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**Resistance welding — Destructive  
testing of welds — Method for the  
fatigue testing of multi-spot-welded  
specimens**

*Soudage par résistance — Essais destructifs des soudures — Méthode  
d'essai de fatigue des échantillons soudés par points multiples*

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 6, *Resistance welding and allied mechanical joining*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html). Official interpretations of TC 44 documents, where they exist, are available from this page: <https://committee.iso.org/sites/tc44/home/interpretation.html>.

This second edition cancels and replaces the first edition (ISO 18592:2009), which has been technically revised. The main changes compared to the previous edition are as follows:

- Clause 3 has been updated;
- Figures and tables have been updated.

## Introduction

This document has been prepared because welding engineers (and most design engineers) are not familiar with fatigue testing and the influence of factors such as load type (e.g. shear load, peel load), and failure criteria.

Tests are used to investigate the existence of specific properties and their qualitative and quantitative evaluation. Fatigue tests, in general, are used to investigate the behaviour of structures and components subjected to cyclic loads. For welded components, fatigue tests are used to determine the influence of different parameters such as joining methods, pitch, material thickness and material combinations, type of load (e.g. shear load, peel load), overlap, location of weld on flange, edge distance, loading condition (e.g. quasi-static, cyclic, load ratio  $R$ ), and the combination of environment and corrosion on the fatigue behaviour (life) of spot welds and/or specimens subjected to various types of loads. Fatigue tests will, if their results are to be used for design purposes, as far as possible, take into consideration such boundary conditions as encountered in a real-life environment. This applies to load types, load amplitudes, and load ratios as well as load distributions and failure criteria<sup>[2]</sup>.

The test specimen selected for the fatigue test will simulate, as closely as possible, the loads and the boundary conditions as they are encountered in service. Furthermore, the failure criterion used must conform to the application in hand. Although the type of primary load is identical in some specimens, e.g. shear load in flat multi-spot specimens, H-shear specimens, KS-2 specimens, and double disc specimens, the results of fatigue tests differ significantly because of the secondary load types resulting from varying degrees of local deformation due to the differences in the local stiffness in the area of the joints. The local deformation, responsible for the magnitude of the peel component, for example, is a function of the local stiffness, increasing with a decrease in stiffness.

This document offers a framework within which the different specimens, described herein, can be modified such that design specifics and production constraints, e.g. flange width and overlap, weld nugget size, pitch, bending radius, and sub-standard welds, can be given due consideration. This helps towards enhancing the significance of the results very appreciably. Note that if welds could be subjected to identical amplitudes of shear and peel loads, their lives would differ by a factor of approximately  $10^4$  (References [8] to [11]). This explains the necessity to use different specimens for the simulation of different load types.

Conformance tests on real components serve the verification of design calculations and are necessary for the qualification of structures. It is therefore necessary to maintain their number at an absolute minimum.

# Resistance welding — Destructive testing of welds — Method for the fatigue testing of multi-spot-welded specimens

## 1 Scope

This document specifies test specimens and procedures for performing constant load amplitude fatigue tests on multi-spot-welded and multi-axial specimens in the thickness range from 0,5 mm to 5 mm at room temperature and a relative humidity of maximum 80 %. The applicability of this document to larger thicknesses can be limited by mechanical properties such as yield strength and formability of the specimen material. The thickness range for advanced high strength steels (AHSS) is generally below 3,0 mm. Greater thicknesses apply for aluminium alloys, for example.

Depending on the specimen used, it is possible from the results to evaluate the fatigue behaviour of:

- spot welds subjected to defined uniform load distribution;
- spot welds subjected to defined non-uniform load distribution;
- spot welds subjected to different defined combinations of shear-, peel- and normal-tension loads; and
- the tested specimen.

