SLOVENSKI STANDARD
SIST-TP CEN/TR 17856:2022

01-september-2022

Merjenje premaznih lastnosti neorientirane elektropločevine

Measurement of the coating properties of non-oriented electrical steel

Bestimmung der Beschichtungseigenschaften bei nicht kornorientiertem Elektroband und -blech

Mesures des propriétés de vernis d’aciers électriques à grains non orientés

Ta slovenski standard je istoveten z: CEN/TR 17856:2022

ICS:

77.140.40	Jekla s posebnimi magnetnimi lastnostmi	Steels with special magnetic properties
77.140.50	Ploščati jekleni izdelki in polizdelki	Flat steel products and semi-products

SIST-TP CEN/TR 17856:2022 en,fr,de

TECHNICAL REPORT

RAPPORT TECHNIQUE

TECHNISCHER REPORT

CEN/TR 17856

July 2022

ICS 77.140.40; 77.140.50

English Version

Measurement of the coating properties of non-oriented electrical steel

Mesures des propriétés de vernis d'aciers électriques à grains non orientés

Bestimmung der Beschichtungseigenschaften bei nicht kornorientiertem Elektroband und -blech

This Technical Report was approved by CEN on 10 July 2022. It has been drawn up by the Technical Committee CEN/TC 459/SC 8.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

Ref. No. CEN/TR 17856:2022 E

Contents

Page

European foreword

This document (CEN/TR 17856:2022) has been prepared by Technical Committee CEN/TC 459 “ECISS - European Committee for Iron and Steel Standardization”[1], the secretariat of which is held by AFNOR.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

Any feedback and questions on this document should be directed to the users’ national standards body. A complete listing of these bodies can be found on the CEN website.

1 Through its sub-committee CEN/TC 459/SC 8 “Steel sheet and strip for electrical applications” (secretariat: DIN).

Introduction

EN 10342 describes the electrical steel coating types. The electrical steels ordered according to standards EN 10106, EN 10265, EN 10303, EN 10341 are supplied either with or without such a coating.

The measurements necessary to qualify these coatings are based on different standards, which are not necessarily dedicated to electrical steel coatings. The lack of a clear description of which evaluation methods to use, with which calibration methods, sample preparation, etc. brings inconsistency in obtained measurement results. The purpose of this technical report is to overcome the problem of differences in coating qualification results, by combining the aspects of Non-Oriented Electrical Steel coating testing in a clear guideline.

In particular, the non-oriented fully processed electrical steels in high efficiency applications, such as electric traction, benefit from the clarifications that this technical report brings to the specific coating challenges, of such high power density machines.

1 Scope

This document describes the qualification methods, relevant for the non-oriented electrical steel coatings described in EN 10342. In particular, it describes the testing methods, sample preparation, calibration methods, that are necessary to obtain reliable results that can be considered a reference for quality evaluation.

This document applies only to the coatings of non-oriented electrical steels.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological 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

4 Curing

A properly cured coating cannot be wiped off and its testing is therefore a resistance against solvents such as ethanol or methyl ethyl ketone, in a wipe test. Other methods use spectrometry. The wipe test, also called solvent rub test, as described in ASTM D5402-19:2019 Method A (Standard Method) or EN 13523-11 represents common practice. The ASTM reference uses a manual rubbing, whereas the EN reference uses a mechanical rubbing system. The outcome of the test can be interpreted as following:

— some discolouration and polishing effect is allowed, localized at the rubbed area;

— the coating is considered properly cured when it is not removed down to the substrate, when it does not smear out, when it does not become soft, when it does not become tacky.

5 Weldability

The welding performance of a coating depends on its coating type, coating thickness, the substrate and welding process. TIG weldability is a well-established process. The use of laser welding has become further established for electrical steels, due to its advantages such as limited Heat Affected Zone.

