STEEL and IRON Testing Standards of the "Verein Deutscher Eisenhüttenleute"

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Ultrasonic testing of forgings and forged steel bars with a diameter or edge length of approx. 100 mm or greater

STEEL and IRON TESTING STANDARD 1921
Version 1

1. Purpose and nature of the Testing Standard

This Testing Standard deals with the ultrasonic testing of generally used forgings and steel bars (referred to below as forgings), mainly for the purpose of detecting internal flaws by means of the pulse-echo method. Ultrasonic testing provides information about reflection sites in terms of their position, size, extent and frequency. For forgings that are subject to acceptance, this Testing Standard serves as a guideline for defining the scope of testing (see Section 6.2) and the acceptance levels (see Sections 6.5 and 6.6). It describes the test methods and the required test conditions with regard to the testing system, the condition of the test workpiece, and the classification of the test results.

2. Scope

The Testing Standard applies to the testing of appropriately shaped, worked and non-worked, untreated and heat-treated forgings, mainly made of alloyed and unalloyed steel (see Section 6.1).

For forgings that have to meet stricter requirements, SEP 0000[1)] applies.

If this method of testing is used on forgings made from steel that does not undergo transformation, sound attenuation and other causes may impair the applicability of the method. In such cases the achievable registration and acceptance levels should be specified to enable the possibility of testing to be assessed. If there is no possibility of testing, the buyer or the buyer's representative should be consulted in order to reach agreement on how to proceed.

3. Classification

Tests of forgings are divided into four test groups, depending on the scope of testing (see Section 6.2), and five dimensional classes, depending on the permissible signal magnitude and length (see Sections 6.4 and 6.5, Table 1). Similarly, the permissible signal frequency is subdivided into five frequency classes (see Section 6.4.3).

[1)] In preparation

4. Preparing the test forgings

Test forgings should be prepared as rough forgings with simple shapes or rotational symmetry (see DIN 54126 Part 1, Section 6). The waviness and roughness of the test surfaces and other surfaces used for reflection must be such that the probes can be adequately coupled to the forging.

A smooth, scale-free surface can suffice for the test, provided adequate coupling is achieved. If the surface has to be worked, as a guideline the mean roughness index R_a must be equal to or less than 20 µm in conformity with DIN 4762.

In the case of non-heat-treated steel, it must be ensured that the sound attenuation of the workpieces is such that the agreed acceptance level (or registration level) can be detected during testing. Provided the steel is capable of undergoing transformation, the forging can be subjected to heat treatment to decrease the sound attenuation.

The surface and structural state of the test forging, and any associated working and heat treatment, must be geared to each other to ensure that flaws and the specified dimensional class of signals can be detected (Table 1).

5. Testing system

5.1 Testing instrument

The ultrasonic testing instrument must make use of the pulse-echo method and must enable echo-peak ratios to be measured with an accuracy of ±2 dB with the help of a gain control element calibrated in decibels (dB). The amplifier must not exhibit any gain threshold or any saturation in the range of instrument sensitivity used.[1)]

It must be possible to set the required adjustment range on the testing instrument. Deviations from linearity of up to 2% of the set adjustment range are acceptable.

5.2 Probes

The nominal frequency of the probe must be geared to the size of the circular reflector to be detected, the length of the sound path and the sound attenuation of the test workpiece. Generally tests are carried out with 1 - 4 MHz but other frequencies can be used provided the limiting values for acceptance, as specified in Section 6.5, are detectable.

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1) More details of the demands made on the test system are contained in DIN 54126 - Allgemeine Regeln zur Prüfung mit Ultraschall - Part 1 - Anforderungen an die Prüfsysteme and Part 2 - Durchführung der Prüfung.

Straight-beam probes are usually used. Other probe types, such as transmitter-receiver (TR) probes or angle-beam probes can be used additionally, e.g. to detect reflection sites located close to the surface, for improved resolution of signals in poorly accessible sections of the forgings, for hollows and for unusual flaw sites. This applies especially to product groups 3 and 4 (see Section 6.2).

A distance-gain-size (DGS) diagram should be known for each probe type so that signals can be evaluated in mm circular reflector size.

