

Non-destructive testing of steel forgings

Part 1: Magnetic particle inspection
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ICS 77.040.20; 77.140.85

Zerstörungsfreie Prüfung von Schmiedestücken aus Stahl – Teil 1: Magnetpulverprüfung

European Standard EN 10228-1 : 1999 has the status of a DIN Standard.*A comma is used as the decimal marker.***National foreword**

This standard has been prepared by Technical Committee ECISS/TC 28.

The responsible German body involved in its preparation was the *Normenausschuß Eisen und Stahl* (Steel and Iron Standards Committee), Technical Committee *Schmiedestücke*.

EN comprises 8 pages.

ICS 77.040.20; 77.140.85

English version

Non-destructive testing of steel forgings

Part 1: Magnetic particle inspection

Essais non destructifs des pièces
forgées en acier – Partie 1: Contrôle
par magnétoscopie

Zerstörungsfreie Prüfung von
Schmiedestücken aus Stahl – Teil 1:
Magnetpulverprüfung

This European Standard was approved by CEN on 1999-03-01.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

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CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

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Foreword

This European Standard has been prepared by Technical Committee ECISS/TC 28 Steel forgings, the Secretariat of which is held by BSI.

The titles of the other parts of this European Standard are:

Part 2 Penetrant testing

Part 3 Ultrasonic testing of ferritic or martensitic steel forgings

Part 4 Ultrasonic testing of austenitic and austenitic-ferritic stainless steel forgings

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association. It is considered to be a supporting standard to those application and product standards which in themselves support an essential safety requirement of a New Approach Directive and which make reference to this European Standard.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, and conflicting national standards withdrawn, by September 1999 at the latest.

In accordance with the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard:

Austria, Belgium, the Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom.

All dimensions are in mm.

1 Scope

This Part of EN 10228 describes a method and acceptance criteria to be used for the magnetic particle inspection of forgings manufactured from ferromagnetic materials. The method described is used for the detection of surface discontinuities. It can also detect discontinuities just below the surface, but sensitivity to such discontinuities diminishes rapidly with depth.

2 Normative references

This European Standard 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 European Standard only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies.

EN 473	Qualification and certification of NDT personnel – General principles
prEN ISO 9934-1	Non destructive testing – Magnetic particle testing – Part 1: General principle (ISO/DIS 9934-1 : 1996)
prEN ISO 9934-2	Non destructive testing – Magnetic particle testing – Part 2: Characterization of products (ISO/WD 9934-2)
prEN ISO 9934-3	Non destructive testing – Magnetic particle testing – Part 3: Equipment (ISO/DIS 9934-3 : 1998)

3 Items for agreement

The following aspects concerning magnetic particle inspection shall be agreed between the purchaser and the supplier at the time of ordering:

- a) the manufacturing stage at which magnetic particle inspection is to be performed (see clause 7);
- b) the surface areas to be examined (see clause 8);
- c) the quality class required, or the quality classes and the surface areas to which they apply (see clauses 8, 9 and 14);
- d) whether the inspection is to be performed with non-fluorescent ink or fluorescent ink or powder (see 6.2);
- e) whether a particular current waveform is required (see 10.2);
- f) the applicable recording and acceptance criteria where different from those detailed in table 2;
- g) whether demagnetization is to be carried out after the inspection, together with the maximum level of residual magnetism (see clause 16);
- h) whether the inspection is to be conducted in the presence of the purchaser or his representative;
- i) whether the written procedure is to be submitted for approval by the purchaser (see clause 4).

4 Written procedure

4.1 General

Magnetic particle inspection shall be performed in accordance with a written procedure. Where specified in the enquiry or order, the written procedure shall be submitted to the purchaser for approval prior to the examination.

4.2 Description

The written procedure shall be one of the following:

- a) a product specification;
- b) a procedure written specifically for the application;
- c) this Part of EN 10228 may be used if it is accompanied by examination details specific to the application.

