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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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Contents

Page

Foreword

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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).

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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.

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. 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[7].

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
ΔL
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

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

ε_{max} maximum strain measured on the specimen

ε_m average strain measured on the specimen

σ_{pt} peel stress transverse to the joint line

σ_{sp} shear stress parallel to or in the axis of the joint line

σ_{st} shear stress transverse to the joint line

ΔF load range

ΔL displacement range ($L_{max} - L_{min}$)

ΔL_0 displacement range at the start of the test

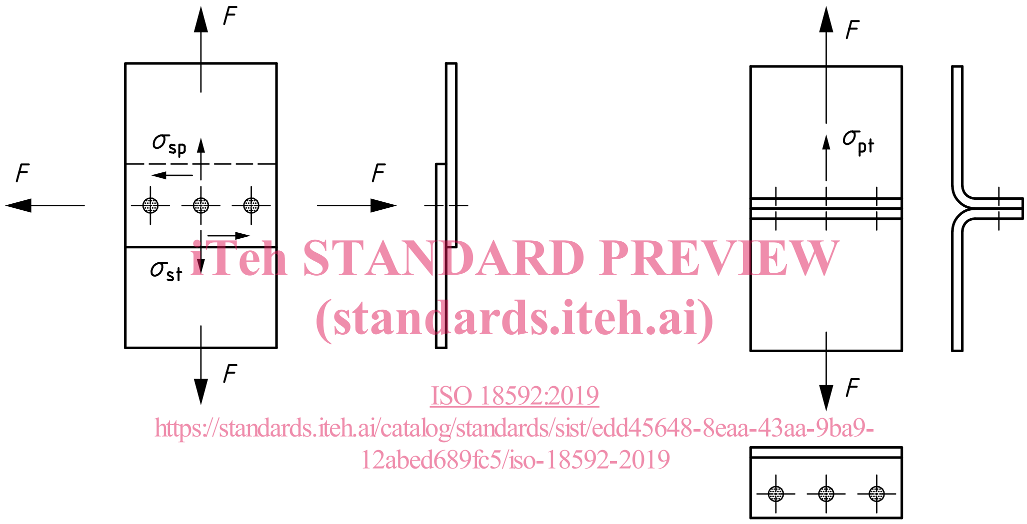
ΔP non-uniform loading

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.

a) 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 ~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;

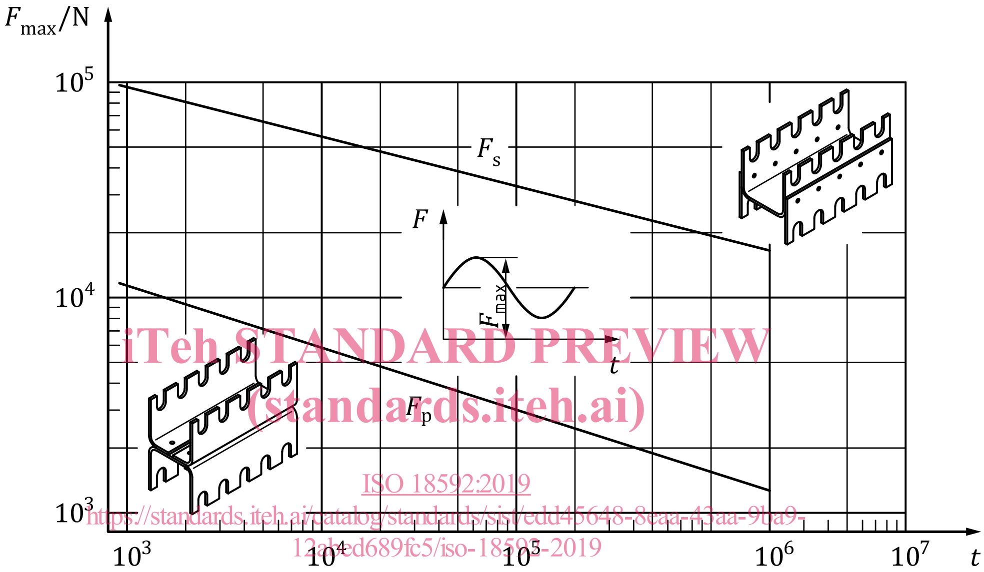
— simulation of the stress distribution in the component;

— effort required for manufacturing and testing; and

— number of specimens required to obtain statistically significant results.

Note that results obtained with specimens with a low stiffness generally bias spot welded joints, especially in the case of high strength steels.

The statistical significance of test results is influenced by their scatter. The larger the number of joints tested under uniform loading in a single specimen, the smaller is the scatter. Therefore, in order to obtain results with the same degree of significance, the number of specimens to be tested with two spot welds, for example, is five times greater than H- or double disc specimens with 10 spot welds. Furthermore, the stiffness of flat specimens is appreciably lower than that of components, so that the results obtained with these specimens are generally misleading. In addition, some specimens cannot be subjected to compressive loads or negative load ratios *R*, e.g. two flat specimens with one or two welds.



NOTE See Clause 4.

Figure 2 — *F-N* diagrams (Wöhler diagrams) of H-specimens subjected to shear and peel loading, load ratio, *R* = 0,1 – schematic

5.3 Specimen fabrication

5.3.1 Sheet material

The sheet material for the coupons may be in the sheared condition, but all burrs should be removed. Care needs to be taken to ensure that the coupons are not bent or distorted. Specimens made using such coupons can have an adverse effect on the test results and increase scatter. The dimensions of the coupons for the different specimens are given in the relevant tables.

If the design under consideration uses extrusions or cast material, then the specimens should also be made using extruded profiles or cast material, e.g. aluminium and magnesium alloys as required by the design.

5.3.2 Bending and forming

The bending of the components of the specimens shall be performed in a press brake to the required bending angle and radius, r_{min} = 2*t*. If the material employed does not allow this radius, it may be bent to the r_{max}. Since the accuracy of the specimens depends on the dimensions of the coupons, to ensure that the tolerances given in the tables are strictly adhered.