

+49 201 8252861

STAHLEISEN Test Sheets of the Verein
Deutscher Eisenhüttenleute

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Ultrasonic testing of forgings and forged steel bars > 100 mm (approx.) diameter or edge length	STAHLEISEN TEST SHEET 1921 First Edition
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1. Purpose and nature of test sheet

This test sheet describes the ultrasonic testing of forgings and steel bars (hereinafter referred to as forging) for general use, preferentially with reference to the detection of internal defects, employing the pulse-echo technique. The ultrasonic test furnishes information on points of reflection as regards their location, size, extent and frequency of occurrence. For forgings requiring acceptance testing this test sheet serves as a directive for defining the scope of testing (see Paragraph 6.2) and the acceptance levels (see Paragraph 6.5 and 6.6). It describes the testing techniques and conditions mandatory for the testing system, the nature of the workpiece and the classification of the test results.

2. Scope

The test sheet applies to the testing of suitably prepared, raw and machined, non-heat treated and heat treated forgings, preferentially made from non-alloy and alloy steels (see Paragraph 6.1).

SSP*0000 applies to forgings subject to more severe requirements.

If the test is performed on forgings from non-transformable steels, the testability can be impaired by sound attenuation and other causes. In cases such as these the attainable recording limits and acceptance levels shall be quoted to facilitate assessment of the testability. If the testability criterion is not met, any subsequent actions require an agreement with the customer or the customer's representative to be reached.

3. Classification

Depending on the scope of testing the test on the forgings shall be subdivided into four test groups (cf. Paragraph 6.2) and depending

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on the permissible height and length of the indication into five size classes (cf. Paragraphs 6.4 and 6.5, Table 1). Similarly, the permissible frequency of the indications is divided into five frequency classes (cf. Paragraph 6.4.3).

4. Preparation of forgings requiring testing

Forgings tested as blanks shall be presented in simple or axially symmetrical form (see DIN 64 126 , Part 1, Paragraph 6). The rippling and roughness of test surfaces and other surfaces used for reflection purposes shall permit an adequate probe-to-forging coupling.

A smooth surface freed from loose scale may be sufficient for testing, provided satisfactory coupling is guaranteed. If the surface has to be machined, an average roughness $R_a \leq 20 \mu\text{m}$ (according to DIN 4762) serves as reference value for machining.

In the case of non-heat treated steel it shall be noted that the sound attenuation of the workpieces sanctions a test as long as the agreed acceptance level (or recording limit) is reached. As far as a "transformable" steel is concerned, the forging can be heat treated to reduce sound attenuation.

The surface finish and the metallurgical structure necessary to achieve the defect detectability demanded in the test as well as the machining and heat treatment condition, if specified, shall be adapted to one another and ensure detection of the size class of the indication quoted in the order (Table 1).

5. Testing system

5.1 Testing equipment

The ultrasonic testing apparatus shall function in accordance with the pulse-echo principle and permit measurement of relative echo-heights within ± 2 dB using a gain controller calibrated in decibels (dB). The amplifier shall not have any amplifier threshold and no saturation within the utilized sensitivity range of the instrument¹⁾.

- 1) For further particulars regarding the requirements laid down for the testing system consult DIN 54 126 - General ultrasonic testing regulations, Part 1: Testing system - Requirements; Part 2: Testing procedures.

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The time base range required for testing shall be adjustable on the instrument. Deviations from linearity of up to 2% of the time base range setting are acceptable.

5.2 Ultrasonic probes

The nominal frequency of the probe shall be adapted to the size of the disc-shaped reflector, the length of the sound path and the sound attenuation of the test object. Testing is generally performed with 1 MHz to 4 MHz; other frequencies may be used provided the acceptance levels laid down in Paragraph 6.5 remain detectable.

Normal (compression wave) probes are generally used. Other probe-types such as transmitter-receiver (TR)-probes or angle probes may additionally be employed e.g. for detecting near-surface reflectors, for the better resolution of indications from relatively inaccessible parts of forgings, as well as for hollow bodies or unusual defect positions. This holds especially for test groups 3 and 4 (see Paragraph 6.2).

One Distance-Gain-Size (DGS in English, AVG in German)-diagram shall be known for each probe-type to assist in the evaluation of indications in mm circular disc reflector size (KSR, in German).

5.3 Control of testing system

This control is based on DIN 54 126 Part I. Reference Block 1 in accordance with DIN 54 120²⁾ shall be available for instrument calibration as well as for the control of the instrument function and the probe.

Reference Block 2 in accordance with DIN 54 122³⁾ or other suitable comparison blocks with reference reflectors may also be used.

- 2) DIN 54 120 - Reference block 1 and its use for the calibration and control of ultrasonic pulse-echo equipment.
- 3) DIN 54 122 - Reference block 2 and its use for the calibration and control of ultrasonic pulse-echo equipment.

5.4 Coupling agents

The coupling agents shall satisfactorily wet the surface of the test object. Water (preferentially with higher viscosity-promoting additives), oils and pastes are suitable. The same coupling agent shall be employed for calibrating the test system and for the subsequent testing tasks. When finish-machined forgings are tested, the coupling agents shall not create any corrosion hazard. After testing the tested surface shall be cleaned or dried.