Multi-spot specimens with which the different load distributions can be realized are the following:

- a) defined uniform load distribution:
  - 1) H-specimens for shear- and peel-loading, (welds subjected to uniform shear or peel loading transverse to the joint line);
  - 2) single- and double-hat specimens subjected to four-point bending (spot welds subjected to uniform shear load in the direction of the row of welds);
  - 3) double-disc specimen under torsion (spot welds subjected to uniform shear load);
  - 4) double-disc specimen under tensile load (spot welds subjected to uniform peel load);
  - 5) double-disc specimen under combined torsion and tensile loading;
  - 6) flat multi-spot specimens using defined grips;
- b) defined non-uniform load distribution:
  - 1) H-specimens with modified grips;
  - 2) modified H-specimens with standard grips;
  - 3) modified H-specimens with modified grips;
  - 4) flat multi-spot specimens with modified grips;
  - 5) modified multi-spot flat specimens with standard grips;
  - 6) modified multi-spot flat specimens with modified grips;
- c) defined combinations of shear-, peel- and normal-tension loads:
  - 1) the KS-2 specimen;

- 2) the double disc specimen;
- d) spot welds subjected to undefined non-uniform load distribution — single-hat, double-hat and similar closed hollow sections under torsion, 3-point bending and/or internal pressure.

The specimens and tests referred to under c) above are not dealt with further in this document, because the results obtained with these specimens are specific to the components as tested and may not be generalized or used for deriving data pertaining to the load-carrying behaviour of the welds. Results obtained with such tests are suitable for comparing the mechanical properties of the tested components with those of similar components tested in the same manner. These tests are, however, not suitable for evaluating or comparing the load-carrying properties of the welds.

The test results of the fatigue tests obtained with component like specimens are suitable for deriving criteria for the selection of materials and thickness combinations for structures and components subjected to cyclic loading. This statement is especially relevant for results obtained with specimens with boundary conditions, i.e. a local stiffness similar to that of the structure in question. The results of a fatigue test are suitable for direct application to design only when the loading conditions in service and the stiffness of the design in the joint area are identical.

NOTE Specimens are modified to take into consideration constraints or specific demands posed by design, e.g. smaller than standard overlap, smaller or larger than standard nugget diameter, and specific load distribution, thus enhancing the value of the test results for the design engineer.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 14324, *Resistance spot welding — Destructive tests of welds — Method for the fatigue testing of spot welded joints*

ISO 15609-5:2011, *Specification and qualification of welding procedures for metallic materials — Welding procedure specification — Part 5: Resistance welding*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 14324 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

### 3.1 fatigue life

#### number of cycles to failure

$N$

number of load cycles at which failure occurs, or before it fulfils a failure criterion defined for the test

### 3.2 fatigue endurance

$N_G$

number of cycles at which it has been agreed to stop the test even if failure does not occur



**3.3*****F-N* diagram**

diagram obtained by plotting the load amplitude (or load range, or maximum load) as ordinate and the fatigue life (or fatigue endurance if the test is terminated before failure) as abscissa, also called the load-amplitude-number of load cycles diagram

Note 1 to entry: It is normal practice to use logarithmic axes.

**3.4****displacement range**
 $\Delta L$ 

change in the length of a specimen due to the application of a load

**3.5****stiffness**
 $c$ 

load  $F$  divided by the corresponding displacement  $L$ , i.e.

$$c = \frac{F_{\max} - F_{\min}}{\Delta L}$$

**3.6****initial stiffness**
 $c_0$ 

stiffness at start of the test, i.e.

$$c_0 = \frac{F_{\max} - F_{\min}}{\Delta L_0}$$

**4 Symbols and abbreviated terms**

$a$	overlap
$b$	test coupon width
$b_i$	internal width of U-member
$c$	stiffness
$c_0$	initial stiffness
$d_c$	diameter of central hole
$d_e$	diameter of pitch circle
$e$	pitch
$F$	load, repeated load
$F_a$	load amplitude
$F_m$	mean load
$F_{\max}$	maximum load
$F_{\min}$	minimum load
$h_i$	inner height

