



SLOVENSKI STANDARD
oSIST prEN IEC 61788-27:2024
01-februar-2024

Merjenje naklona praktičnih superprevodnih žic - Metoda merjenja naklona kompozitnih superprevodnikov NbTi in Nb₃Sn

Twist pitch measurement of practical superconducting wires - Twist pitch measurement method of NbTi and Nb₃Sn composite superconductors

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ICS:

17.220.20	Merjenje električnih in magnetnih veličin	Measurement of electrical and magnetic quantities
29.050	Superprevodnost in prevodni materiali	Superconductivity and conducting materials

oSIST prEN IEC 61788-27:2024

en



90/507/CDV

COMMITTEE DRAFT FOR VOTE (CDV)

PROJECT NUMBER:

IEC 61788-27 ED1

DATE OF CIRCULATION:

2023-10-20

CLOSING DATE FOR VOTING:

2024-01-12

SUPERSEDES DOCUMENTS:

90/498/CD, 90/502/CC

IEC TC 90 : SUPERCONDUCTIVITY	
SECRETARIAT: Japan	SECRETARY: Mr Jun Fujikami
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TITLE:

Twist pitch measurement of practical superconducting wires - Twist pitch measurement method of NbTi and Nb₃Sn composite superconductors

PROPOSED STABILITY DATE: 2031

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83 INTERNATIONAL ELECTROTECHNICAL COMMISSION

84 **SUPERCONDUCTIVITY–**85 **Part 27: Twist pitch measurement of practical superconducting wires—**
86 **Twist pitch measurement of Nb-Ti/Cu and Nb-Sn/Cu composite**
87 **superconductors**88 **FOREWORD**

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121 Superconductivity.

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

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

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

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

126 The committee has decided that the contents of this document will remain unchanged until the
127 stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to
128 the specific document. At this date, the document will be

- 129 • reconfirmed,
130 • withdrawn,
131 • replaced by a revised edition, or
132 • amended.

133 The National Committees are requested to note that for this document the stability date
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135 THIS TEXT IS INCLUDED FOR THE INFORMATION OF THE NATIONAL COMMITTEES AND WILL BE DELETED
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INTRODUCTION

138 Twisting of multi-filamentary superconductors is an important step in the development of wires
139 with AC losses at an acceptable level for AC applications. The necessary twist pitch depends
140 on wire architecture, critical current density, matrix material, and external factors such as
141 temperature, frequency and applied magnetic field.

142 Therefore, twist pitch is a very important parameter in the design and application of composite
143 superconducting wires, which often needs to be inspected in the last stage of fabrication. Due
144 to the different architectures of different composite superconductors, appropriate test methods
145 should be adopted for specific architectures.

146 This standard specifies the untwisting method for measuring the twist pitch of Nb-Ti/Cu and Nb-
147 Sn/Cu composite superconductors [1]. As supplementary methods, the direct measurement
148 method and the image processing method [1] are specified in Annex A and Annex B,
149 respectively.

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SUPERCONDUCTIVITY –

Part 27: Twist pitch measurement of practical superconducting wires – Twist pitch measurement method of Nb-Ti/Cu and Nb-Sn/Cu composite superconductors

1 Scope

This International Standard specifies a test method for the twist pitch measurement of Nb-Ti and Nb-Sn/Cu composite superconductors by an untwisting method.

The test method is applicable to Nb-Ti/Cu and Nb-Sn/Cu composite superconducting wires with monolithic structures, which have either a round cross section with a diameter ranging from 0,2 mm to 2 mm or a rectangular cross section that is equivalent in area to the round cross-sectional wires. These wires possess a filament diameter ranging from 6 μm to 200 μm , a twist pitch between 5 mm to 50 mm, and a matrix of copper or copper alloy. This standard uses nitric acid to remove the matrix (copper or copper alloy), so the surface of the composite superconducting wire is allowed to be plated with a material that is dissolvable by nitric acid.

Though uncertainty may increase, the method could apply to Nb-Ti/Cu or Nb-Sn/Cu composite superconducting wires when the parameters of cross-sectional area, filament diameter and/or twist pitch are out of the limit.

The test method described in this standard is expected to apply to other types of composite superconducting wires after some appropriate modifications.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their contents constitute 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 60050-815, *International Electrotechnical Vocabulary (IEV) – Part 815: Superconductivity*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

3.1

twist

turns made by a filament around a central wire axis

[SOURCE: IEC 60050-815, 815-13-46 Modified]

3.2

twist direction

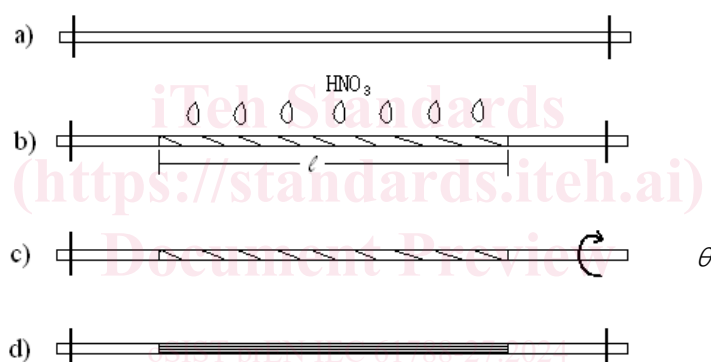
direction of a filament in twist, which can be divided into two types: Z-twist (sometimes referred to as right-hand twist) and S-twist (sometimes referred to as left-hand twist)

NOTE It is called Z-twist when the filament or strand is twisted in a clockwise direction, otherwise it is called S-twist.