4.3 Content

The procedure shall contain the following details as a minimum:

- a) description of the forgings to be inspected;
- b) reference documents;
- c) qualification and certification of inspection personnel;
- d) stage of manufacture at which the inspection is carried out;
- e) surface areas specified in terms of the applicable quality classes;
- f) magnetizing technique(s);
- g) description of inspection equipment;
- h) calibration and checking of equipment;
- i) waveform and flux density and/or tangential field strength required for each technique used;
- j) detection media, and any contrast paint used;
- k) surface condition;
- l) viewing conditions;
- m) method of marking or recording indications;
- n) whether demagnetization is required; if so, the method to be used and required maximum level of residual magnetism;
- o) acceptance criteria;
- p) examination report.

5 Personnel qualification

Personnel shall be qualified and have been certified in accordance with EN 473.

6 Testing system

6.1 Magnetizing equipment

If the contact current flow magnetization method with prods is used on a finished machine surface, then the prod contact points shall be checked after magnetization for damage, using an alternative magnetization technique, penetrant testing or visual examination.

All equipment shall be calibrated and checked in accordance with prEN ISO 9934-3.

One or more of the following types of magnetizing equipment shall be used:

- a) alternating current electromagnetic yokes (see annex A);
- b) current flow equipment, with prods (see annex A);
- c) permanent magnets;
- d) magnetic flow equipment with flexible cable or coil;
- e) central conductor;
- f) magnetic induction;
- g) equipment enabling multiple magnetizing techniques, either coincidentally or in sequence.

6.2 Detection media

Detection media shall conform to the requirements detailed in prEN ISO 9934-2.

6.3 Functional checks

A functional check shall be carried out prior to the inspection to ensure the proper functioning of the inspection system. The check shall be performed as detailed in prEN ISO 9934-1.

NOTE: The temperature of the forging should be checked to ensure that it is within the detection media manufacturer's specified temperature limits.

7 Stage of manufacture

Where practicable, final acceptance inspection shall be performed on the forging in its as delivered condition (see clause 3).

8 Surface condition

8.1 General

Surfaces to be examined shall be clean and free from scale, oil, grease, machining marks, thick paint coats and any other foreign matter that could adversely affect detection sensitivity or the interpretation of indications. Cleaning and preparation of the surfaces shall not be detrimental to the material, the surface finish or the detection media.

8.2 Surface condition related to quality class

The finish of surfaces to be examined shall conform to the requirements detailed in table 1 for the applicable quality class.

Table 1: Surface condition

Surface roughness parameter $R_a^*)$, in μm	Quality classes ¹⁾			
	1	2	3	4
Above 6,3 up to 12,5	x	x	-	-
Up to 6,3	x	x	x ²⁾	x ³⁾
¹⁾ x signifies the quality class that can be achieved for the specified surface finish. ²⁾ Quality class not applicable to the examination of surfaces with a machining allowance greater than 3 mm per face. ³⁾ Quality class not applicable to the examination of surfaces with a machining allowance greater than 1 mm per face. ^{*)} R_a = arithmetical mean deviation of the profile.				

8.3 As-forged surface condition

It is difficult to carry out a comprehensive examination on a forged surface. The surface to be inspected shall be prepared by shot-blasting, sandblasting or surface grinding so that defects can be clearly distinguished from indications resulting from surface irregularities.

For general applications, quality classes 1 and 2 shall be applicable. For closed die forgings, quality class 3 shall be the maximum requirement.

9 Coverage

Practical inspection shall be performed so that a 100 % coverage of the surface under examination is achieved. Viewing the area under examination shall be completed before proceeding to the next area or the next stage of magnetization.

10 Magnetization

10.1 Direction of magnetization

Magnetization shall be performed in accordance with the requirements detailed in prEN ISO 9934-1.

The surface shall be examined in at least two approximately perpendicular directions to detect defects lying in any orientation.

NOTE 1: Where the probable nature and orientation of flaws in a forging can be forecast with confidence as, for example, in certain long forged parts, and where specified in the enquiry or order, magnetization may be performed in a single direction.