6. Testing procedure

6.1 Time of test

Preliminary tests shall be carried out at the earliest to enable a decision on the testability and serviceability of the forging to be reached. Acceptance tests are generally performed on the test object in its simplest form, however after the heat treatment which is critical for the properties of the material or in agreed prefabrication stages.

6.2 Scope of testing

In accordance with the different demands made on the forgings the scope of testing can be subdivided into four test groups. Parts of forgings that are discarded during machining need not be considered.

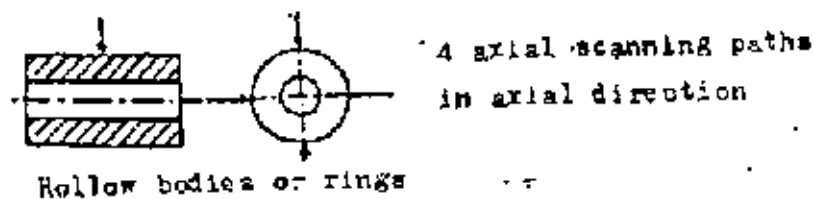
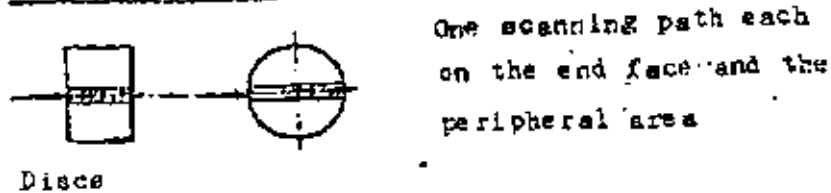
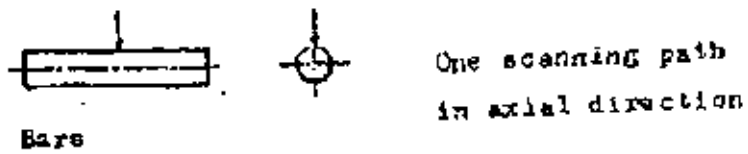
Test Group 1:

Testing with normal (compression wave) probes along one or several scanning paths of 50 mm maximum width on the external surface over the entire length of the perimeter - in the case of discs also on the end face - where the core zone of the cross section shall generally be covered.

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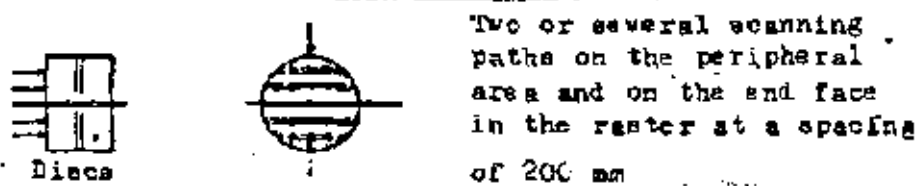
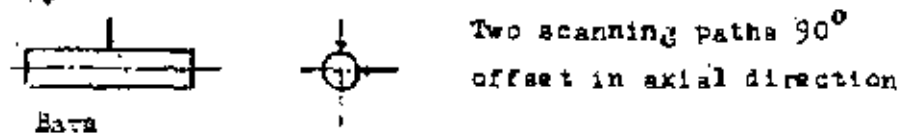
Examples:



Test Group 2:

Testing with normal probes along two or more scanning paths of 50mm maximum width - in the case of discs with a raster scan on the end face - over the entire length of the surface line or peripheral line. The core zone of the cross section and an additional part of the volume is covered.

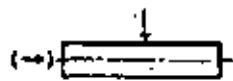
Examples:



Test Group 3:

Testing with normal probes from two directions at 90° to each other on the surface accessible from the outside with coverage of the largest possible volume of the forging. Other probe-types may also be used for an evaluation of the indications.

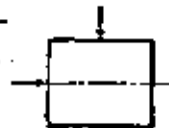
Examples:



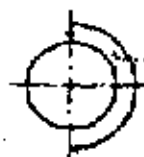
Bars



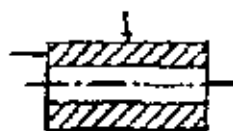
At least half the circumference over the entire length; one axial test from one end face is subject to separate agreement.



Discs



At least half the circumference of the peripheral area and one complete end face



Hollow bodies or rings



Complete external peripheral area and one end face

Test Group 4:

Testing of the entire attainable volume in cases of special testing requirements. The scope of testing, the application of several probe-types as well as the directions of testing and incidence, call as a rule for an agreement between the manufacturer and the customer or shall be designated by the contractor.

Note: In cases of special testing requirements it is possible to fall back, if need be, on SEP 0000*).

