, in mm

d_P	distance for the application of the block probe, in mm
d_S	distance along the flexible for the application of the flexible probe, in mm
d_{ST}	depth of serration tooth (of the serrated fixing face of the brush-holder), in mm
e_H	distance between the tip of the tooth and the axis of application of the mounting of the brush-holder, in mm
F	clamping force of the brush holding device, in N
F_f	pull-out force of the brush-flexible connection, in N
h_{ST}	pitch of the serrated fixing face of the brush-holder, in mm
L_T	length of terminal, in mm
l_S	length of flexible, in mm
q_i	insertion depth of the flexible in the brush block, in mm
R_f	electrical resistance of the brush-flexible connection, in mΩ
r	radial dimension of the brush, in mm
r_m	safe length of the brush, in mm
t	tangential dimension of the brush, in mm
w_T	width of terminal, in mm
w_{ST}	width of the tooth of the serrated fixing face of the brush-holder, in mm
w_i	remaining material width, in mm
w_p	pressure area width, in mm
x_T	dimension of the terminal perpendicular to the flexible axis direction, in mm
y_T	dimension of the terminal parallel to the flexible axis direction, in mm
z_T	distance from screw axis to the extremity of the terminal closed to the flexible, in mm
α	contact bevel angle, in °
β	top bevel angle, in °
γ_{ST}	angle between the teeth of the serrated fixing face of the brush-holder, in °

NOTE For uniformization of standards relative to carbon brushes and brush-holders, the subscripts have been harmonized:

- B is relative to the entire brush (total brush voltage drop U_B),
- i is relative to the inside of the brush block (insertion depth q_i or internal brush drop U_i for example),
- f refers to the brush-flexible connection (electrical resistance R_f , etc.),
- S corresponds to the flexible (length l_S , diameter D_S),
- T corresponds to the terminal (length L_T , width w_T), and
- H corresponds to the brush-holder (c_H).

4 Units and marking

4.1 Units

As International Standards shall only use SI units (see the various parts of ISO/IEC 80000 series), all length dimensions of this document are expressed in metric units.

Since the imperial system (inch, pound, etc.) is still used in some countries, dimensions in inches are included in Annex A. It means that values in millimetres in the main body text have a corresponding value in inches in the tables of Annex A.

It is important that each system be used independently of the other. Combining values from the two systems may result in non-conformance with the specification and may affect brush performances in operation.

4.2 Marking

4.2.1 Units

To avoid confusion between dimensions in millimetres (metric system) and in inches (imperial system, also known as British Imperial), brushes, as well as brush-holders, should be marked by using one of the symbols of Table 1.

Table 1 – Symbols for each unit system

Unit system	Symbol
metric (millimetres)	□ ^a
imperial (inches)	△ ^b
^a Square.	
^b Triangle.	

The symbol shall be easy to be read, and not less than 3 mm wide.

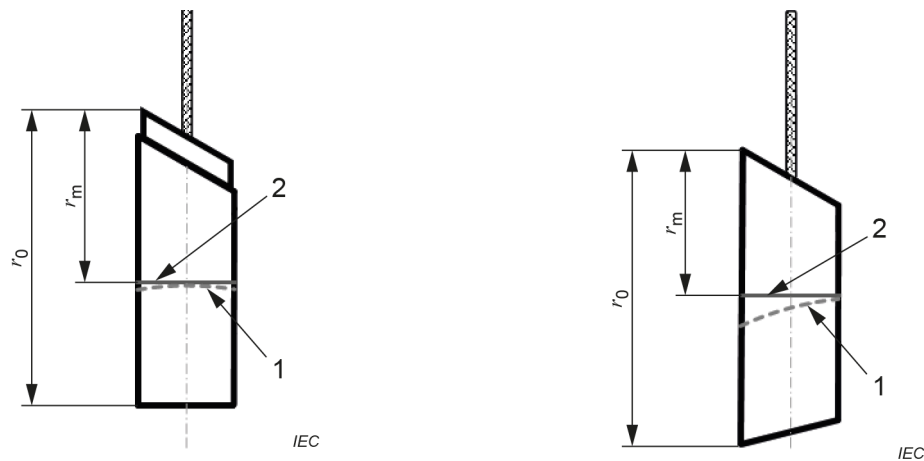
For brushes, the symbol should be so placed that it will still be visible when the brush is fully worn, that is to say near the top of the brush. If the brush is too small, there is no unit marking.

For brush-holders, considering the great variety of shapes and constructions, the marking may be applied where the manufacturer prefers, provided it is visible by the user when the brush-holders are mounted on the machine.

4.2.2 Additional marks on the brush

In addition, the remaining brush length, as defined in 3.1.8 (see also 6.6), should be identified by a mark on the tangential side of the brush. The mark may be a groove line, a small blind hole, or a painted line. When the contact surface reaches one point of the mark, the brush is worn out. Figure 13 gives some examples.

The unit marking as per 4.2.1 shall not be used as a safe worn length mark.



a) Radial brush with a bevelled top
($\alpha = 0$ / $\beta \neq 0$) and a top plate

b) Inclined brush with a bevelled top
($\alpha \neq 0$ / $\beta \neq 0$)

Key

- 1 contact surface when the brush is about to be worn out
- 2 mark indicating the safe remaining length
- r_0 initial radial dimension
- r_m safe length of a worn brush

Figure 13 – Safe remaining length mark for different brush designs

The brush may also be marked so that the user can identify the brush, for example: name or logotype of the manufacturer, the grade name of the block, an index of traceability, etc. Preferably all markings are applied on the same face unless there is not enough space. Generally, the marking is applied on the largest face of the brush. As for the unit mark, it should be so placed that it will still be visible when the brush is fully worn.

4.2.3 Additional marks for brush-holders

As for brushes, the brush-holder may also be identified by an additional marking, generally the manufacturer's name or its logotype and a part number.

5 Principal dimensions and tolerances of brushes

5.1 Sequence

5.1.1 For a brush with a rectangular cross-section, the principal dimensions shall be stated within the sequence (1):

$$t \times a \times r \quad (1)$$

where

- t is the tangential dimension of the brush;
- a is the axial dimension;
- r is the radial dimension;
- $\times$ is a sign applied between the dimensions.

NOTE 1 t , a and r are defined in IEC 60276 and reproduced in Figure 1.

NOTE 2 t is always stated before a , even when t is larger than a (for example slip-rings applications). See figures in item 102 (commutator type) and 103 (slip-ring type) of IEC 60276:2018.

Dimensions are expressed in millimetres or inches. Units are identified on the brush by a marking according to 4.2.1.

5.1.2 For cylindrical brushes, the dimension t corresponds to its diameter. Therefore, the corresponding sequence will be (2).

$$t \times r \quad (2)$$

where

t is the diameter of the brush.

5.1.3 For wedge-edge brushes (trapezoidal section), there are two tangential dimensions, as represented on Figure 14:

- largest tangential dimension: t_1 ;
- smallest tangential dimension: t_2 ,

where t_1 is larger than t_2 .

