



# Ultrasonic testing of forgings and forged steel bars from ~100 mm diameter or edge length

Iron-steel  
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Edition 1

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## 1. Principle and Purpose of the Test Specification

This test specification deals with the ultrasonic testing of forgings and forged steel bars (hereinafter designated "forging") in general use, preferably for detecting internal defects using the impulse and echo technique. The ultrasonic test enables data to be collected on the position, size, extent and frequency of reflectors. For forgings subject to acceptance criteria, this test specification serves as a guideline for establishing the scope of testing to be carried out (see section 6.2) and the acceptance limits (see sections 6.5 and 6.6). It describes the test process and the conditions to be observed with regard to the test system, the quality of the workpiece being tested and the classification of the test results.

## 2. Field of Application

This test specification applies to the testing of suitably designed, machined or unmachined, untreated and heat-treated forgings, preferably of unalloyed or alloyed steel (see section 6.1).

For forgings on which higher demands are made, SEP 0000<sup>\*)</sup> is applicable.

If the test is being carried out on non-transformable steels, the testability may be impaired by acoustic decay and other factors. In such cases, the achievable registration and acceptance limits should be stated in order to assess testability. If testing is not practicable, another method of proceeding should be agreed with the customer or his representative.

## 3. Classification

Depending on the scope of testing, forgings are classified in four groups (see section 6.2), and depending on the size and length of indication acceptable, into five categories or classes (see sections 6.4 and 6.5, table 1). The acceptable frequency of indications is also divided into five frequency classes (see section 6.4.3).

## 4. Preparation of the Forgings

For testing, rough forgings should be simple in form or dynamically balanced (see DIN 54 126 part 1, section 6). Test surfaces and other surfaces to be used for reflection should be sufficiently even to allow adequate probe-to-specimen contact.

A smooth even surface which is free of loose scale may be suitable for testing provided that adequate contact can be achieved. Should it be necessary to machine the surface, an approximate average roughness of  $< 20 \mu\text{m}$  to DIN 4762 should be aimed at.

In the case of steels which have not been heat-treated, it should be ensured that the acoustic decay of the workpieces allows the agreed acceptance limit (or registration limit) to be detected. If transformable steel is being used, the forging may be heat treated to reduce the acoustic decay.

The surface and structural condition required for efficient detection of defects must, if necessary, be adapted to the machining and heat treatment and allow the indication of defects of the agreed size and category (table 1).

<sup>\*)</sup> in preparation

## 5. Test System

### 5.1 Test Equipment

The ultrasonic testing device should function on the impulse and echo principle, and possess an amplification regulator calibrated in decibels (dB) which allows echo conditions to be measured with an accuracy of  $\pm 2$  dB. The amplifier should not show amplification threshold or saturation<sup>1)</sup> in the field of sensitivity of the unit in use.

It should be possible to adjust the test unit to the setting range required for the test. Deviations from linearity of up to 2% of the setting range are permitted.

### 5.2 Probes

The nominal frequency of the probe should be adapted to the size of the circular disk reflector to be detected, to the length of the sound wave path and to the acoustic decay of the workpiece. In general, testing is done at between 1 and 4 MHz; however, other frequencies may be used provided that the acceptance limit values fixed in section 6.5 are detectable.

As a rule, vertical probes are used. In addition, other types of probes such as transmitter-receiver (SE) probes or angular probes may be used for example to locate reflectors close to the surface, to improve the resolution of indications in inaccessible areas of the forging, as well as with hollow bodies or for special types of defects. This applies especially to groups 3 and 4 (see section 6.2).

For the analysis of indications of circular disk reflector size, a distance-amplification (AVG) diagram for every type of contact should be familiar.

### 5.3 Monitoring the Test System

For basic principles, see DIN 54 126 part 1. For equipment setting and monitoring of the functions both of equipment and probes, test specimen 1 (DIN 54120<sup>2)</sup>) should be available.

For monitoring the test system, test piece 2 (DIN 54 122<sup>3)</sup>) or other suitable test specimen with reference reflectors may be used.

### 5.4 Contact Medium

The contact agent (see DIN 54 126 part 1, section 5.6) must wet the surface of the workpiece thoroughly. Appropriate for this purpose are water (preferably with additive for increasing viscosity), oils, and pastes. The same agent should be used for setting the test system and for all subsequent test work. If machined forgings are being tested, the contact agent should not give rise to corrosion. If necessary, the test surface should be cleaned or dried following testing.