NOTE 2: Where magnetization is performed by locally applying the current flow method or using the magnetic flow method with a portable electromagnetic yoke, it is recommended that the surface under examination should be marked in a grid to ensure a 100 % coverage. The recommended size of the grid and magnetizing directions are detailed in annex A.

10.2 Current waveform

It shall be the supplier's responsibility to decide which waveform to use unless a specific current waveform (e.g. alternating current or half-wave rectified alternating current) has been agreed between the purchaser and supplier.

NOTE: Reference should be made to prEN ISO 9934-1 for guidance.

10.3 Flux density and field strength

The tangential flux density shall be at least 1,0 T. The adequacy of the flux density or field strength shall be verified on the surface under examination, in each magnetizing direction, prior to or during the examination, using one or more of the methods detailed in prEN ISO 9934-3.

A flux density of 1,0 T is generally achieved with a tangential field strength from 2 kA/m to 6 kA/m, depending upon the magnetic permeability of the material being inspected.

11 Use of detection media

The continuous method of application shall be used. The ink or powder shall be applied immediately prior to or during magnetization. Magnetization shall be continued for at least two seconds after the application has ceased to allow indications to build up and for the ink, if applicable, to drain.

Ink shall be thoroughly mixed prior to application.

NOTE 1: Large forgings may be examined in sections to ensure adequate ink application.

NOTE 2: Pre-wetting of the forging facilitates distribution of the ink.

12 Viewing conditions

Viewing conditions shall be as follows.

a) Non-fluorescent detection media

The surface under examination shall be viewed under white light of at least 500 lx intensity on the surface. Glare and reflections shall be avoided.

NOTE: Lower levels of intensity may be agreed between purchaser and supplier.

b) Fluorescent detection media

The surface under examination shall be viewed under UV-A (black light) of at least 100 W/m² intensity on the surface.

The background white light intensity shall not exceed 20 lx.

Prior to the examination, at least 5 min shall be allowed for the inspector's eye to become adapted to the reduced background lighting.

UV-A lamps shall be allowed to warm up for at least 5 min.

13 Classification of indications

The following rules shall apply (see figure 1):

a) An indication shall be considered 'isolated' when it is not aligned with any other indication, or when it is aligned with another indication but separated from it by more than five times the length of the longer of the two indications considered.

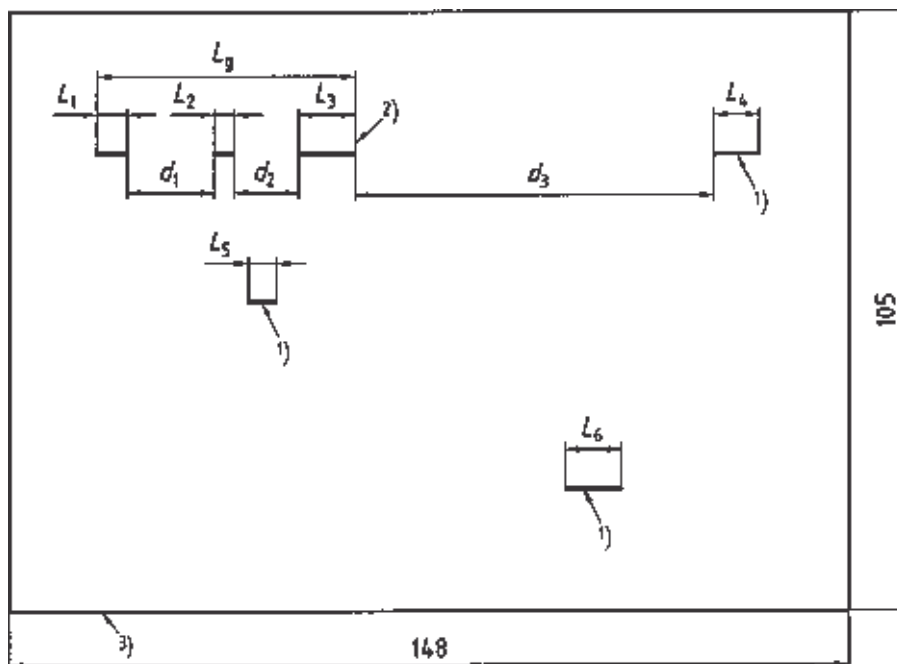
b) Interacting indications are two (or more) indications which are aligned, and shall be considered as one continuous length for the purpose of assessment if their spacing is less than five times the length of the longer of the two indications considered. The length of interacting indications is the length measured between the opposite ends of the two outer indications.