5.3 Checking the testing system

The basis is DIN 54126 Part 1. Calibration block 1 in accordance with DIN 54120[2)] must be available for instrument adjustment and monitoring of the instrument functions and the probes.

Calibration blocks 2 in accordance with DIN 54122[3)] or other suitable calibration blocks with reference reflectors can also be used to check the test system.

5.4 Coupling agents

Coupling agents (see also DIN 54126 Part 1, Section 5.6) must wet the surface of the workpiece thoroughly. Water (preferably with viscosity-increasing additives), oil and pastes are suitable for this purpose. The same coupling agent must be used to set the test system and for all subsequent testing activities. If finished forgings are tested, the probes must not cause any corrosive damage. If necessary the tested surface must be cleaned or dried after testing.

6. Carrying out the test

6.1 When to carry out the test

Preliminary tests should be undertaken as soon as possible to determine whether the forgings are testable and usable. User's inspections are usually carried out in the most contour-free state possible, but after the heat treatment, which is crucial for the material properties, or in agreed preliminary manufacturing stages.

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

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

e of testing

can be divided into four test groups, depending on the
t demands made on the forging. Types of mechanical
that are of no relevance can be ignored.

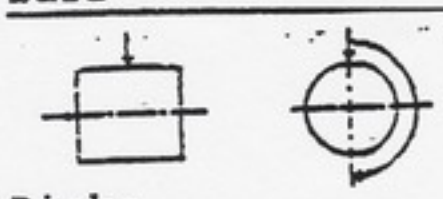
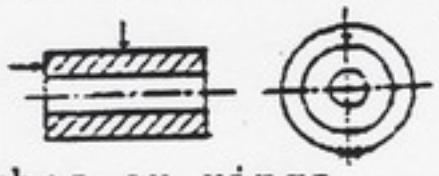
oup 1:
with straight-beam probes on one or more scanning
f no more than 50 mm width on the outside surface over
ole length of the surface (in the case of disks also on
ce); in general the scan should cover the core zone of
oss section.

es:	One scanning path in the longitudinal direction
	One scanning path on the face and one on the circumference
ks	4 axial scanning paths in the longitudinal direction
ubes or rings	

est group 2:
esting with straight-beam probes on two or more scanning
paths of no more than 50 mm width on disks with a grid patte
on the face, over the whole length of the surface or the
circumference. The scan covers the core zone of the cross
section and a further part of the volume.

Examples:	Two scanning paths in the longitudinal direction at ri angles to each other
Bars	Two or more scanning paths the circumference and on th face in the grid with 200 m between lines
Disks	More than four axial scan paths in the longitudinal direction.
Tubes or rings	

Test group 3:
Testing with straight-beam probes from two mutually perpendicular directions on the external accessible surface, covering the greatest possible volume of the forging. Other probe types can be used to evaluate the signals.

Examples:	
 Bars	At least half the circumference over the whole length; an axial test of a face must be specially agreed
 Disks	At least half the circumference and a complete face
 Tubes or rings	Complete outside circumference and one face

Product group 4:
Testing the whole accessible volume if special test demands apply. The scope of the testing, the use of several probe types, and the test and beam directions are usually agreed between manufacturer and buyer or are specified by the client.

Note:
SEP 0000[t)] can be applied if there are special test requirements.

6.3 Test procedure

Testing is to be carried out in conformity with DIN 54126 Part 2. The surfaces of the test forging are scanned in the manner appropriate to the test group. First of all the instrument system is set and tested at typical sites (plane-parallel areas or rotationally symmetrical zones) in order to determine whether the structure of the forging is such that testing is possible at the selected nominal frequency. This can be done by:

1) determining the necessary gain from the DGS diagram[4)], taking account of sound attenuation and transfer loss, or

2) by setting the corresponding reference reflectors in a reference or calibration block, if necessary taking account of sound attenuation and transfer loss.

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t) In preparation

4) Geometry and /or the dimensions of the test material place limits on the use of the DGS method (sidewall effect, near-probe flaws, curved surfaces).

If the noise margin relative to the registration level (see Section 6.6) is less than or equal to 5 dB, the manufacturer and buyer must reach agreement on how to proceed. The signals that have to be registered must be expressed in mm circular reflector or as echo-peak excesses relative to the reference reflector in dB.

