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Dense shaped refractory products - Part 11: Determination of resistance to thermal shock

Prüfverfahen für dichte geformte feuerfeste Erzeugnisse - Teil 11: Bestimmung der Temperaturwechselbeständigkeit

Méthodes d'essai des produits réfractaires façonnés denses - Partie 11: Détermination de la résistance au choc thermique

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Dense shaped refractory products — Part 11: Determination of resistance to thermal shock

Prüfverfahen für dichte geformte feuerfeste Erzeugnisse – Teil 11: Bestimmung der Temperaturwechselbeständigkeit

This Technical Specification (CEN/TS) was approved by CEN on 23 January 2003 for provisional application.

The period of validity of this CEN/TS is limited initially to three years. After two years the members of CEN will be requested to submit their comments, particularly on the question whether the CEN/TS can be converted into a European Standard.

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Foreword

This document CEN/TS 993-11:2003 has been prepared by Technical Committee CEN /TC 187, "Refractory products and materials", the secretariat of which is held by BSI.

This document supersedes ENV 993-11:1997.

Reproducibility and repeatability data are not available at present but will perhaps be included in a subsequent edition.

EN 993 'Methods of test for dense shaped refractory products' consists of 20 Parts:

Part 1 : Determination of bulk density, apparent porosity and true porosity

Part 2 : Determination of true density

Part 3 : Test methods for carbon-containing refractories

Part 4 : Determination of permeability to gases

Part 5 : Determination of cold crushing strength

Part 6 : Determination of modulus of rupture at ambient temperature

Part 7 : Determination of modulus of rupture at elevated temperatures

Part 8 : Determination of refractoriness-under-load

Part 9 : Determination of creep in compression

Part 10 : Determination of permanent change in dimensions on heating

Part 11 : Determination of resistance to thermal shock

Part 12 : Determination of pyrometric cone equivalent (refractoriness)

Part 13 : Specification for pyrometric reference cones for laboratory use

Part 14 : Determination of thermal conductivity by the hot-wire (cross-array) method

Part 15 : Determination of thermal conductivity by the hot-wire (parallel) method

Part 16 : Determination of resistance to sulphuric acid

Part 17 : Determination of bulk density of granular materials by the mercury method with vacuum

Part 18 : Determination of bulk density of granular materials by the water method with vacuum

Part 19 : Determination of thermal expansion

Part 20 : Determination of resistance to abrasion at ambient temperature

Introduction

Thermal shock of refractory materials placed in furnaces is influenced by three items:

— brick dimensions;

— heating/cooling conditions;

— material properties

Thermal shock tests usually intend to test material properties. This is done by standardizing brick dimensions and heating conditions. In this way, a relative order of the quality of different types of bricks can be established. However, in case of thermal shock, this can lead to complications in the field of engineering.

The major complication is that, depending on the type of heating conditions, various material properties are involved. This can be best illustrated on the basis of thermal stress parameters which are a measure for critical crack initiation.

Table 1 — Type of heating condition

Hot face condition	Stress parameter	Example
sudden temperature jump	ε/α	filling of metallurgical vessels
constant heat flow into brick	$\lambda .\varepsilon /\alpha$	Furnace preheating
constant heating rate	$\lambda /(\rho . c_p) .\varepsilon /\alpha$	Controlled preheating

Where:

ε maximum allowable deformation

α coefficient of expansion

λ thermal conductivity

ρ bulk density

c_p specific heat

1 Scope

This Technical Specification specifies two alternative methods for determining the resistance to thermal shock of dense shaped refractory materials by the air quenching method which proved to give the most reliable results as compared with the behaviour of the refractories placed in furnace linings. Method B can be applied to unshaped refractory materials too.

2 Normative references

This Technical Specification incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this Technical Specification only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 993-6 *Methods of test for dense shaped refractory products – Part 6: Determination of modulus of rupture at ambient temperature.*

3 Terms and definitions

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

3.1
thermal-shock resistance
resistance of refractory bricks to damage caused by sudden temperature changes between 950°C and room temperature due to air blowing

3.2
measure of thermal-shock resistance
for method A the number of quenchings withstood under the conditions of this test and for method B the residual cold MOR and residual sonic velocity of standard test pieces after 5 quenchings under the condition of this test

4 Principle

4.1 Method A

The test piece is homogeneously heated to 950 °C in an electric furnace, then removed, placed on a steel plate and exposed to air blowing. After quenching, the test piece is subjected to a stress of 0,3 MPa in a bending machine. This cycle is repeated until failure of the test piece.

The resistance to thermal shock is defined by the number of cycles withstood by the test piece before breaking.

4.2 Method B

The test pieces are homogeneously heated to 950 °C in an electric furnace, then removed, placed on a steel plate and exposed to air blowing. After quenching, this cycle is repeated 4 times. After cooling down the residual cold MOR and the residual sonic velocity has to be determined.

The resistance to thermal shock is defined by the percentage of residual MOR and residual sonic velocity related to the MOR and sonic velocity of non quenched test pieces.

NOTE Sonic resonance frequency can be measured too but the results might be different.