c) The cumulative length is the sum of the lengths of all indications detected in the reference surface (i.e. 148 mm × 105 mm, or = A6 size).

NOTE: Discontinuity indications in forgings are normally linear. This European Standard, therefore, considers only linear indications, i.e. those the lengths of which are at least three times the width.

d) The inspector shall carry out any necessary testing and observations to eliminate false indications.

NOTE: False indications may occur during inspection due to spurious effects such as magnetic writing, changes in section or boundaries between materials of different magnetic properties.



1) Interacting indications

2) Isolated indications

3) Reference surface

Explanations:

a) Reference surface = 148 mm × 105 mm (i.e. A6 size).

b) $d_1 < 5L_1$; $d_2 < 5L_2$; $d_3 < 5L_3$.

c) L_1 , L_2 and L_3 = individual lengths of interacting indications.

d) Total interacting length, $L_g = (L_1 + d_1) + (L_2 + d_2) + L_3$.

e) L_4 , L_5 and L_6 = lengths of isolated indications.

f) $L_g + L_4 + L_5 + L_6$ = cumulative length of indications in reference surface.

g) The total number of indications in the reference surface is 4 (as identified by L_g , L_4 , L_5 and L_6); see table 2.

Figure 1: Classification of linear indications

14 Recording and acceptance criteria

Forgings or parts of forgings shall be classified into four quality classes, class 4 being the most stringent one, dictating the smallest recording level and the smallest acceptance standard. For general-purpose forgings supplied in the as-forged surface condition only, quality classes 1 and 2 are applicable. For closed die forgings, quality class 3 shall be the minimum requirement.

The relevant quality class(es) shall be agreed between the purchaser and supplier prior to inspection. Table 2 details recording levels and acceptance criteria that are to be applied for the quality classes.

NOTE: Where agreed, recording levels and acceptance criteria different from those detailed in table 2 may be used.

Table 2: Quality classes, recording levels and acceptance criteria

Parameter	Quality class			
	1	2	3 ¹⁾	4 ²⁾
Recording level: Minimum indication length (mm)	5	2	2	1
Maximum allowable length of isolated indications, L , and maximum allowable length of interacting indications, L_g (mm)	20	8	4	2
Maximum allowable cumulative length of indications in the reference surface (mm)	75	36	24	5
Maximum allowable number of indications in the reference surface	15	10	7	5
1) Quality class not applicable to the examination of areas with a machining allowance greater than 3 mm per face.				
2) Quality class not applicable to the examination of areas with a machining allowance greater than 1 mm per face.				

15 Removal of defects

Indications which do not meet the relevant acceptance criteria shall be considered defects. Removal of a defect shall be followed by a further magnetic particle inspection. Provided that the forging dimensions remain within the tolerances specified, defects shall be eliminated by grinding and machining. Elimination of defects by grinding shall be carried out in the direction perpendicular to the defect and in such a manner as to blend the resulting hollow with the remaining surface.

16 Demagnetization

Where agreed between the purchaser and the supplier, demagnetization shall be carried out after the inspection by decreasing the current or magnetic flux in accordance with the requirements set out in prEN ISO 9934-1. Unless otherwise agreed, the relevant level of residual field strength shall not exceed 800 A/m.