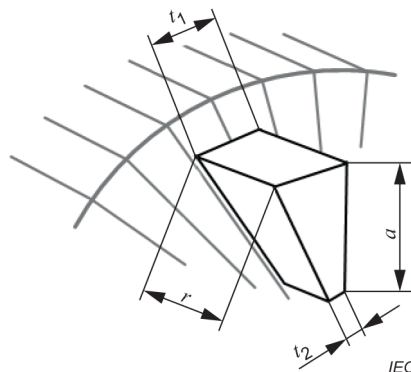


Figure 14 – Main dimensions for a wedge-edge brush

The dimensions are expressed by the sequence (3):

$$(t_1 / t_2) \times a \times r \quad (3)$$

where

t_1 is the largest tangential dimension;

t_2 is the smallest tangential dimension.

NOTE On Figure 14, r does not correspond to the definition of the radial dimension of the brush, but to the "length" of the brush that will be worn. This naming was found to be necessary for the application of this document (standard dimensions, tolerances, safe length, etc.).

5.2 Standard dimensions

The brushes dimensions are expressed by their nominal value and shall be selected from the values given in Table 2.

Table 2 – Standard dimensions of brush block

Dimensions in mm

Dimension	Standard nominal value ^a
t or a	1,6; 2; 2,5; 3,2; 4; 5; 6,3; 8; 10; 12,5; 16; 20; 25; 32; 40; 50; 64; 80
r	6; 8; 10; 12,5; 16; 20; 25; 32; 40; 50; 64; 80; 100; 125
^a Values are taken or rounded from the Renard Series (ISO 3 – base R10). NOTE Standard dimensions in inches are given in Table A.1.	

5.3 Tolerances on principal dimensions

5.3.1 General tolerances

The brush shall be guided along a sufficient height with a suitable clearance to avoid both jamming and beating. Therefore, Table 3 specifies tolerances on the principal dimensions of the brush.

Dimensions shall be measured within a device capable of checking the tolerances specified in Table 3 and at different locations on the brush. It is recommended to use a micrometer, a digital-indicator gauge or a calliper having an accuracy of $\pm 0,01$ mm or better. The average value is reported.

NOTE 1 The design and metrological characteristics of the above instruments are specified in respective standards ISO 3611, ISO 13102 and ISO 13385-1.

It is up to the brush manufacturer to define a suitable statistical sampling method for the control during and/or after production.

NOTE 2 One can refer to ISO standards for sampling procedures, for example ISO 2859-1.

Nominal dimensions and tolerances of a brush shall be expressed on the drawing according to ISO 129-1.

EXAMPLE

For a brush with $t \times a \times r$ equal to $16 \times 25 \times 40$, the tolerances are described as follows:

$$16_{-0,15}^{-0,04} \times 25_{-0,13}^{-0,04} \times 40_{\pm 0,8}$$

NOTE 3 Clearances between brushes and brush-holders are given in 9.2.2.

Table 3 – Tolerances on t , a and r

Dimensions in mm

Nominal dimension	Tolerances on t or a		Tolerances on r
	Lower	Upper	
1,6 2 2,5 3,2	–0,03	–0,09	±0,3
4 5 6,3 8 10	–0,03	–0,11	±0,3
12,5 16 20 25	–0,04	–0,13	±0,5
32 40 50 64 80	–0,05	–0,15	±0,8
NOTE Standard dimensions in inches system are given in Table A.1.			

5.3.2 Split brushes

The dimension (t or a) for which the brush is split in several wafers (see item 138 in IEC 60276:2018) shall be indicated in the dimensions sequence by a dash followed by the number of wafers.

Depending on the split configuration, Formula (1) becomes one of the following Formula (4) or Formula (5):

- when split within t dimension:

$$t / 2 \times a \times r \quad (4)$$

- when split within a dimension:

$$t \times a / 2 \times r \quad (5)$$

Unless otherwise specified by the user and the supplier, the tolerance of the value of t or a of a set of split brushes (or divided brushes) is increased by 20 µm (or 0,8 thousandths of an inch) by reducing its lower limit, whilst maintaining its upper limit unchanged.

EXAMPLE

For a brush with $t \times a \times r$ sequence 16/2 mm $\times$ 25 mm $\times$ 40 mm, the tolerances are described as follows:

$$16 / 2_{-0,15}^{-0,06} \times 25_{-0,13}^{-0,04} \times 40^{\pm 0,8}$$

5.3.3 Metal-graphite brushes

For those grades of brushes which have an abnormally high thermal expansion, for example certain metal graphite and unburnt graphite grades, the dimensions should be reduced at the discretion of the brush manufacturer, as specified in Annex B.

These brushes shall, however, be designated by the nominal values of Table 2.

To facilitate inspection, the brush manufacturer should state the reduced nominal dimensions on the drawing or on a control report when dispatching the brushes.

5.4 Recommended combinations of principal dimensions

5.4.1 Combination for t and a

Table 4 gives recommendations of combinations for t and a and preferred values of r . The preferred combinations are printed in bold character.

Table 4 – Recommended combination of t , a and r

Dimensions in mm

t	a														
	2	2,5	3,2	4	5	6,3	8	10	12,5	16	20	25	32	40	50
1,6	8	8													
2		8	8												
2,5			8 10	8 10	10 12,5										
3,2		10		8 10 12,5	10 12,5	12,5 16									
4		10	10		10 12,5	12,5 16	16 20	16 20							
5			12,5	12,5		12,5 16	16 20 25	16 20 25	20 25 32	20 25 32	25 32	32 40	32 40		
6,3			12,5	12,5 16	16		20 25	20 25 32	20 25 32	25 32	25 32 40 50	32 40 50	32 40 50		

Dimensions in mm

<i>t</i>	<i>a</i>														
	2	2,5	3,2	4	5	6,3	8	10	12,5	16	20	25	32	40	50
8				16 20	16 20	20		20 25 32	25 32	25 32 40	25 32 40 50	32 40 50	32 40 50 64		
10					16 20	16 20 25	20 25 32		25 32 40	25 32 40	25 32 40 50 64	32 40 50 64	32 40 50 64	40 50 64	
12,5						20 25	25 32	25 32		25 32 40	32 40 50	32 40 50 64	32 40 50 64 80	40 50 64 80	50 64 80
16						20 25	25 32	25 32 40	32 40		32 40 50	32 40 50 64	32 40 50 64 80	40 50 64 80	50 64 80
20							25 32	25 32 40	32 40 50	32 40 50		32 40 50 64	32 40 50 64 80	40 50 64 80	50 64 80 100
25							32 40 50	32 40 50	32 40 50 64	32 40 50 64	32 40 50 64		40 50 64 80 100	40 50 64 80 100	50 64 80 100

Dimensions in mm

<i>t</i>	<i>a</i>														
	2	2,5	3,2	4	5	6,3	8	10	12,5	16	20	25	32	40	50
32								32	32	32	32				
								40	40	40	40	40		40	
								50	50	50	50	50		50	50
								64	64	64	64	64		64	64
										80	80	80		80	80
											100	100		100	100
												125		125	125
40									40	40	40	40	40		
									50	50	50	50	50		
									64	64	64	64	64		64
										80	80	80	80		80
											100	100	100		100
50											40	40			
											50	50	50		
											64	64	64	64	
											80	80	80	80	
											100	100	100	100	
												125	125	125	

Care should be exercised when using brushes with high *r* values that they can be satisfactorily used in the design of the brush-holder in use.