The SEP 1210 was established for welding testing of the TIG process. It eliminates the steel substrate effect by testing the coatings using a low Si grade in 0,50 mm gauge. The use of a standardized sample geometry, a standardized welding test process, allows considering the welding speed and current as a measure for the coating's TIG weldability.

For laser welding such standardized test has not been identified yet.

6 Surface insulation

The surface insulation measurement occurs according to EN 60404-11. This document is written within the series of EN 60404 and reflects well all aspects to be taken into account for electrical steel coatings. It refers to measurements at room temperature, which are generally communicated.

It can be relevant to verify the insulation level of the coating at the operating temperature of the electrical machine, in which the insulated steel lamination will be used. ASTM A717-12 allows for heating the sample using a hot plate, during the Franklin measurement described in EN 60404-11. Clearly such specific measurement remains within the purpose of an approval procedure and is not performed for certification purposes.

7 Thermal endurance

The thermal endurance measurement occurs according to IEC 60404-12. This document is written within the series of EN 60404 and reflects well all aspects to be taken into account for electrical steel coatings. The application cases to be considered are:

— continuous temperature resistance;

— stress relief annealing;

— refurbishing;

— Al- or Cu- die casting.

The aspects of the coating relevant as thermal endurance measurement are:

— adhesion;

— surface insulation resistance;

— compressibility.

8 Corrosion resistance

Corrosion testing needs to be identified for the relevant application conditions of the non-oriented electrical steel application. The medium / temperature / time profile of the test is set accordingly. The application cases to be considered are:

air, at elevated temperatures, according to IEC 60404-12;

— humidity;

— refrigerants;

— transformer oil.

IEC 60404-12 uses the flexibility test and the surface insulation resistance measurement, after the corrosion treatment, to evaluate the coating.

9 Friction coefficient

The friction coefficient of coated non-oriented electrical steels preferably is not too low, because a too slippery surface presents a risk in electrical steel coil stability, but it also preferably is not too high, because a too high friction surface does not allow for sufficiently fluent movement of the electrical steel through the punching presses. Hence the friction coefficient is a relevant property.

The testing reference standards used are either the ASTM D202 (or TAPPI T815) for inclined plane testing or the ASTM D1894:2014 for horizontal testing (method of assembly e in Figure 1). Neither of these standards are written for coated steel sheets but rather for sheets of paper (ASTM D202) or plastic (ASTM D1894). They propose testing the surface of the sample against a reference surface of a selected reference testing block with a selected weight and surface state. The reference block can be replaced by a second sample of the material to be tested, hence having bilateral contact of the tested coated electrical steel surfaces. The ASTM D202 detects the onset of movement by increasing the inclination of the plane; the ASTM D1894 by increasing the motor pulling force. Hence the criterion evaluated thus rather is the static friction coefficient (although the motor pulling force can also be used as measure for the kinetic coefficients). The testing methodologies identified allow for comparative testing in the process of coating approval procedures, based on in-house experience. Both the inclined plane and horizontal testing method yield for the different types of coatings for fully-processed non-oriented electrical steels, a coherent evaluation method. They can both identify which coatings are of a lower or higher friction nature. They are not suited for individual production coil assessment due to the lack of established industry reference criteria and standards. Its testing remains within the purpose of an approval procedure and is not performed for certification purposes.

10 Compressibility

The compressibility of non-oriented electrical steel coatings is a test necessary to evaluate the in-life behaviour of a non-oriented electrical steel stack. It combines a stacking factor measurement as described in EN IEC 60404-13, at a specific time/temperature exploitation condition, as described in IEC 60404-12.

11 Adhesion

The cross-cut test according to EN ISO 2409 is suitable for testing adhesion of steel coatings. However, this cross cut test is hardly discriminating in non-oriented electrical steel coatings and therefore gives no relevant results.

The outcome of the bending test, is depending on the flexibility of the coating, its adhesion to the electrical steel substrate, the type of electrical steel substrate and the bending radius of the cylindrical mandrel. The flexibility test is described in Clause 13.