3.3

192 **twist pitch**193 L_p 194 axial length in which a filament firstly returns to its original relative position in a twisted
195 superconducting wire

196 [SOURCE: IEC 60050-815, 815-13-47 Modified]

197 **3.4**198 **twist angle/untwist angle**199 θ 200 angle at which all filaments of a twisted superconducting wire return to parallel original axial
201 positions during the untwisting process202 **4 Principle**203 Low temperature superconducting wire is usually composed of tens to even thousands of
204 superconducting filaments embedded in copper and/or copper alloy matrix. After the
205 superconducting wire is twisted, the inner filaments are also regularly twisted with a specific
206 twist pitch. This standard specifies an untwisting method to measure the twist pitch (see Figure
207 1).

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Figure 1—Principle demonstration

209 The untwisting method can be briefly described as follows:

210 a) Fix the two ends of the specimen (Figure 1a).

211 b) Remove the copper or copper alloy matrix in the middle section of the specimen with HNO₃
212 solution (Figure 1b).213 c) Measure the length of the dissolved zone (denoted as l , explanation see 8.4).214 d) Rotate one end of the wire to untwist it until the filaments in the dissolved zone are parallel
215 (Figure 1c and d). Record the rotated angle (denoted as θ).216 e) Calculate the twist pitch L_p using l and θ (see Eq. (1) and (2)).217 The other two normative methods, the direct measurement method and the image processing
218 method, are specified in Annex A and Annex B, which are recommended as equivalent
219 alternatives.220 **5 Reagents and auxiliary materials**

221 The following reagents shall be prepared for specimen preparation:

222 — detergent and/or degreaser

- 223 — anhydrous ethanol
- 224 — nitric acid solution (40% to 65%, mass percentage concentration, recommend)
- 225 NOTE Rubber gloves and acid resistant tweezers should be used when handling acid solution.

226 The following auxiliary materials and tools shall be prepared for specimen preparation:

- 227 — 300 to 800 mesh fine sandpaper (apply to Nb-Sn/Cu specimens only)

228 **6 Apparatus and tools**

229 The apparatus and tools required for measurement shall include:

- 230 — an auxiliary tool for twist pitch measurement, which has an angle scale with accuracy 5°
- 231 or better (an example in Annex C)
- 232 — fume hood
- 233 — slide gauge (accuracy 0,02 mm or better)
- 234 — oven or dryer

235 **7 Specimen preparation**

236 **7.1 Requirements**

237 It is recommended to use the untwisting method for twist pitches in the range of 5 mm to 50 mm
238 to ensure adequate accuracy for the measurement. The specimen length shall be longer than
239 6 times of the nominal twist pitch.

240 The specimen shall be free from torsion and bend.

241 **7.2 Cleaning**

242 Detergent and/or degreaser shall be used to remove oil stains and other contamination from
243 the specimen. Then, the specimen shall be rinsed repeatedly with running water, and finally
244 dehydrated by anhydrous ethanol.

245 **7.3 Drying**

246 After cleaning, the specimen shall be dried completely in an appropriate manner. For example,
247 dried with hot air or placed into an oven (60 °C to 70 °C).

248 **7.4 Removing matrix copper and sanding barrier (apply to Nb-Sn/Cu specimen of external stabilizer type only)**

250 Some Nb-Sn/Cu wires have a Nb or Ta external diffusion barrier that is diffusional nitric acid.
251 When the external copper stabilizer is dissolved, this barrier prevents the inner copper from
252 being corroded by nitric acid, therefore needs to be removed. The following steps are
253 recommended when removing the barrier: These steps are not applied to distributed barrier
254 wires.

- 255 a) Removing matrix copper: Immerse the Nb-Sn/Cu specimen in nitric acid solution, and leave
256 the container in a fume hood for about 15 minutes until the copper sheath of the specimen
257 is completely dissolved. Take the specimen out by acid resistant tweezers, rinse it with
258 running water, and then dehydrate it with anhydrous ethanol, and dry it.

259 NOTE For safety, wearing long sleeves, trousers, and rubber gloves to prevent nitric acid from splashing on the skin.

- 260 b) Inspecting barrier surface for barrier seam: If the barrier has a seam, inspect the surface
261 of the barrier which will follow the filament position underneath. If a seam is clearly visible,
262 the specimen needs no further preparation.

- 263 c) Sanding barrier: Take a fine sandpaper, evenly sand the measuring section until the
264 internal copper red is completely exposed.

265 NOTE Use fume hood during sanding.