

Non-destructive testing of steel forgings-

Part 1: Magnetic particle inspection (BS EN 10228-1:1999)

1 Scope

This part of EN 10228 describes the 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 part of EN 10228 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 part of EN 10228 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 enquiry and order:

- a) the manufacturing stages(s) at which magnetic particle inspection is to be performed (see clause 8);
- b) the surface areas to be examined (see clause 9);
- c) the quality class required, or the quality classes and the surface areas to which they apply (see clauses 9, 10 and 15);
- d) whether the inspection shall be performed with non-fluorescent inks or fluorescent inks or powders (see 7.2);
- e) whether a particular current waveform is required (see 11.2);
- f) the applicable recording and acceptance criteria if 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 17);
- h) whether the inspection is to be conducted in the presence of the purchaser or his representative;
- i) whether the written procedure shall be submitted for approval by the purchaser (see clause 5).

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

This 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 requirement:

- 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 contrast paint if 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 certificated in accordance with EN 473.

6 Testing system

6.1 Magnetizing equipment

If the contact current flow (prods) magnetization method is used on a finished machined 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 Function checks

A function 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 delivery condition (see clause 4).

8 Surface condition

8.1 General

Surfaces to be examined shall be clean and free from scale, oil, grease, machining marks, heavy paint and any other foreign matter that could adversely affect inspection 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 finish	Quality classes ¹⁾
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	1	2	3	4
$6,3 \text{ mm} < R_a \leq 12,5 \text{ mm}$	X	X		
$R_a \leq 6,3 \text{ mm}$	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, sand-blasting 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 minimum requirement.

9 Coverage

Where practical, inspection shall be performed such that 100 % coverage of the surface under examination is achieved.

Viewing of 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 100 % coverage. The recommended size of the grid and magnetizing directions are detailed in annex A.

10.2 Current waveform

The supplier shall 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 and/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, dependent upon the magnetic permeability of the material being inspected.

11 Application of detection media

The continuous method of application shall be used.

The ink or powder shall be applied immediately prior to and 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.

The 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 accelerates 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 the purchaser and supplier.

b) Fluorescent detection media The surface under examination shall be viewed under UV-A (black light) of at least 10 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 eyes 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 separation 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 3 105 mm, or = A6 format).

NOTE Discontinuity indications in forgings are normally linear. This European Standard, therefore, considers only linear indications, i.e. those the length 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.

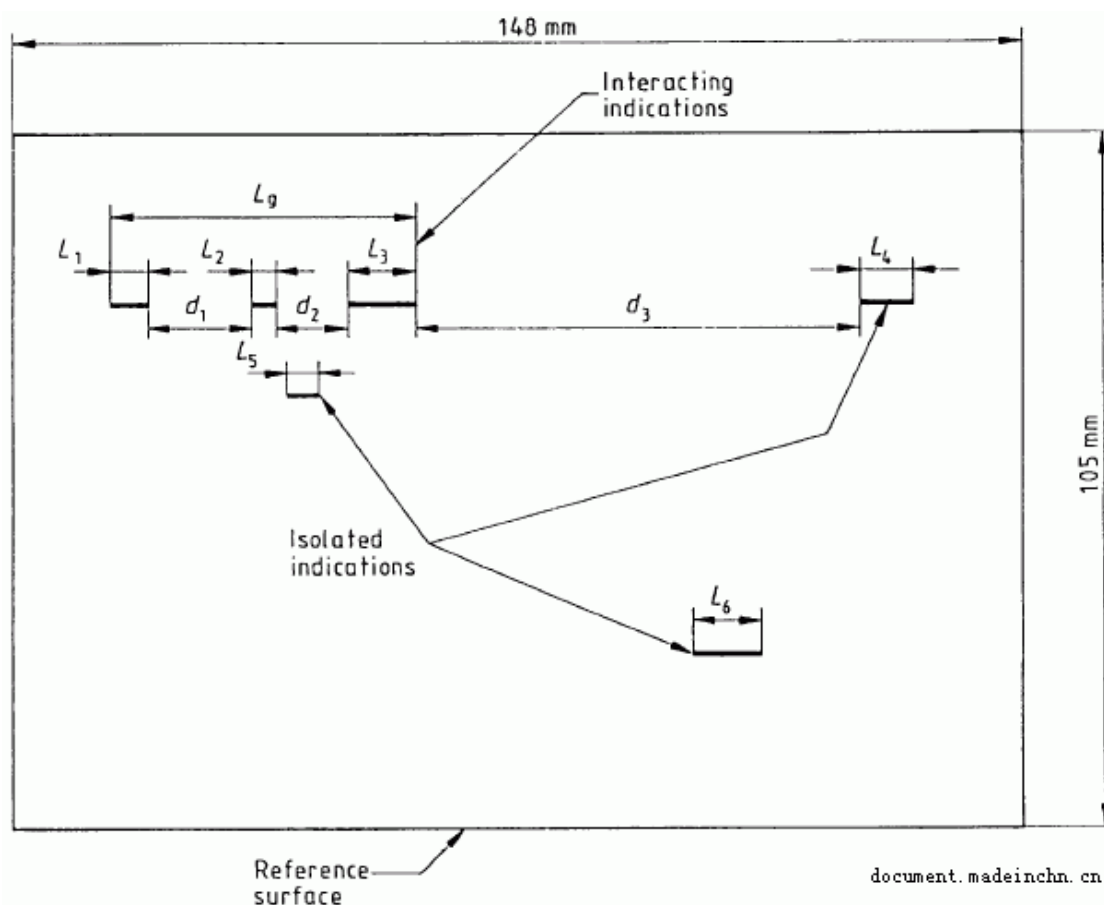
14 Recording and acceptance criteria

Four quality classes shall be applied to a forging or to parts of a forging. Quality class 4 is the most stringent, dictating the smallest recording level and the smallest acceptance standard. For forgings for general application 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 applicable quality class(es) shall be agreed between the purchaser and supplier prior to the inspection. Table 2 details recording levels and acceptance criteria that shall be applied for four quality classes.