Given there is no practice of an adhesion testing method that brings relevant grading of non-oriented electrical steel coatings, it is common practice to refer to the flexibility testing, to identify adhesion performance. For certification purposes of coating adhesion, the flexibility testing of Clause 13 is commonly used, using a cylindrical mandrel radius of 5 mm. (It is clear that in such case the substrate impact can affect the outcome of the test, hence the testing results according to Clause 11 and Clause 13 are not necessarily identical.)

Adhesion of the coatings can also be evaluated by a falling-weight test, in an evaluation of rapid-deformation or impact resistance, which can be considered as more representative of material behaviour during the punching process. The reference standard EN ISO 6272-1 describes as a classification method, the height of the weight being dropped, at which cracks or detachment of the coating occur. The evaluation is visual and it can be done directly on the sample, or else, as in the cross cut test (EN ISO 2409:2020, Annex A) by evaluating visually a standardized tape, that has been applied to the coated surface. The tape test then is performed on the back side of the sample, on the convex shape of the dent.

12 Hardness

The hardness of electrical steel coatings can be determined by pencil hardness according to EN 13523-4 or Persoz pendulum hardness. The common practice to perform first qualification of non-oriented electrical steel coatings is to use pencil hardness testing. The hardness of the coating is defined by its nature and is therefore fixed when the cured state is achieved. Therefore, it is not necessary to test the hardness for serial production certification.

13 Flexibility

The coating flexibility is determined according to EN ISO 1519. In coating first qualification procedures, the substrate needs to be fixed, in order to eliminate its effect on the outcome of the test. It is common practice to use a low alloyed 0,50 mm non-oriented electrical steel substrate for such purpose. In such approval testing, the radius of the cylindrical mandrel can be decreased after each test positive test result, in order to identify the flexibility limit. The flexibility of the coating is defined by its nature and is therefore fixed when the cured state is achieved. Therefore, it is not necessary to test the flexibility for serial production certification.

14 Thickness

The coating thickness is measured either with an inductive measurement system according to EN ISO 2178 or else with a beta backscattering technique according to EN ISO 3543. Depending on calibration systems and measurement procedures, results can vary strongly, for non-oriented electrical steel coatings.

For both the inductive as the beta backscattering measurement method, the calibration influences the average measurement outcome of the thickness, and hence the accuracy. Identifying specific calibration foils, does not bring an improvement to the accuracy. The preferred calibration system is one that fits the documentation of the equipment and is best suited for the specific coating to be measured.

The choice to use either the inductive or the beta backscatter method can be guided by the targeted coating thickness as well as the required accuracy. Whilst both measurements have a different precision, they also present a different measurement effort. Typically, an inductive measurement yields a more localized result, whereas a beta backscatter measurement yields a result averaged over a larger area. Therefore, factors such as surface roughness have a larger influence on single inductive results, compared to single beta backscattered results. Both the application and the available equipment can guide the measurement type choice.

For measurements made with the magnetic inductive method, only standard deviations on averaged measurements, made on the same spot, and not the min-max limits on individual measurements can be evaluated. For such equipment, a relevant measurement result is achieved by taking the average of at least five measurements, a standard deviation lower than 1 µm can be achieved, for non-oriented electrical steel coatings with an average thickness range between 0,5 µm and 4 µm.

For measurements made with the beta backscattering method, using a carbon-14 source (carbon isotope 14) is common practice. For such equipment, a relevant measurement result is achieved by taking the average of five measurements, each using a measurement duration of 20 s, leading to a standard deviation of 0,1 µm, for non-oriented electrical steel coatings with an average thickness range between 0,5 µm and 4 µm. It can be verified that the source is in good condition, by checking that the standard deviation reduces, when increasing the measurement time from 5 s to 20 s, still for five measurement repeats. Prolonging the measurement time from 20 s to 30 s does not reduce the standard deviation substantially.

It remains a point of attention that most EC-6 type coatings cannot be measured with the beta backscattering technique.