## 6. Conduct of the Test

### 6.1 Timing of the Test

Preliminary testing should be carried out as soon as possible in order that a decision can be taken as to the testability and useability of the forging. In general, acceptance testing is carried out when as few contours as possible are present on the forging, but following the heat treatment essential for the material characteristics, or at another agreed stage early in the production process.

<sup>1)</sup> For further details concerning the requirements placed on the test system, see DIN 54126 - Allgemeine Regeln zur Prüfung mit Ultraschall - Teil 1 - Anforderungen an die Prüfsystem - sowie Teil 2 - Durchführung der Prüfung.

<sup>2)</sup> DIN 54120 - Kontrollkörper 1 und seine Verwendung zur Justierung und Kontrolle von Ultraschall-Impuls-Echo-Geräten -

<sup>3)</sup> DIN 54122 - Kontrollkörper 2 und seine Verwendung zur Justierung und Kontrolle von Ultraschall-Impuls-Echo-Geräten -

## 6.2 Scope of Testing

Depending on the demands being made on the forging, the scope of testing can be divided into four sub groups. Areas which are subsequently removed by machining do not require testing.

### Test Group 1:

Testing with vertical probes on one or several paths (maximum width 50 mm) on the outer surface, over the entire length of the surface lines, with disks, also on the front surface. In general, the central area of the cross section are covered.

#### Examples:



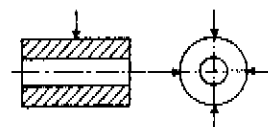
Bars

One test path in axis direction



Disks

One path on front surface and one circumference surface



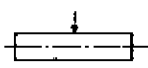
Hollow bodies and rings

4 axial test paths in axis direction

### Test Group 2:

Testing with vertical probes on two or several paths (maximum width 50 mm), on disks with grid on front surface, over the entire length of the surface or circumference lines. The central area of the cross section and a wider part of the volume are covered.

#### Examples:



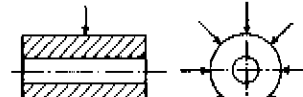
Bars

Two test paths in axis direction at 90° to one another



Disks

Two or more paths on the circumferential surface, grid at 200 mm clearance on front surface.



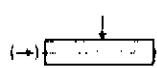
Hollow bodies and rings

More than four axial test paths in axis direction.

### Test Group 3:

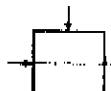
Test using vertical probes from two directions vertical to one another on the outer accessible surface. The greatest possible volume of the forging should be covered. To evaluate the indications, other types of probes may be used.

#### Examples:



Bars

At least half the circumference over the entire length, axial testing of one front surface should be agreed separately.



Disks

At least half the circumference surface and one entire front surface.



Hollow bodies and rings

Entire outer circumference surface and one front surface

### Test Group 4:

In the case of special test requirements, testing of the entire accessible volume. The scope of testing, the use of several probe types, test angles and angles of penetration should in general be arranged between manufacturer and customer or specified by customer.

#### Note:

In the case of special test requirements, SEP 0000\* may be referred to .

\*) In preparation

### 6.3 Test Process

The test should be carried out in accordance with DIN 54 126, part 2. Depending on the test group, the surfaces of the forging are scanned by the probe. First, the system equipment is set and tested at typical points (plane parallel or dynamically balanced areas) in order to establish whether the forging is testable in view of structure and selected nominal frequency. This can be done by:

- 1) fixing the required amplification from the AVG diagram <sup>4)</sup>; the acoustic decay and the transfer loss should be taken into account; or
- 2) setting to reference reflectors in a comparative or setting specimen; if necessary, the acoustic decay and the transfer loss should be taken into account.

If the ratio of signal to background (see section 6.6) is  $\leq 6$  dB, further steps to be taken should be agreed between manufacturer and customer. Indications which must be recorded are given in mm KSR (circular disk reflector) or as echo height exceeding the reference reflector in dB.

The test sensitivity should be set so that indications whose recording is obligatory, reach at least one fifth of the screen height. If this is not possible, a note to this effect should be made in the test report.

With screen monitoring, the test speed should not exceed  $100 \text{ mm s}^{-1}$ . With automatic testing, the test speed and the impulse frequency should be so coordinated that permissible indicator sizes and lengths (table 1) are reliably detected.