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

Figure 1 - Classification of linear indications



Explanations

- a) Reference surface = 148 mm \times 105 mm (i.e. A6 format).
- b) $d1 < 5L1$; $d2 < 5L3$; $d3 > 5L3$.
- c) $L1$, $L2$ and $L3$ = individual lengths of interacting indications.
- d) Total interacting length $L_g = (L1 + d1) + (L2+d2) + L3$.
- e) $L4$, $L5$ and $L6$ = lengths of isolated indications.
- f) $L_g + L4 + L5 + L6$ = cumulative length of indications in reference surface.
- g) The total number of indications in the reference surface is 4 (as identified by L_g , $L4$, $L5$ and $L6$), see Table 2.

Table 2 - Quality classes, recording levels and acceptance criteria				
Parameter	Quality class			
	1	2	3 1)	4 2)
Recording level: indication length (mm)	≥ 5	≥ 2	≥ 2	≥ 1
Maximum allowable length L of isolated indications and maximum allowable length L_g of interacting indications (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 applicable acceptance criteria shall be considered as defects.

Removal of a defect shall be followed by further magnetic particle inspection. Provided that the forging dimensions remain in tolerance, defects shall be eliminated by grinding and machining. Elimination of a defect 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 rest of the surface.

16 Demagnetization

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

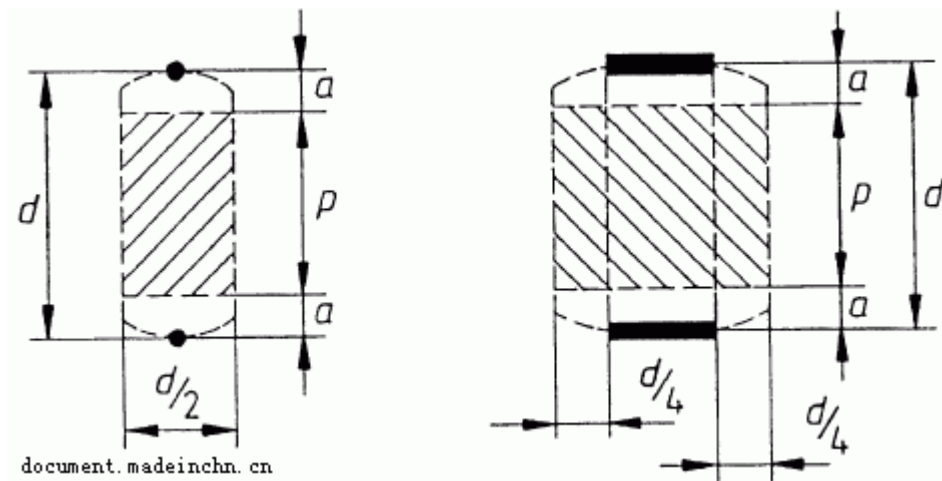
17 Reporting

All magnetic particle inspection shall be the subject of a written report which shall include the following as a minimum requirement:

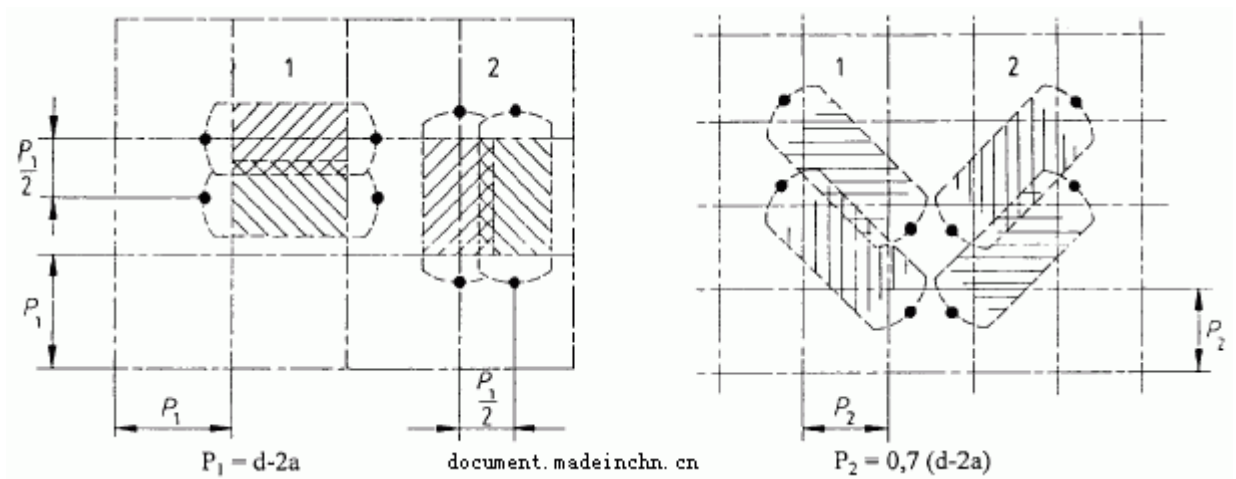
- a) name of supplier;
- b) order number;
- c) identification of forging(s) under examination;
- d) scope of inspection: surface areas and applicable quality classes;
- e) stage of manufacture at which magnetic particle inspection was performed;
- f) surface condition;
- g) equipment used;
- h) magnetizing 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 in 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 operator.

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 size

$75 < d < 250$ mm

1 and 2: Magnetization directions

$a = 25$ mm