It is not recommended to use a brush of *r* dimension value above 125 mm. In particular, the brush stability shall be considered (see Annex C).

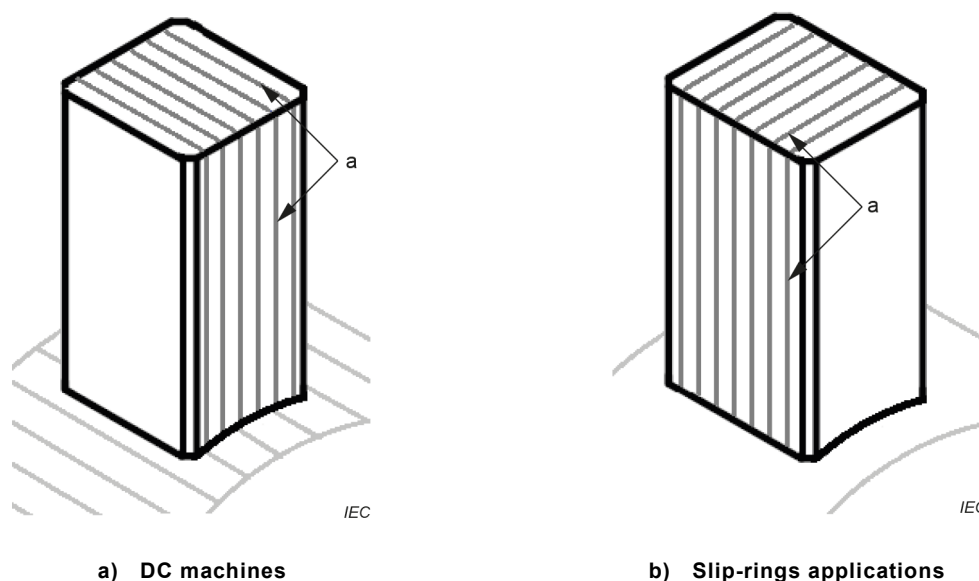
5.4.2 Square brush

Square section brushes are not recommended, in particular when using an anisotropic grade, such as metal-graphite grade. The cutting direction of the block shall be in accordance with the direction of the grain orientation towards the sliding surface, which depends on the application.

Figure 15 illustrates the preferred orientation for DC machines and slip-rings applications.

When the customer confirms he/she wishes the use of a square brush, it is highly recommended to use a non-reversing chamfer to identify the correct position of the brush in its brush box with respect to the cutting direction.

Recommended dimensions of the non-reversing chamfer are specified in 6.1.3 for brushes and 9.2.3 for brush-holders.



Key

- a Orientation plan of grains during moulding operation (perpendicular to the force of pressing in case of uniaxial pressing in a mould)

Figure 15 – Preferred orientation for anisotropic grades depending on the application

6 Complementary dimensions of brushes

6.1 Chamfers

6.1.1 Angle

An angle of 45° shall be applied for the chamfer of brushes, as indicated by Figure 16.

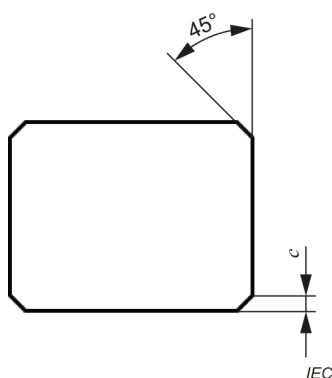


Figure 16 – Angle of chamfers

6.1.2 Dimension

The values of chamfer height c , as represented on the Figure 2 and Figure 16, are related to the dimensions t or a of the brush.

The nominal of the chamfer, defined as being a minimum value to ensure a proper guidance of the brush inside its box, shall be chosen from Table 5 according to the smallest value between t and a .

Table 5 also provides a recommended nominal and maximum value.

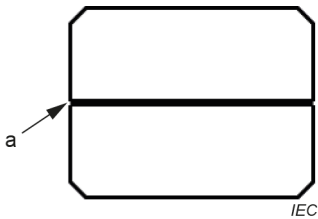
When other values of chamfers (and their tolerances) are used, they shall be stated on the brush drawing.

Table 5 – Dimension of chamfer height *c*

Dimensions in mm

The smallest value between dimensions <i>t</i> and <i>a</i>	Values of <i>c</i>		
	Nominal (recommended)	Minimum	Maximum (recommended)
$(t \text{ or } a) \leq 3,2$	0,1	0,1	0,4
$3,2 < (t \text{ or } a) \leq 6,3$	0,3	0,3	0,6
$6,3 < (t \text{ or } a) \leq 8$	0,5	0,5	0,8
$8 < (t \text{ or } a) \leq 20$	1,0	1,0	1,5
$20 < (t \text{ or } a)$	2,0	2,0	2,5
NOTE Standard dimensions in inches system are given in Table A.2.			

For split brushes (double, triple, etc.), the value of outer chamfers *c* is given in Table 5 in relationship with the nominal dimension *t* or *a*. Between the individual brushes no chamfers are required. Anyway, to avoid any chipped edges during manufacturing, the edges between individual wafers could be slightly broken as shown by the arrow in Figure 17.



Key
a Broken angle location

Figure 17 – Split brush

The corresponding chamfer height of the brush-box, *c_H*, as defined in 3.1.14, shall be in accordance with 9.2.3.

6.1.3 Non-reversing chamfer

A non-reversing chamfer may be added when it is necessary to mount the brush at a specific position on the electrical rotating machine (see item 146 of IEC 60276:2018). This brush feature is typically applied for square brushes (see 5.4.2), but is not limited to them.

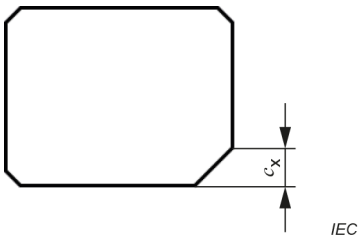


Figure 18 – Non-reversing chamfer height

The recommended height c_x of the non-reversing chamber, as defined in Figure 18, is presented in Table 6. In any case it shall be strictly superior to the maximum tolerance value of c (see 6.1.2).

Table 6 – Recommended values of non-reversing chamfer height

Dimensions in mm

The smallest between dimension t and a	Values of c_x	
	Nominal (and minimum)	Upper tolerance
$(t \text{ or } a) \leq 6,3$	2	+0,3
$6,3 < (t \text{ or } a) \leq 10$	2,5	+0,3
$10 < (t \text{ or } a) \leq 16$	3	+0,3
$20 < (t \text{ or } a)$	4	+0,5
NOTE Standard dimensions in inches system are given in Table A.2.		