The test sensitivity must be adjusted so that the signals that have to registered occupy at least 1/5 of the screen height. If this is not possible it must be noted in the test report.

If the screen is observed during the test, the test speed should not exceed 100 mm s^{-1}. In the case of automatic testing the test speed and the pulse frequency should be geared to each other so that the permissible signal sizes and lengths (Table 1) will certainly be found.

If a test area is to be scanned completely, as is required for groups 3 and 4, the scan paths must overlap by about 15%.

6.4 Signals

6.4.1 Non-extended signals

Non-extended signals are echoes that are received from reflector sites and exhibit the same amplitude decay in all directions when the site is scanned uniformly by a probe. Their size is described by the diameter of the acceptable circular reflector in line with Table 1.

6.4.2 Extended signals

Extended signals do not have the same amplitude decay in all directions. The extension is determined by the half-value method. The extension is greater than the diameter of the acceptable circular reflector. With regard to the acceptance levels, Table 1 shows maximum lengths per size class. The sound field properties of the probe must be taken into account.

6.4.3 Signal frequency

Signal frequency is the number of signals above the registration level in the volume of the forging or from agreed zones (see Section 6.5). Table 2 shows a distribution by frequency classes a to e. The order must specify the frequency class and the reference variable (volume of the entire forging, longitudinal sections or zones of different stress).

6.4.4 Backwall echo decay

If there is an appreciable backwall echo (reduction of the amplitude of the backwall echo until it is the range of the registration level), examine the relevant zones with another test frequency and another beam direction.

6.5 Acceptance level

The limiting value for the acceptability of signals must be agreed between manufacturer and buyer in accordance with the size classes in Table 1 and the frequency classes in Table 2. If parts of a forging are subject to different stresses, zones can be defined in which different signal sizes and frequencies are acceptable, depending on the class distribution in Table 1 and Table 2 respectively.

6.6 Registration level

Unless otherwise agreed, the registration level shall be equal to the corresponding acceptance level (see Table 1). In this case there is no need to specify the signal frequency. The registration level can be agreed in addition to the acceptance level. In this case the relationship registration level/acceptance level must be at least 6 dB. The noise margin to the registration level must also be at least 6 dB (see Section 2).

7. Test report

The test report must contain the following information:

a) characteristic data of the test piece;
b) test guideline data;
c) type of test instrument and type of probe;
d) state of the test areas;
e) coupling agent;
f) scope of testing per test group;
g) registration limits and acceptance limits;
h) findings.

Ultrasonic signals above any agreed registration limits should be described in terms of location, size, extent and frequency in accordance with the order or - if necessary - shown in a scale diagram of the forging or of the cross section, or in a developed view of the surface. In the case of test groups 3 and 4, the type of adjustment, the beam direction, the sound attenuation and the transfer correction must also be specified. If zones that have to be assessed differently are agreed, they must be shown accordingly in the diagram.

9. Information concerning the assessment

For orders based on this Testing Standard, agreement must be reached with regard to the test group, the size class, if appropriate the permissible frequency (see size class 6.4.3), the registration level, the condition of the surface, and the necessary heat treatment state.

Table 1: Size classes for acceptable limiting values of the signals (see Sections 6.4.1 and 6.4.2)

Size class	Acceptance levels		
	Non-extended signals[1] in mm CR[2]	Extended signals in mm CR[2]	Maximum extension in mm[3]
A	14	10	80
B	10	7	60
C	7	5	40
D	5	3	30
E	3	2	30

1) Non-extended signals should have a separation of 5 x mm circular reflector, depending on the size class. If the separation is shorter, the signals are to be regarded as "extended signals". Agreements on the acceptable frequency must be reached in accordance with Table 2.

2) CR = circular reflector. The grading of size classes is based on amplitude differences of about 6 dB.

3) By agreement, signals that exceed the maximum extension can be taken into consideration, taking the acceptable frequency into account. A signal with an extension of, for example, 160 mm length for size class A corresponds to a frequency of 160:80 = 2.

Table 2: Frequency classes (see Section 6.4.3)

Frequency class	Acceptance levels[1]	
	Number of non-extended signals	Number of extended signals
a	32	16
b	16	8
c	8	4
d	4	2
e	2	1

1) The reference variable is to be agreed depending on the size, zone or length of the forging