Perfect scanning of a surface by the probes according to groups 3 and 4 means that the paths should overlap one another by approximately 15%.

### 6.4 Indications

#### 6.4.1 Indications with no extension

Indications with no extension are echos received from reflectors which, on even scanning with the probe, show a constant drop in amplitude in every direction. Their size is stated by means of the diameter of the permissible circular disk reflector in accordance with table 1.

#### 6.4.2 Indications with extension

Indications with extension are those which show no constant drop in amplitude in at least one direction. Their extension is determined using the half value method. The extension is greater than the diameter of the permitted disk reflector. For acceptance limits, table 1 contains data on maximum lengths divided into various categories of size. The sound field properties of the probe must also be taken into consideration.

#### 6.4.3 Frequency of Indication

Frequency of indication is the number of indications above the registration limit in the volume of the forging or of agreed areas (see section 6.5). Table 2 shows the division of indications into frequency classes a to e. The class of frequency, and the reference figure (total volume of the forging, longitudinal sections, or zones of varying stress) should be fixed at placement of order.

<sup>4)</sup>The application of the AVG method is restricted by the geometry and /or the dimensions of the material being tested (side wall effect, defects close to probe, curved surfaces)

#### 6.4.4 Back Echo Drop

If there is a considerable decline in the back echo, (decrease of the amplitude of the back echo down to the vicinity of the registration limit) the areas concerned should be tested using another test frequency and another angle of sonic penetration.

#### 6.5 Acceptance Limit

The acceptance limit for indications should be agreed between manufacturer and customer on the basis of the size and frequency classes given in tables 1 and 2. For areas of a forging subject to varying stress, zones may be fixed in which different sizes and frequencies in accordance with tables 1 and 2 respectively, are permissible.

#### 6.6 Registration Limit

Unless otherwise agreed, the registration limit should be equated with the acceptance limit (see section 6.5 and table 1). In this case, the frequency of indication is not stated. The registration limit may be fixed in addition to the acceptance limit. In such a case, the relation of registration limit to acceptance limit is 6 dB. The signal-background ratio should also be at least 6 dB (see section 2).

### 7. Test Report

The test report must contain the following information:

- a) identification data of the test piece,
- b) test guideline,
- c) type of test equipment and probe,
- d) condition of test surface,
- e) contact medium,
- f) scope of testing with reference to test groups,
- g) registration and acceptance limit,
- h) result.

Ultrasonic indications above the agreed registration limit must be described with regard to position, size, extension, or frequency as specified in the order or, if necessary, entered on a scaled drawing of the forging, the cross section or a developed view of the surface. For test groups 3 and 4, the type of setting, the directions of penetration, the acoustic decay and the transfer correction should also be stated. If zones subject to varying assessment were agreed, these should also be entered on the sketch.

### 8. Notes on Ordering

When ordering in accordance with this test specification, the test group, the class of indication according to size, if necessary, the permissible frequency (see section 6.4.3), the registration limit, the surface quality and the heat treated condition required for testing should be agreed.

Table 1

Size classification for acceptance limits Indications (see sections 6.4.1 and 6.4.2):

Acceptance Limits			
Size class	Indications without extension <sup>1)</sup> in mm KSR <sup>2)</sup>	Indications with ext. in mm KSR <sup>2)</sup>	Maximum extension in mm <sup>3)</sup>
A	14	10	80
B	10	7	60
C	7	5	40
D	5	3	30
E	3	2	30

- 1) Indications without extension should, depending on their size classification, have a distance of 5 x mm KSR from one another. If the clearance is less, they are to be regarded as indications with extension. Agreement on frequency should be made according to table 2.
- 2) KSR = circular disk reflector. The size grading is based on differences in amplitude of approx. 6 dB.
- 3) Greater than maximum extensions can on agreement be taken into account by deducting the permissible frequency. E.g. an indication with an extension of 160 mm length for size class a corresponds to a frequency of  $160:80=2$

Table 2: Frequency classes (see section 6.4.3)

Acceptance Limits		
Size class	Number of indications without extension	Number of indications with extension
a	32	16
b	16	8
c	8	4
d	4	2
e	2	1

- 1) The reference figure should be agreed in relation to size, zone and length of the forging.