For both methods A and B other quenching temperatures may be agreed upon by the parties concerned and shall be noted in the test report.

5 Apparatus

— electrically heated furnace, capable of maintaining a temperature 950°C ± 25 °C

— thermocouple for use for temperatures in excess of 1000 °C

— drying oven

— heating cabinet for preheating at 250 °C to 300 °C

— blowing device with a 8 mm diameter nozzle of 5 mm length

— equipment for measuring the cold MOR according to EN 993-6

— steel plate of 400 mm x 250 mm x 20 mm with pins to determine the location of the test piece under the blast; according to the dimensions of the test-piece, the pins will be located in such a manner that the air jet blows at the intersection of the diagonals of the test-piece on cooling

— equipment for measuring the sonic velocity

NOTE Equipment for measuring the sonic velocity in refractories is commercially available and should be used in accordance with the manufacturers' instructions.

6 Test pieces

6.1 Number of test pieces

6.1.1 Method A

Unless a different number of test pieces has been agreed upon, one test piece shall be taken from each item.

6.1.2 Method B

Unless a different number of test pieces has been agreed upon, four test pieces have to be used. Two test pieces have to be taken for the determination of the cold MOR before testing (=MOR $_{non\ quenched}$). The other two test pieces have to be taken for the thermal shock test. Determine from each the sonic velocity axially in length of the test pieces before testing (=SV $_{non\ quenched}$).

6.2 Preparation of test pieces

6.2.1 Shape

For method A the test pieces shall have the dimensions of a quarter-standard brick, i.e. 114 mm x 64 mm x 64 mm and for method B of a half-standard brick, i.e. 230 mm x 64 mm x 54 mm. They shall be sawn or ground from bricks.

NOTE The use of other shapes can be agreed by the parties, but the results will not be directly comparable with those obtained using the test-pieces stated above.

The test pieces shall be prepared with great care so that the brick texture is not damaged. The location in the bricks from which the test pieces are to be taken shall be agreed upon.

6.2.2 Drying of the test pieces

Dry the test pieces at 110 °C ± 5 °C to constant mass. Constant mass is obtained when the change in mass after two successive periods of one hour drying, is not more than 0,1 %. Protect test pieces from moisture before testing.

7 Procedure

7.1 Heating

7.1.1 Place the test pieces on one of their long faces, i.e. for method B on a 230 mm x 64 mm face, into a heating cabinet previously heated to 250 °C to 300 °C and keep them at this temperature for, at least, four hours.

7.1.2 Put the test pieces into the furnace at 950 °C ± 25 °C. The temperature of the furnace is measured with a thermocouple positioned over the centre of the basal area of the furnace approximately 20 mm above the test pieces. Immediately after the door of the furnace has been closed, the temperature should not be less than 750 °C.

7.1.3 The heat capacity of the furnace shall be sufficient for the temperature to rise again to 950 °C within 15 to 30 min after placing the first test piece into the furnace. After the temperature has risen to 950 °C, the test pieces stay in the furnace for a further 45 min.

7.2 Cooling

Remove a test piece as quick as possible from the furnace using insulated iron tongs and place its long face on the steel plate, taking care that the nozzle of the air-blowing device and the centre of the upper face are aligned, with the help of the locating pins. The distance between the nozzle and the test piece shall be 100 mm. Blow compressed air on the test piece for five minutes, the pressure immediately before the nozzle shall be constant and equal to 0,1 MPa ± 0,01 MPa. Be sure that the compressed air is at room temperature and does not contain moisture likely to concentrate in droplets. Always expose the same face of the test piece to the blast.

NOTE If conditions remain in accordance with 7.1 and 7.2, more than one test-piece can be simultaneously or successively tested.

Should it be necessary to interrupt the test, the test pieces shall be maintained in the heating cabinet at 250 °C to 300 °C after the last quenching. When testing is resumed, the test pieces shall be placed immediately in the furnace at 950 °C ± 25 °C.

7.3 Measurement

7.3.1 Method A

7.3.1.1 After quenching, the test piece is submitted to a bending strength of 0,3 MPa ± 0,05 MPa gradually and without shock.

7.3.1.2 The distance between supports shall be 100 mm. The thrust column and the supports shall have a radius of 5 mm.

NOTE If the test piece breaks, the test is completed.

7.3.1.3 If the test piece withstands the bending stress, place it again into the furnace at 950 °C and start the same cycle. Continue the test until the test piece breaks in the bending test or breaks up into two or more pieces under the cooling blast. The test shall be ended when the test piece has withstood thirty quenchings.

7.3.2 Method B

After 5 quenchings, the following measurements and determinations have to be applied :

7.3.2.1 After cooling down to ambient temperature the sonic velocity has to be measured again (=$SV_{quenched}$)

NOTE It can be interesting to study the behaviour of the sonic velocity in function of cycles. In this case the test pieces are cooled down to ambient temperatures after each cycle before the measurements.

7.3.2.2 The determination of the cold MOR has to be made so that the blown face is now the bottom face during the test (=$MOR_{quenched}$)