17 Test report

Magnetic particle inspection shall be the subject of a written report, which is to include the following (as a minimum):

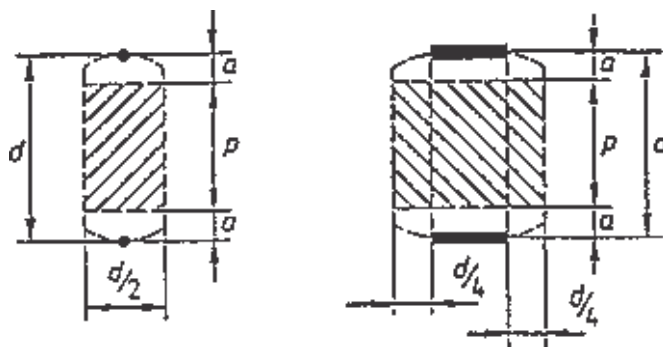
- a) name of supplier;
- b) order number;
- c) identification of forging(s) under examination;
- d) scope of inspection: surface areas and applicable quality classes;
- e) stage of manufacture at which magnetic particle inspection was performed;
- f) surface condition;
- g) equipment used;
- h) magnetization technique(s) used;
- i) waveform and flux density and/or tangential field strength for each technique used;
- j) detection media and contrast paint used;
- k) viewing conditions;

- l) reference to this Part of EN 10228 or to the written procedure used (where applicable);
- m) results of inspection:
 - 1. location;
 - 2. classification;
 - 3. orientation and size of all indications exceeding the appropriate recording level;
 - 4. number of recorded indications on reference surface;
 - 5. description of unacceptable indications;
- n) level of residual magnetism (where required);
- o) details of any restrictions to the required coverage;
- p) date of examination;
- q) name, qualification and signature of tester.

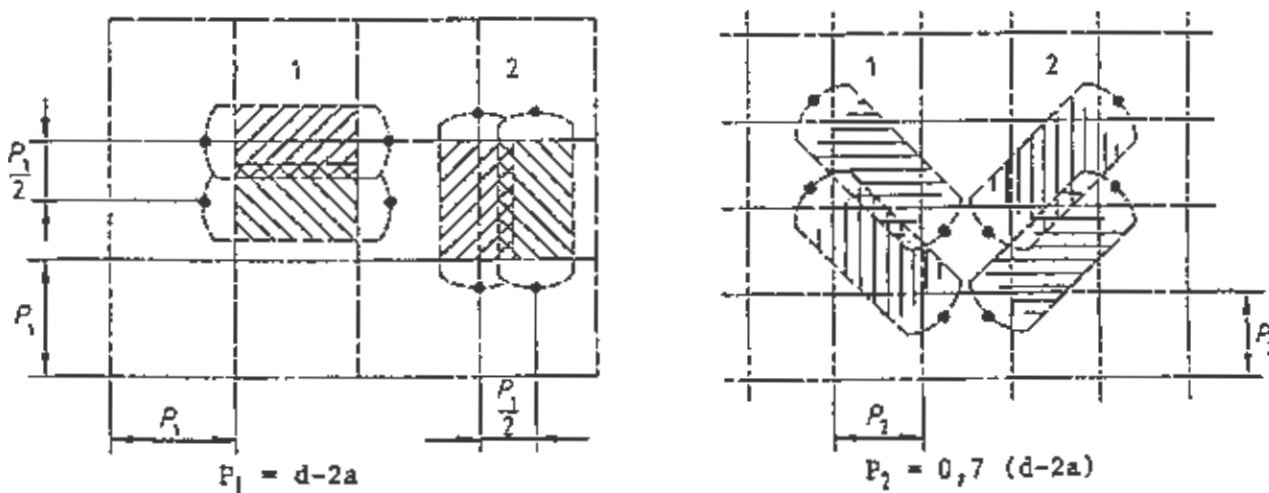
Annex A (normative)

Magnetization using prods or electromagnetic yoke

A.1 Definition of inspected area with prods or yoke



A.2 Definition of search pattern and examination sequence



●	prods	■	poles
d = prod spacing or pole spacing			
p, p_1, p_2 = grid dimensions			
$75 < d < 250$ mm			
1 and 2: Magnetization directions			
$a = 25$ mm			