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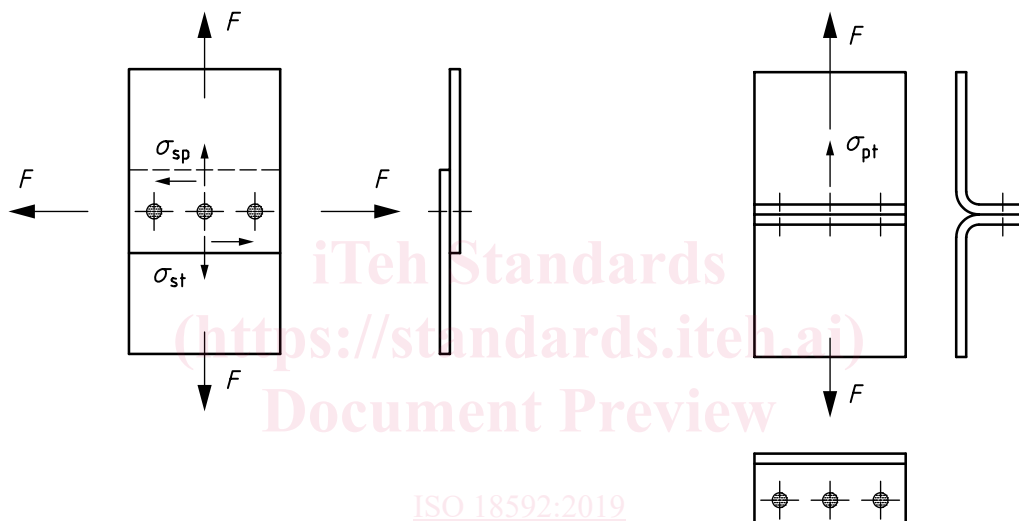
$h_s$	height of side plate or side member
$h_L$	height of L member
$h_U$	height of U member
$l_a$	distance between grip and overlap
$l_c$	length of clamped area
$l_e$	edge distance
$l_g$	specimen length between grips
$l_S$	total length of specimen
$l_t$	length of test coupon
$l_w$	distance from wall
$L_{\max}$	crosshead position at maximum load
$L_{\min}$	crosshead position at minimum load
$N$	number of cycles to failure
$N_G$	fatigue endurance
$p$	probability
$r_1$	bend radius for sheet thickness $t_1$
$r_2$	bend radius for sheet thickness $t_2$
$r_{\min}$	minimum bend radius
$r_{\max}$	maximum bend radius
$R$	load ratio
$S$	stress
$t; t_1; t_2$	sheet thicknesses
$\varepsilon_{\max}$	maximum strain measured on the specimen
$\varepsilon_m$	average strain measured on the specimen
$\sigma_{pt}$	peel stress transverse to the joint line
$\sigma_{sp}$	shear stress parallel to or in the axis of the joint line
$\sigma_{st}$	shear stress transverse to the joint line
$\Delta F$	load range
$\Delta L$	displacement range ( $L_{\max} - L_{\min}$ )
$\Delta L_0$	displacement range at the start of the test
$\Delta P$	non-uniform loading

## 5 Specimens

### 5.1 General

The specimens are designed to simulate, for joints in thin-walled structures, three basic types of loadings in their primary forms, i.e. shear load transverse to the joint line, shear load parallel to or in the axis of the joint line, and peel load (see [Figure 1](#)).

NOTE 1 For true-to-life thin-walled structures, it can generally be assumed that joints are never subjected to any of these types of stresses either singly or in a pure form. For lap joints, at least one type of shear stress and, due to the local deformation of the sheets caused by it, peel stress are present. Even if the primary stress in a lap joint is pure shear, a peel stress component is generated, whose absolute value depends on the magnitude of the deformation caused by the shear stress in the joint. This deformation is a function of the bending moment, which depends on the sheet thicknesses involved, the magnitudes of the forces acting and the local stiffness. The stiffness itself is a function of the sheet thicknesses, the Young modulus of the material(s), the flange width, the overlap, the location of the joint on the flange, the bending radii, etc. (References [8] to [11]).



a) Shear load transverse to the joint line and shear load in the axis of the joint line

b) Peel or one-sided cross-tension load

NOTE See [Clause 4](#).