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6.3 Testing procedure

Testing shall be carried out in accordance with DIN 54 126, Part 2. In compliance with the test group, the surfaces of the forging requiring testing are scanned with the probe. To do this the testing system has initially been adjusted at characteristic points (plane parallel surfaces or axially symmetrical zones) and checked in order to ensure that the existing metallurgical structure and the chosen nominal frequency guarantee adequate testability. This can be done by:

- 1) calculating the required gain from the DGS-diagram⁴⁾ with an allowance having to be made for the sound attenuation and the transfer loss, or
- 2) adjustments at the corresponding reference reflectors in a comparison or reference block, if necessary with an allowance being made for sound attenuation and transfer losses.

If the signal-to-noise ratio related to the recording limit (see Paragraph 6.6) is ≤ 6 dB, any further actions require an agreement between manufacturer and customer. Indications requiring recording shall be expressed in mm KSR (circular disc reflector) or the amount in dB the height exceeds the reference reflector.

The adjustment of the testing sensitivity shall be so carried out that the recorded indications attain at least $1/5$ of the screen height. If this is not possible, an appropriate entry shall be made in the test report.

When the screen image is visually examined the testing speed shall not exceed 100 mm s^{-1} . Under automatic scanning conditions the testing speed and the pulse repetition frequency shall be so adjusted relative to each other that the permissible sizes and lengths of the indications (Table 1) are reliably detected.

- 4) The geometry and/or the dimensions of the test object limit the application of the DGS-method (side wall effect, near-probe defects, curved surfaces).

When a test surface is continuously scanned in compliance with test groups 3 and 4 the scanning paths shall overlap by approximately 15%.

6.4 Indications

6.4.1 Indications without extent

Indications without extent are the echoes received from points of reflection suffering uniform gain losses in all directions during steady probe scanning. Their magnitude is described by the diameter of the permissible circular disc reflector according to Table 1.

6.4.2 Indications with extent

Indications with extent have no uniform gain decrease, at least not in one direction. The extent is determined with the half-value method. The extent is greater than the diameter of the permissible circular disc reflector. Particulars of the maximum lengths according to size class are listed in Table 1 for different acceptance levels. An allowance shall be made for the sound field characteristics of the probe.

6.4.3 Indication frequency

The indication frequency is the number of indications above the recording limit in the body of the forging or agreed zones (see Paragraph 6.5). Table 2 gives the subdivisions into frequency classes a to e. The frequency class and the reference size (volume of total forging, longitudinal section or zones subjected to different loads) shall be specified in the order.

6.4.4 Bottom echo decrease

If the bottom echo decreases significantly (decline of bottom echo amplitude down to the zone of the recording limit), the corresponding zones shall be scanned with another test frequency and in another direction of incidence.

6.5 Acceptance level

The acceptance level of indications requires the agreement between manufacturer and customer in accordance with the size classes in

Table 1 and the frequency classes in Table 2. For parts of forgings exposed to different stresses, zones can be demarcated in which different indication sizes in accordance with the classification in Table 1 and frequency according to classification in Table 2 can be accepted.

6.6 Recording limit

Unless otherwise agreed, the recording limit shall be equated to the corresponding acceptance level (cf. Paragraph 6.5) (see Table 1). In this case it suffices to quote the indication frequency. The recording limit can be quoted in addition to the acceptance level. In this case the ratio of the recording limit to the acceptance level amounts to 5 dB. The signal-to-noise ratio to the recording limit shall likewise amount to at least 6 dB (see Paragraph 2).

7. Test report

The test report shall contain the following data:

- a) Characteristic data of test pieces.
- b) Data of testing regulation
- c) Type of test equipment and probe
- d) Condition of test surface
- e) Coupling agent
- f) Scope of testing in accordance with the test group
- g) Recording limit and acceptance level
- h) Result

Ultrasonic indications above the recording limit (which may, on occasions, be subject to agreement) shall be described in terms of their location, size, extent or frequency in compliance with the order or - if required in a true-to-scale sketch of the forging, the cross section or a development of the surface. For test groups 3 and 4 the type of adjustment, angles of incidence, sound attenuation and transfer correction shall additionally be quoted. In cases where an agreement on zones demanding different evaluation has been reached, they have to be appropriately indicated in the sketch.

8. Ordering instructions

For orders to this Test Sheet an agreement shall be reached regarding the test group, the size class of the indications, if necessary the permissible frequency (cf. Paragraph 6.4.3), the recording limit, the surface condition and the heat treatment condition required for testing.

Table 1: Size classes for permissible limits of the indications (see Paragraphs 6.4.1 and 6.4.2)

Acceptance Levels			
Size class	Indications without extent in mm KSR ²⁾	Indications with extent in mm KSR ²⁾	Maximum extent in mm ³⁾
A	14	10	80
B	10	7	60
C	7	5	40
D	5	3	30
E	3	2	30

- 1) Depending on the size class indications without extent shall have a spacing of 5 x mm KSR. If the spacings are shorter, the indications shall be regarded as "indications with extent". Agreement according to Table 2 shall be reached regarding to the permissible frequency.
- 2) KSR = circular disc reflector. The gradation of the size classes is based on differences in gain of approximately 6 dB.
- 3) Subject to agreement an allowance can be made for exceeding the maximum extent, with account being taken of the permissible frequency. An indication with extent e.g. of 160 mm length for size class A corresponds to a frequency of $160:80 = 2$.