The corresponding non-reversing chamfer height of the brush-box, c_{HX} , as defined in Figure 11, shall be chosen so that no jamming nor friction exist between the brush and its box (see also 9.2.3).

6.2 Angles for contact and top bevels

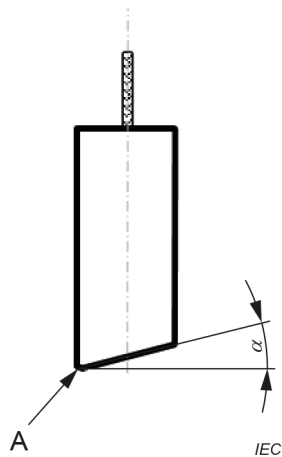
6.2.1 Angles for contact bevel

The contact bevel angle α (see Figure 3) should be selected among values given in Table 7.

The contact bevel angles in Table 7 reflect the most commonly applied values in use for rotating electrical machines in operation, and thus constitute a standard for most of the carbon brush manufacturers. For values over 20° , it is recommended to study the stability of the brush, in combination with the top bevel angle and the rotating direction (see 6.2.3).

Tolerances for all values of angles are $\pm 1^\circ$.

When α is greater than 15° and t is greater than 8 mm (5/16 in), the sharp edge of angle A may be removed by the manufacturer, as shown by Figure 19, either by a flat surface (toe) or rounded shape or a chamfer of not more than 1 mm (0,04 in) width.



Key

A Sharp edge at the bottom of the brush

Figure 19 – Sharp edge when a contact bevel angle α is applied

NOTE In the field many old-designed DC motors or generators still use intermediate angles or angles higher than 35°. For example: on reversing rotation motors, V-tandem brush-holders with an angle α of 40° is applied.

6.2.2 Angles for top bevel

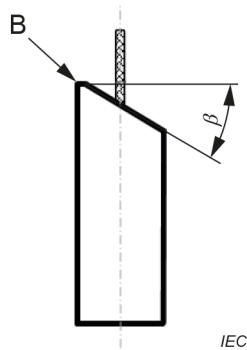
Preferred values of top bevel angle β (see Figure 4) are given in Table 7.

Table 7 – Preferred values for contact bevel angle α and top bevel angle β

Dimensions in °	
Angle	Nominal values ^a
α	0; 7,5; 15; 20; 22,5; 30; 35
β	0; 7,5; 15; 20; 22,5; 25; 30
^a Values specified are absolute values (angles α and β may be positive or negative).	

Tolerances for all values of angles are $\pm 1^\circ$.

When β is greater than 15°, it is recommended to remove the sharp edge B by a flat surface of not more than 1 mm width (0,04 in), as shown in Figure 20.



Key

B Sharp edge at the top of the brush

Figure 20 – Flat surface of edge when a top bevel angle β is applied

Angles greater than 30° are not recommended since it may affect the brush stability, particularly when the brush is worn (see 6.2.3).

6.2.3 Combination of angles

Angles are related to the stability of the brush when in operation. A study of stability may be helpful to define the proper α and β angles. Particularly, the study shall consider the specific pressure, the location of pressure application, the rotating direction and the friction coefficient of the brush grade. Annex C explains the considerations regarding brush stability.

Table 8 gives some typical historical values of combination of contact and top angles.

Table 8 – Typical combination values for contact bevel angle α and top bevel angle β

Dimensions in $^\circ$	
Values of α	Recommended values of β
0 ^a	0; 7,5; 15
7,5 to 8 ^b	0; 7,5; 15
15 ^b	0; 7,5; 15
20 ^b	20; 25
22,5	22,5; 25
> 25 and < 40 ^c	25; 30; 35; 40
NOTE Values of angles specified in this table are absolute values. ^a Radial brush. ^b Typical dimension for a trailing brush ($\alpha < 0$). ^c Typical dimension for a reaction brush ($\alpha > 0$).	

6.3 Pressure area

The top of the brush shall have an area symmetrical about the centre line of the brush top, left clear of brush connections, on to which the pressure may be applied. The pressure area width w_p is important for the definition of the pressure system dimensions, in particular of recoiling type.

The values of pressure area width w_p are related to either a or t depending on the type of the machine, as illustrated in Figure 5:

- for DC machines: w_p is along the axial direction (relative to a),
- for slip-rings machines: w_p is along the axial direction (relative to t).

The recommended minimum values of w_p are given in Table 9.

Table 9 – Recommended minimum values of pressure area width w_p

Dimensions in mm

Dimension t or a	Minimum value of w_p
12,5	6,3
16	6,3
20	10
25	12,5 ^a
32	16
40	20
50	25

NOTE Dimensions in inches are given in Table A.3.

^a It is recognized that for brushes with a or t of 25 mm (1 in), many brush-holders use pressure fingers 12,5 mm (1/2 in) wide. In such cases, the brush manufacturers will increase w_p to a suitable value or use two flexibles (shunts).

In cases where it is difficult or impossible to use the type of connection shown in the figures of this document, it is left to the discretion of the manufacturer to use any other type of insertion for the flexible (shunt).

6.4 Depth of insertion q_i of the flexible (shunt) in the brush

The brush manufacturer generally uses, for the insertion of the flexible in the brush material the part of the brush nearest to the top, as illustrated by Figure 6.

The value of q_i depends on the diameter of the flexible D_S . The recommended values of q_i are disclosed in Table 10.

Table 10 – Maximum values of depth of insertion q_i

Dimensions in mm

Dimension D_S	Recommended maximum value of q_i
1	6
1,2	6
1,4	7
1,6	8
1,8	9
2	10
2,2	11
2,5	12
2,8	13
3,2	14
3,6	15
4	16
4,5	17
5	18
5,6	19
6,3	20

NOTE Standard dimensions in inches system are given in Table A.4.

In the case of tandem and split brushes, the maximum q_i value should be taken from Table 10 corresponding to the cross-section of each block.

As the flexible is defined according to both the grade of the brush block and its dimensions (flexibles are specified in 7.1), the depth of insertion may slightly differ from one brush to another. It also includes a tolerance for discrepancies in drilling the holes.

If the brush manufacturer cannot ensure a satisfactory connection by applying the values given in Table 10, it should notify the customer and provide the amended q_i value necessary.

EXAMPLE

The values given in Table 11 represent the maximum values of q_i determined for a standard brush made of a grade chosen in EG (electrographite) family for a DC machine.

