

# PRE-RELEASE VERSION (FDIS)

---

**Rotating electrical machines – Test methods and apparatus for the measurement of the operational characteristics of brushes**

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

---

ICS 29.160.10

**Warning! Make sure that you obtained this publication from an authorized distributor.**



This is a preview - click here to buy the full publication

2/2045/FDIS

FINAL DRAFT INTERNATIONAL STANDARD (FDIS)

PROJECT NUMBER:

IEC 60773 ED2

DATE OF CIRCULATION:

2021-01-29

CLOSING DATE FOR VOTING:

2021-03-12

SUPERSEDES DOCUMENTS:

2/1967/CDV, 2/2033/RVC

IEC TC 2 : ROTATING MACHINERY	
SECRETARIAT: United Kingdom	SECRETARY: Mr Charles Whitlock
OF INTEREST TO THE FOLLOWING COMMITTEES:	HORIZONTAL STANDARD: <input type="checkbox"/>
FUNCTIONS CONCERNED: <input type="checkbox"/> EMC <input type="checkbox"/> ENVIRONMENT <input type="checkbox"/> QUALITY ASSURANCE <input type="checkbox"/> SAFETY	
<input checked="" type="checkbox"/> SUBMITTED FOR CENELEC PARALLEL VOTING <b>Attention IEC-CENELEC parallel voting</b> The attention of IEC National Committees, members of CENELEC, is drawn to the fact that this Final Draft International Standard (FDIS) is submitted for parallel voting. The CENELEC members are invited to vote through the CENELEC online voting system.	<input type="checkbox"/> NOT SUBMITTED FOR CENELEC PARALLEL VOTING

This document is a draft distributed for approval. It may not be referred to as an International Standard until published as such.

In addition to their evaluation as being acceptable for industrial, technological, commercial and user purposes, Final Draft International Standards may on occasion have to be considered in the light of their potential to become standards to which reference may be made in national regulations.

Recipients of this document are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

TITLE:

**Rotating electrical machines – Test methods and apparatus for the measurement of the operational characteristics of brushes**

PROPOSED STABILITY DATE: 2022

NOTE FROM TC/SC OFFICERS:

Copyright © 2021 International Electrotechnical Commission, IEC. All rights reserved. It is permitted to download this electronic file, to make a copy and to print out the content for the sole purpose of preparing National Committee positions. You may not copy or "mirror" the file or printed version of the document, or any part of it, for any other purpose without permission in writing from IEC.

## CONTENTS

FOREWORD.....	6
1 Scope.....	8
2 Normative references .....	8
3 Terms, definitions, symbols and abbreviated terms.....	8
3.1 Terms and definitions.....	9
3.2 Symbols.....	15
3.2.1 Symbols and units .....	15
3.2.2 Subscripts .....	16
3.3 Abbreviated terms.....	17
4 Test rig specification.....	18
4.1 Common specification.....	18
4.1.1 General .....	18
4.1.2 Rings.....	18
4.1.3 Brushes .....	19
4.1.4 Brush holders .....	19
4.1.5 Power supply.....	21
4.1.6 Instrumentation.....	21
4.2 Test rig specification for commutators.....	31
4.2.1 General .....	31
4.2.2 Test rings .....	31
4.2.3 Brushes arrangement .....	34
4.2.4 Special brush for voltage drop measurement.....	35
4.3 Test rig specification for slip rings.....	36
4.3.1 General .....	36
4.3.2 Ring.....	36
4.3.3 Brushes .....	38
4.3.4 Configuration for DC and AC operation.....	38
5 Test schedule and operating conditions .....	40
5.1 General.....	40
5.2 Environmental conditions .....	41
5.2.1 Laboratory environment.....	41
5.2.2 Ambient air temperature and ring surface temperature.....	41
5.2.3 Ambient humidity .....	41
5.3 Operating conditions .....	41
5.4 Test preparation and inspection .....	42
5.4.1 General .....	42
5.4.2 Test rig.....	42
5.4.3 Brush-holders .....	42
5.4.4 Test brushes.....	42
5.4.5 Ring roughness .....	42
5.4.6 Brush bedding .....	43
5.4.7 Brushes measurement.....	43
5.5 Test sequence .....	43
5.5.1 Test starting .....	43
5.5.2 Test duration .....	43