**Figure 1 — The three basic load cases for joints**

NOTE 2 The specimens have been designed to permit the use of different joining technologies and, thus, allow a comparison of the load-carrying properties of joints made with different methods.

NOTE 3 For single- and double-hat specimens subjected to torsion and 3-point bending loads, the joints themselves are subjected to complex loads, whereby the ratios of the load types and the load distribution are non-uniform and undefined. Furthermore, the ratios of the three basic types of loads listed above are a function of the load amplitude, the clamping conditions, and the sheet material- and thickness combinations.

The quality, value and usefulness of the results of fatigue tests depend to a large extent on the degree of care taken in the fabrication of the specimens, their testing, the acquisition and evaluation of test data, and the comprehensiveness of the documentation.

The documentation should contain the following information.

- Material(s): Material specification, type and thickness of coating(s), sheet thickness, surface condition and mechanical properties should be noted.

b) Coupons

- The coupons should, if possible, be taken from the same material lot.
- The rolling direction shall be identical for all coupons and documented.
- The required tolerances shall be adhered to.
- Unintentional deformation of the coupons and damage to the surfaces is to be avoided.

c) Welding

- Suitable jigs should be used to ensure accurate alignment of the coupons and location of the welds.
- The welding parameters and the equipment used shall be documented.

d) Documentation

- The relevant standards shall be referenced.
- Any deviation from the referenced standards shall be documented.

The specimens shall be modified for the different joining methods, such that the joints are able to perform under optimum boundary conditions, e.g. the flange width for laser welds can be reduced considerably as compared to the length required for resistance spot welds. Similarly, because of the smaller space requirements, the location of rectangular clinch joints on the flange can be much closer to the radius than is the case with resistance spot welds unless eccentric welding electrodes are being used.

## 5.2 Selection of suitable specimens

The selection of a suitable specimen for the fatigue tests depends on the planned usage of the test results. A basic requirement of the specimen is that it allows the relevant load type and load ratio to be simulated. If the results are to be used for design purposes, then it is important to employ specimens with which a similar type of load distribution can be realized. Furthermore, the stiffness of the specimen in the joint area should be similar to that of the component under consideration.

Besides considering the primary loading condition of the welds, bear in mind the local stiffness of the joint area in the component in question. The fatigue life of welds is primarily influenced by the peel load and not by the shear load. For example, if welds could be subjected to identical amplitudes of shear and peel loads, their lives would differ by a factor of  $\sim 10^4$ . However, as can be seen in [Figure 2](#), spot welds under shear load would never fail under a load at which identical welds have a life of about 1 000 cycles. As stated above, the magnitude of the peel component depends on the shear load and the local stiffness of the specimen. Especially in the case of the single spot specimen, [Figure 4](#), the local stiffness is much lower than is usual in real structures. Therefore, the peel/shear ratio is comparatively large, resulting in a significantly shorter fatigue life as compared to identical welds tested on H-specimens, for example. In addition, some materials are particularly sensitive to peel stress in the as-welded condition, so that results obtained with specimens with a low stiffness can be misleading with regard to the behaviour of such welds in structures.

The H-specimens allow the investigation of almost all parameters including different stress ratios and stress distributions. They require special grips for testing and their manufacture is relatively complicated. However, under uniform loading, it is possible with these specimens to obtain results with a high significance with 5 to 7 specimens.

When selecting a specimen, some of the main considerations are:

- the simulation of the type of loading and load ratio in the component under consideration;
- simulation of design parameters such as stiffness, pitch, edge and flange distance;
- simulation of the stress distribution in the component;