Table 11 – Example of maximum values of q_i for an EG grade

Dimensions in mm

Values of t	Values of a										
	5	6,3	8	10	12,5	16	20	25	32	40	50
5	^a	6	6	6	6	7	8 ^b	9 ^b	10 ^b	12 ^b	
6,3	6	^a	6	6	7	8	9	10 ^b	12 ^b	13 ^b	
8	6	6	^a	7	8	9	10	12	13 ^b	15 ^b	
10	6	7	7	^a	^a	11	12	13	15	16 ^b	18
12,5	6	7	8	^a	^a	^a	13	15	16	18	19
16	7	8	9	11	^a	^a	15	16	18	19	20
20	8 ^b	9	10	12	13	15	^a	18	19	20	^c
25	9 ^b	10 ^b	12	13	15	16	18	^a	20	^c	^c
32	10 ^b	12 ^b	13 ^b	15	16	18	19	20	^a	^c	^c
40	12 ^b	13 ^b	15 ^b	16 ^b	18	19	20	^c	^c	^a	^c
50				18	19	20	^c	^c	^c	^c	^a
^a Combination not recommended as explained in 5.4.2.											
^b Combination not recommended as per Table 4.											
^c Combination not recommended since generally 2 flexibles should be used.											

Lower values of q_i may be applied upon the customer's request to increase the brush lifetime. It shall be borne in mind that the properties relative to the brush-flexible connection (electrical resistance and pull-out resistance) may be affected. Therefore, an agreement shall be found between the customer and the brush manufacturer based on the desired properties of the brush, which are to be defined from the viewpoint of the final application of the machine.

6.5 Residual material width adjacent to the flexible

The width of the residual material adjacent to the flexible, defined in 3.1.7 and illustrated by Figure 7, shall be minimized to avoid any crack inside the brush block when drilling and/or fixing the flexible (either by tamping nor riveting). The values specified in Table 12 are the minimum width relative to the flexible diameter to be respected.

Values of Table 12 concern brush grades with a minimum flexural strength of 20 MPa, which represents the majority of EG, CG and MG grades.

For fragile grades such as NG or BG, thus with a lower flexural strength than 20 MPa, a value of 0,2 mm should be added to the values specified in Table 12.

For high flexural resistance grades (such as a flexural strength higher than 60 MPa) a lower value may be applied after a feasibility study is carried out by the carbon brush manufacturer.

As it can be seen from Table 12 and Table 9, there could be a conflict between the two concepts of minimum surface for the application of pressure w_p and the minimum width of residual material w_i . Therefore, an agreement shall be found between the user and the brush manufacturer to ensure both a good operation of the brush and its manufacturing. One shall keep in mind that the choice of the brush-holder type will have an influence on the brush design.

NOTE IEC 60413 specifies the method for the determination of the flexural strength of brush grades.

Table 12 – Minimum width of residual material

Dimensions in mm	
Dimension D_s	Minimum residual material width w_i
1	1,4
1,3	1,4
1,6	1,5
1,8	1,6
2	1,6
2,4	1,7
2,7	1,9
3,3	2,4
3,7	2,9
4,2	2,9
4,7	3,5
5,3	3,5
5,9	4,0
6,7	4,0
NOTE The tolerance range is generally between +0 mm and +0,5 mm.	

6.6 Safe length of a worn brush r_m

The safe length of a worn brush, defined in 3.1.8 and Figure 8, will be slightly in excess of the value of q_i . r_m depends on various factors, such as:

- actual values of q_i ,
- elements (or parts of elements) fitted on to brush and included in r dimension, such as top pads, which take part in the pressure application (see example b) of Figure 8),
- pressure spring type, particularly the remaining pressure when the brush is worn.

It is the user who shall supervise the brush wear, the purpose being to replace the brush when the safe worn length r_m is reached.

A mark, showing the safe worn length, shall be made on the new brush by the manufacturer if requested by the user or on his/her own initiative. The marking shall be in accordance with 4.2.2.

The value of r_m is not mentioned in this document since it depends upon the design of the brush and its application (particularly the wear rate).

However, for the purposes of guiding, marking, etc., the dimension r_m is limited to a minimum value:

- For radial brushes and inclined brushes with $\alpha \leq 15^\circ$, it is recommended that the value of r_m not be lower than 35 % of the value of r .
- For inclined brushes with $\alpha > 15^\circ$, it is recommended that the value of r_m be ≥ 30 % of the value of r .

If special arrangements are to be included to prevent wear beyond r_m , they shall be secured to the brush and not to the brush-holder.

7 Terminations of brushes: flexibles and terminals

7.1 Flexibles

7.1.1 General

Flexibles (or shunt in US) are composed of several single metal wires arranged together. Two main arrangements are used for brush flexibles: strand and braid, as illustrated by Figure 21.



Figure 21 – Flexible configuration illustration

NOTE A strand is constituted by an assembly of several single wires helicoidally twisted. Generally, several strands are stranded together to obtain the flexible. A braid is constituted by several single wires (or strands) braided together.

Generally, the material of the single wire is copper. Copper shall be chosen among Cu-ETP (Electrolytic Tough Pitch) or Cu-OF (Oxygen free), as defined in ISO 197-1. The single wire may be plated with tin, silver or nickel, when a higher resistance to chemicals or oxidation is needed.

It shall be noted that dimensions of the flexible may differ slightly depending on the configuration and chemical nature of the metal.

Configurations other than those illustrated by Figure 21 are possible (such as flat braided flexible, with a rectangular section). Therefore, it is possible that some clauses of this document will not apply.

The position of the flexible onto the brush shall be chosen carefully so that the flexible is not impacted during installation nor during operation of the brush (for example wires could be cut if the flexible touches a metal element of the brush-holder). Annex E gives an example of a definition of location points.

7.1.2 Nominal area and maximum diameter of flexibles

The definition of the flexible shall be studied from an electrical point of view: its cross-section area has a relationship with the current carrying capacity.

The values of nominal current per flexible indicated in Table 13 should serve as a guide for the determination of the flexible configuration. Table 13 gives recommended values of nominal area and maximum diameter of the flexible D_S .

NOTE The diameter of the flexible is a function of its configuration (diameter of single wires, material, arrangement, etc.). Therefore, only a maximum value of flexible diameter is reported in Table 13. Some configuration examples are given for reference in Annex D.

In practice, the nominal current per flexible is calculated from the current to be passed per brush and the number of flexibles per brush. It is recommended to apply almost 2 flexibles per wafer in case of any issue in operation (flexible cut or pulled out). If the calculated nominal current per flexible does not exactly match the value in Table 13, it shall be rounded up to the next value.

Table 13 – Recommended nominal area for flexibles and their corresponding maximum diameter

Nominal current per flexible ^a	Nominal area	Maximum diameter D_S
A	mm ²	mm
7	0,25	1,0
9	0,5	1,3
12	0,75	1,6
15	1,0	1,8
17,5	1,25	2,0
20	1,5	2,2
24	2,0	2,4
28	2,5	2,7
32	3,2	3,0
38	4,0	3,3
44	5,0	3,7
50	6,0	4,2
60	8,0	4,7
75	10,0	5,3
85	12,5	5,9
100	16,0	6,7
^a It corresponds to a continuous current (and not a maximum) for which the properties of the flexible are not altered. NOTE Standard dimensions in inches system are given in Table A.5.		