5.6	Measurements and observations .....	43
5.6.1	General .....	43
5.6.2	Interval between measurements .....	44
5.6.3	Before starting a test sequence .....	44
5.6.4	Measurements during a test sequence .....	45
5.6.5	Measurements after a test sequence .....	45
6	Determination of friction coefficient.....	45
6.1	General.....	45
6.2	Test conditions .....	46
6.3	Measurements .....	46
6.3.1	General .....	46
6.3.2	Test rig arrangement of Method a).....	46
6.3.3	Test rig arrangement of Method b).....	46
6.4	Calculation of friction coefficient .....	46
6.4.1	Test rig arrangement of Method a).....	46
6.4.2	Test rig arrangement of Method b).....	47
6.5	Report.....	47
7	Determination of voltage drop .....	48
7.1	General.....	48
7.2	Test conditions .....	49
7.3	Measurements .....	49
7.3.1	General .....	49
7.3.2	Brush total voltage drop $U_B$ .....	49
7.3.3	Brush contact voltage drop $U_C$ .....	49
7.4	Calculation.....	50
7.4.1	Brush total voltage drop $U_B$ .....	50
7.4.2	Brush contact voltage drop $U_C$ .....	50
7.5	Report.....	51
8	Determination of brush wear .....	52
8.1	General.....	52
8.2	Test conditions .....	52
8.3	Measurements .....	52
8.4	Calculation of brush wear.....	53
8.5	Report.....	54
9	Determination of commutation ability of brush grades by a specific black-band test on a DC machine .....	54
9.1	General.....	54
9.2	Set-up.....	55
9.3	Test procedure.....	58
9.3.1	Preparation of the test .....	58
9.3.2	Operating conditions and test sequence .....	58
9.4	Black-band graph.....	59
9.5	Interpretation .....	60
9.5.1	General .....	60
9.5.2	Influence of commutator skin thickness on the black-band zone .....	61
9.5.3	Influence of brush contact resistance.....	62
9.5.4	Estimation of mechanical contact stability deviation by comparing the black-band figures before and after longtime critical operation.....	64

Annex A (informative) Additional information for friction coefficient measurement .....	67
A.1 Details of calculation of friction coefficient by using method a) of 4.1.6.1.2 .....	67
A.2 Adjustment of strain sensor for calculation of friction coefficient by using method b) of 4.1.6.1.3.....	68
A.2.1 General .....	68
A.2.2 Correlation between output voltage and load .....	68
A.2.3 Correlation between friction coefficient and load .....	68
Annex B (informative) Black-band zone deviation cases .....	71
B.1 Black-band zone in case of limited contact area.....	71
B.2 Influence of brush mechanical contact instability of brush chattering on the black-band zone .....	72
B.3 Black-band zone hysteresis between increased $I_a$ and decreased $I_a$ .....	73
Annex C (informative) Test report example .....	75
Bibliography.....	77
Figure 1 – Profile and determination of height of profile elements .....	9
Figure 2 – Forces acting on a brush.....	12
Figure 3 – Voltage drops in a brush when in operation.....	12
Figure 4 – Brush holder configuration .....	20
Figure 5 – Measurement of the mechanical torque by Method a).....	22
Figure 6 – Brush test machine for Method b).....	23
Figure 7 – Test rig arrangement with a load cell.....	24
Figure 8 – Brush contact probe application point for $U_c$ .....	27
Figure 9 – Thermocouples insertion position.....	28
Figure 10 – Evaluation of contact temperature $\theta_c$ by interpolation.....	29
Figure 11 – Illustration of bar grooves dimensions and preparation.....	32
Figure 12 – Brush covering.....	34
Figure 13 – Brushes configuration .....	35
Figure 14 – Control brush arrangement.....	36
Figure 15 – Characteristics of grooves.....	37
Figure 16 – Test rig arrangement for DC operation with 2 brushes per polarity .....	39
Figure 17 – Test rig arrangement for AC operation with 2 brushes .....	40
Figure 18 – Example of friction coefficient $\mu$ graph as a function of peripheral speed $v_p$ .....	48
Figure 19 – Example of brush total voltage drop $U_B$ graph as a function of current density $J_B$ .....	52
Figure 20 – Example of brush wear rate $WR_i$ of brushes during the test for a test rig with 4 brushes .....	53
Figure 21 – Black-band test circuit configuration using DC generator and resistance load ...	56
Figure 22 – Black-band test circuit configuration for Brondell's loading-back method .....	57
Figure 23 – Determination of black-band zone for a specified constant speed of rotation .....	60
Figure 24 – Influence of commutator film thickness on the black-band zone.....	62
Figure 25 – Comparison of black-bands for a high contact resistance brush and a low contact resistance brush in case of a motor .....	63