Other configuration may be used when the application parameters are specific, for instance for traction motors, windmill generators or earthing. This includes flat braided flexibles.

In cases of exceptional current overload or restricted ventilation, the brush manufacturer should be advised so that the flexible size can be adjusted accordingly.

7.1.3 Length of flexible

The length of flexibles l_s shall be measured as shown in Figure 9 and should be chosen among values specified in Table 14, which also specifies tolerances.

Table 14 – Standard lengths of flexibles l_s and tolerances

Dimensions in mm

Nominal value ^a of l_s	Tolerances	
	Lower	Upper
16; 20; 25; 32; 40	0	+3
50; 56; 63; 71; 80; 90; 100	0	+5
112; 125; 140; 160; 200; 250	0	+8

^a Values are taken from the Renard Serie (ISO 3 – Ra10).

NOTE Standard dimensions in inches system are given in Table A.6.

7.1.4 Flexible protection

A sleeve may be applied around the flexible to protect the flexible for:

- insulation, when high voltage is expected, to prevent short-circuits,
- mechanical resistance, when high vibration level is suspected on the machine, to prevent wires breaking.

It shall be kept in mind that such flexible protection has a negative effect in case of a high temperature in the brush since materials are generally thermal insulators.

7.2 Terminals

7.2.1 General

For spade, flag, double shoe, tubular, formed spade and pin terminals, the main dimensions indicated on the figures of this Subclause 7.2 are to be adhered to:

- terminal hole diameter (corresponding to the screw): D_T ;
- terminal width: W_T ;
- terminal (total) length: L_T ;
- distance between the screw hole and the base of the terminal (which does not include the part attached to the flexible) along the flexible direction: y_T ;
- distance between the screw hole and the flexible side perpendicular to the flexible direction: x_T ;
- distance between the free extremity of the terminal and the base of the terminal (which does not include the part attached to the flexible): z_T .

NOTE Such terminals are defined in 5.4 of IEC 60276:2018: item 402 for spade, item 401 for flag, 404 for double shoe, 407 for pin.

The details of terminal shapes and other dimensions are left to the manufacturer's discretion.

Dimensions in Table 15 to Table 20 provide the minimum clearance for a box spanner or wrench.

Tolerances on D_T nominal value are between 0 and +0,3 (indication $DT_0^{+0,3}$ on the drawing).

Material thickness may be selected from the values given in Annex F.

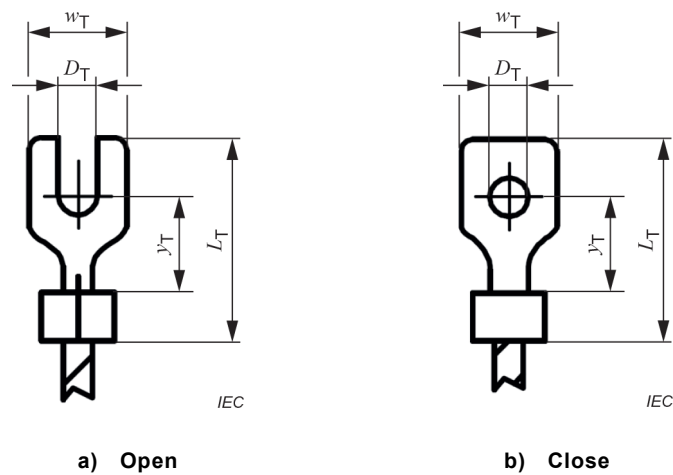
Crimped terminals are covered by 7.2.2 to 7.2.5, whereas some soldered terminals are defined in 7.2.6.

Terminals that do not require the use of a screw, such as quick connect type (for example item 405 of IEC 60276:2018), are allowed providing that their dimensions are agreed between the brush manufacturer and the designer of the machine.

When installing new brushes, it is highly recommended to apply a proper torque in accordance with the specific standards of the screw that is used (diameter and material).

7.2.2 Axial spade terminals

Figure 22 defines the general shape and main dimensions of axial spade terminals.



Key

- D_T terminal hole diameter
- w_T terminal width
- L_T total terminal length
- y_T distance between the screw hole and the base of the terminal (which does not include the part attached to the flexible)

Figure 22 – Definition of shape and dimensions of axial spades terminals

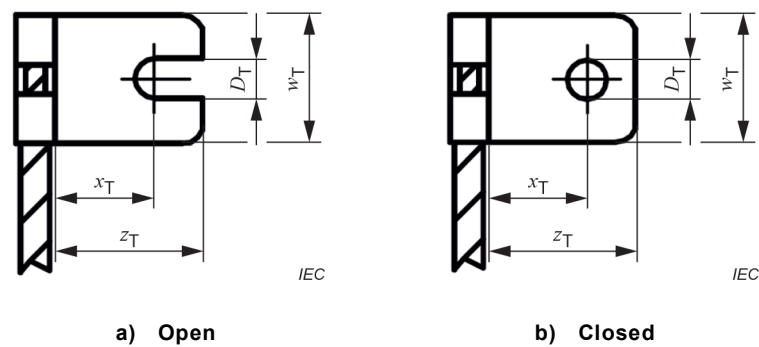
Table 15 gives standard values of spade terminals dimensions according to the screw diameter.

Table 15 – Standard values of spades terminals dimensions

Dimensions in mm				
Nominal screw diameter	Nominal value of D_T	Maximum value of W_T^a	Maximum value of L_T	Minimum value of y_T
2,5	2,8	7	14	
4	4,3	11	18	6
5	5,2	13	20	7
6	6,5	17	28	8,5
8	8,5	21	32	10,5
10	10,5	23	40	13
^a Standard strip widths may be used for width dimension W_T .				

7.2.3 Flag terminals

Figure 23 defines the shape and the main dimensions of flag terminals.



Key

- D_T terminal hole diameter
- w_T terminal width
- x_T distance between the screw hole and the side of the flexible perpendicular to the flexible direction
- z_T distance between the free extremity of the terminal and the base of the terminal

Figure 23 – Definition of shape and dimensions of flag terminals

Table 16 gives standard values of flag terminals dimensions according to the screw diameter.

Table 16 – Standard values of flag terminals dimensions

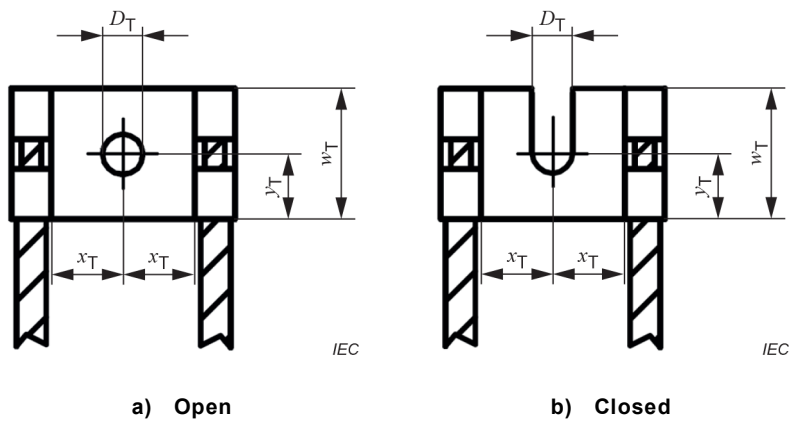
Dimensions in mm

Nominal screw diameter	Nominal value of D_T	Maximum value of W_T ^a	Maximum value of z_T	Minimum value of x_T
2,5	2,8	7	8	
4	4,3	11	12	6
5	5,2	13	13	7
6	6,5	17	16	8,5
8	8,5	21	20	10,5
10	10,5	23	25	13

^a Standard strip widths may be used for width dimension W_T .