Figure 26 – Comparison of black-bands for a high contact resistance brush and a low contact resistance brush in case of a generator .....	64
Figure 27 – Black-band figure deviation of before and after the critical operation of repetitive peak load application of 225 %, for a "strong" grade .....	65
Figure 28 – Black-band figure deviation of before and after the critical operation of repetitive peak load application of 225 %, for a "week" grade .....	66
Figure A.1 – Correlation of load cell output voltage $U_{IC}$ with mass $m$ .....	68
Figure A.2 – Example of correlation between load and friction coefficient $\mu$ .....	69
Figure B.1 – Limited contact area and reduction of tangential dimension at contact .....	71
Figure B.2 – Black-band zone in case of a limited contact area.....	72
Figure B.3 – Influence of brush mechanical contact instability of brush chattering on the black-band zone.....	73
Figure B.4 – Black-band zone hysteresis between increasing $I_{arm}$ and decreasing $I_{arm}$ .....	74
Table 1 – Dimensions of test brushes .....	19
Table 2 – Test conditions .....	42

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

# ROTATING ELECTRICAL MACHINES – TEST METHODS AND APPARATUS FOR THE MEASUREMENT OF THE OPERATIONAL CHARACTERISTICS OF BRUSHES

## 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.

International standard IEC 60773 has been prepared by IEC technical committee 2: Rotating machinery.

This second edition cancels and replaces the first edition published in 1983. It constitutes a technical revision.

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

- The clause structure has been modified on the view point of a laboratory testing procedure. The new sequence is as follows: test rig specification (Clause 4), general testing procedure (Clause 5), and specific procedure for each operational characteristic (Clauses 6 to 8).
- A new Clause 9 has been added to introduce the black-band test for the characterisation of the brush grades for DC machines.

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

FDIS	Report on voting
2/XX/FDIS	2/XX/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://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.



# ROTATING ELECTRICAL MACHINES – TEST METHODS AND APPARATUS FOR THE MEASUREMENT OF THE OPERATIONAL CHARACTERISTICS OF BRUSHES

## 1 Scope

This document applies to test methods for the measurement of the operational characteristics of brushes designed to operate on commutating and slip ring machines under specified test conditions.

By extension some tests may be relevant for other kinds of sliding electrical contacts for electrical appliances.

## 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 60034-19:2014, *Rotating electrical machines – Part 19: Specific test methods for d.c. machines on conventional and rectifier-fed supplies*

IEC 60136, *Dimensions of brushes and brush-holders for electrical machinery*

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

IEC 60356, *Dimensions for commutators and slip-rings*

IEC 60584-1:2013, *Thermocouples – Part 1: EMF specifications and tolerances*

IEC 60751:2008, *Industrial platinum resistance thermometers and platinum temperature sensors*

IEC TR 61015, *Brush-holders for electrical machines. Guide to the measurement of the static thrust applied to brushes*

ISO 1190-1:1982, *Copper and copper alloys – code of designation – Part 1: Designation of materials*

ISO 3274:1996, *Geometrical Product Specifications (GPS) – Surface texture: Profile method – Nominal characteristics of contact (stylus) instruments*

ISO 15510:2014, *Stainless steels – Chemical composition*