7.2.4 Double shoe terminals

Figure 24 defines the shape and the main dimensions of double shoe terminals.



Key

- D_T terminal hole diameter
- w_T terminal width
- y_T distance between the screw hole and the base of the terminal
- x_T distance between the axis of screw hole and the side of flexible perpendicular to the flexible direction

Figure 24 – Definition of shape and dimensions of double shoe terminals

For closed double shoe terminals, the value of y_T is generally equal to the value of W_T divided by 2.

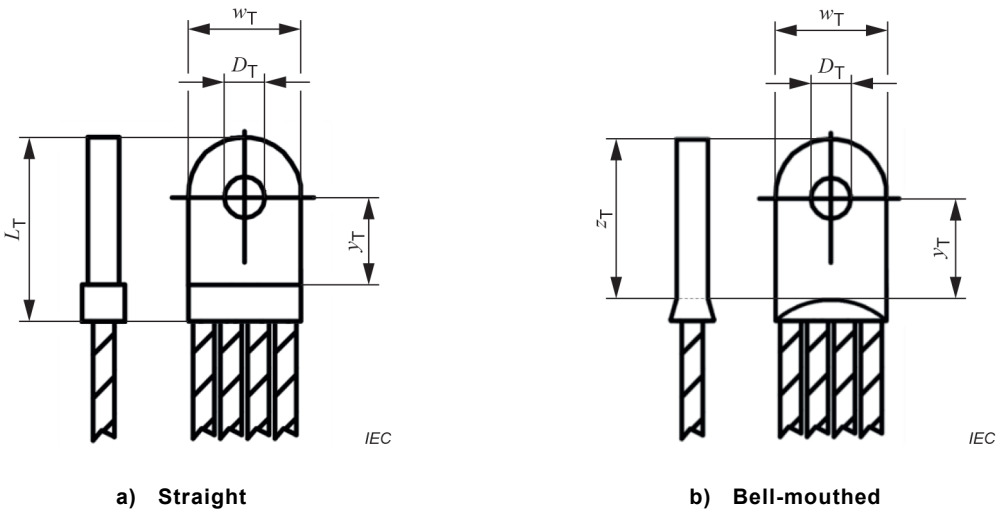
Table 17 gives standard values of double shoe terminals dimensions according to the screw diameter.

Table 17 – Standard values of double shoe terminals dimensions

Dimensions in mm				
Nominal screw diameter	Nominal value of D_T	Maximum value of w_T ^a	Maximum value of y_T ^b	Minimum value of 2 times the value of x_T
4	4,3	11	6	12
5	5,2	13	7	14
6	6,5	17	9	17
8	8,5	21	11	21
10	10,5	23	11	26
^a Standard strip widths may be used for the width dimension w_T .				
^b Applies only in the case of open double shoe terminals.				

7.2.5 Tubular terminals

Figure 25 defines the shape and the main dimensions of tubular terminals (also named box or folded terminals).



Key

- D_T terminal hole diameter
- w_T terminal width
- L_T terminal length
- y_T distance between the screw hole and the base of the terminal (which does not include the part attached to the flexible)
- z_T distance between the free extremity of the terminal and the base of the terminal

NOTE Subfigures a) and b) above are examples of tubular terminals. Other shapes are possible, for example: rectangular extremity (part where the screw hole is located), straight crimping part, open, etc.

Figure 25 – Definition of shape and dimensions of tubular terminals

Table 18 gives standard values of tubular terminals dimensions according to the screw diameter.

Table 18 – Standard values of tubular terminals dimensions

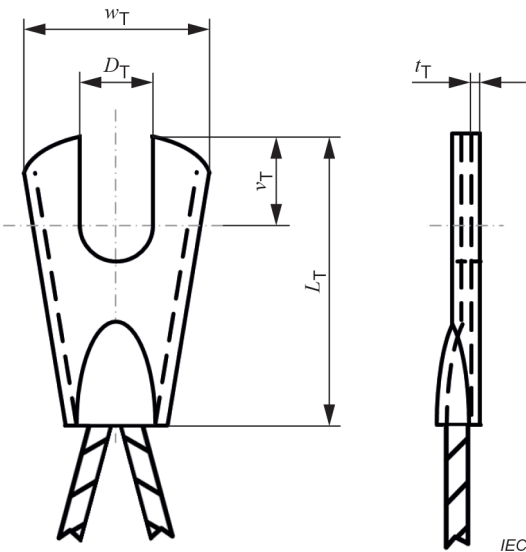
Dimensions in mm				
Nominal screw diameter	Nominal value of D_T	Maximum value of W_T	Maximum value of z_T or L_T	Minimum value of y_T
4	4,3	11	12	6
5	5,2	13	13	7
6	6,5	17	16	8,5
8	8,5	21	20	10,5
10	10,5	23	25	13

If the terminal is required to be bell-mouthed, as illustrated by case b) of Figure 25, it should be extended so that the belled part does not encroach on the portion $W_T \times L_T$ and $W_T \times y_T$, which shall be flat.

7.2.6 Soldered terminals

7.2.6.1 Formed spade terminal

Figure 26 shows one type of formed spade terminal and Table 19 gives its main dimensions.



Key

- D_T terminal hole diameter
- w_T terminal width
- L_T terminal length
- v_T distance between the axis of the screw hole and the free extremity of the terminal
- t_T thickness of the terminal plate

NOTE v_T corresponds to z_T minus y_T (used in Figure 22 to Figure 25).

Figure 26 – Definition of shape (example) and dimensions of formed spade terminal

Table 19 – Standard values of formed spade terminals dimensions and tolerances

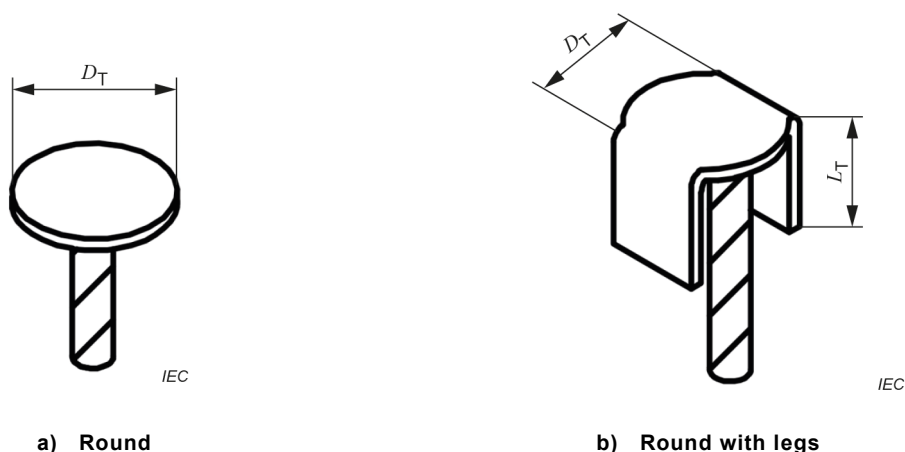
Dimensions in mm

Nominal screw diameter	Nominal value of D_T	Nominal value of L_T	Nominal value of W_T	Nominal value of r_T	Nominal value of t_T
M5	5,5	20	13	6,5	0,45
M6	6,5	24	16	8	0,45
M8	8,5	29	19	9,5	0,45
Tolerances (Lower/Upper)	-0,1 / +0,3	$\pm 1,5$	$\pm 0,8$ except $\pm 1,0$ for M8	-	$\pm 0,05$

NOTE This type of terminal is commonly in use in Japan (JIS C2802).

7.2.6.2 Pin terminal

Figure 27 shows two examples of pin terminals that are used generally for cartridge type brush-holders.



Key

D_T terminal diameter

L_T terminal length

[SOURCE: IEC 60276:2018 – item 407 – dimensions added]

Figure 27 – Definition of shape (examples) and dimensions of two types of pin terminals

The shape and the dimensions shall be agreed between the user and the manufacturer.

7.2.7 Current capacity of terminals

In order to prevent small terminals being used with large section flexibles or vice versa, it is desirable to determine the current capacity for each terminal.

Table 20 defines the current capacity recommended for terminals according to the screw diameter. Higher values may be used by agreement between manufacturer and user.

Table 20 – Minimum values of current capacity for terminals

Nominal screw diameter	Current capacity ^a for spade and flag terminals	Current capacity ^a for double shoe terminals
mm	A	A
2,5	15	-
4	32	64
5	50	100
6	76	120
8	100	150
10	150	240
^a It corresponds to the maximum allowable current at continuous rating.		

The current values given above correspond to the maximum section of one or several flexibles which can be fitted correctly to a given terminal.

The values of current relate to terminals with rolled or crimped shank. The values of current for tubular terminals (7.2.5) and soldered terminals (7.2.6) are not included in this document.

The use of the smallest terminal compatible with the maximum current value required is recommended as far as possible.

8 Test procedures for determining physical properties of brushes

8.1 General

After manufacturing the manufacturer shall control the main dimensions as covered in Clause 5 and the quality of the flexible connection, which is assessed by the control of the electrical resistance and the pull-out force of the brush-flexible connection.

A control report may be issued by the brush manufacturer upon request of the brush user. It shall specify that the measurement was in accordance with this document and any possible deviation from it.

It is up to the brush manufacturer to define the size of the sampling for the production quality control.

NOTE One method to define the number of items to be taken from a production lot according to the number of items of the considered lot is given in ISO 2859-1.

8.2 Measurement of electrical resistance of brush/flexible connection

8.2.1 General

As explained in IEC 60773, electrical losses are linked to the total voltage drop of a brush, which is the sum of different voltages inside the brush from its terminal to the contact surface, in particular the flexible-brush body connection voltage drop U_f . The flexible-brush body connection resistance R_f is therefore important to be checked prior to the brush operation.

The test equipment is defined in 8.2.2.

The method described in 8.2.3 is recommended for quality control check after the brush manufacturing. It gives the relative connection resistance value to be compared with a specification, which is defined to ensure a proper brush operation.

It is up to the brush manufacturer to define the size of the sampling for the production quality control.

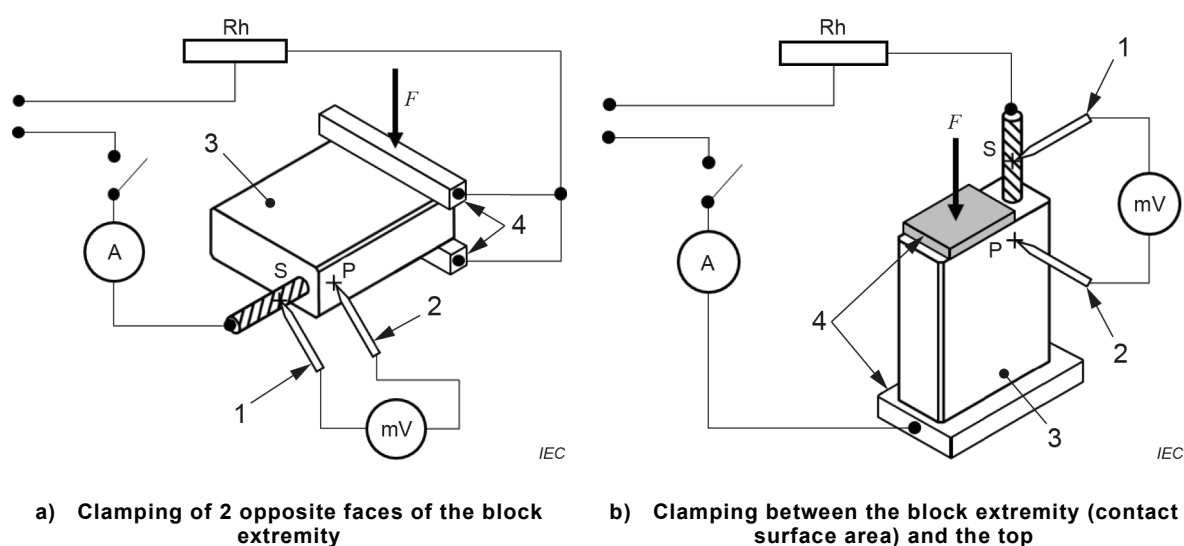
When it is intended to perform calculations of voltage drop afterwards (connection voltage drop U_f and/or total voltage drop U_B), the mathematical method described in 8.2.4 shall be used since it precisely defines the location of the measurement on the brush block.

8.2.2 Test equipment

8.2.2.1 Principle

The method consists in passing a current inside the brush and measuring the voltage (therefore the resistance) between two points P and S located on both sides of the flexible-bush body connection.

The testing device shall conform to 8.2.2.2. Figure 28 illustrates 2 examples of arrangements of electric circuit and brush holding device.



Key

A	ammeter (Ampere meter)
F	clamping force applied by the holding device
mV	millivoltmeter
P	probe location on the brush
S	probe location on the flexible
Rh	Rheostat (current adjusting resistor)
1	probe 1
2	probe 2
3	brush
4	brush block holding device

NOTE In Subfigure b), the part in grey color is made of insulated material.

Figure 28 – Examples of testing device for the measurement of the connection electrical resistance