
**Resistance welding — Weldability —
Part 3:
Evaluation procedures for weldability
in spot weld bonding**

Soudage par résistance — Soudabilité —

Partie 3: Méthodes d'évaluation de l'aptitude au soudocollage par points

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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).

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).

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

For an explanation on 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 the following URL: 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*.

A list of all parts in the ISO 18278 series can be found on the ISO website.

Requests for official interpretations of any aspect of this document should be directed to the Secretariat of ISO/TC 44/SC 6 via your national standards body. A complete listing of these bodies can be found at www.iso.org.

Introduction

This document describes procedures for evaluating the weldability of weld bonding using the resistance spot welding process by determining the welding current range and electrode life.

These procedures can be used to evaluate the following:

- a) the effect of electrode material, shape, dimensions and electrode cooling;
- b) the effect of material types and thicknesses and coatings being welded;
- c) the effect of welding conditions;
- d) the effect of welding equipment;
- e) the effect of adhesive on welding.

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Resistance welding — Weldability —

Part 3:

Evaluation procedures for weldability in spot weld bonding

1 Scope

This document specifies procedures for the determination of the acceptable welding current range and the electrode life for spot weld bonding using resistance spot welding with adhesive bonding.

This document is applicable for the evaluation of the weldability of prepared assemblies of uncoated and coated metal sheets with individual thicknesses from 0,4 mm to 6,0 mm.

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 669, *Resistance welding — Resistance welding equipment — Mechanical and electrical requirements*

ISO 5182, *Resistance welding — Materials for electrodes and ancillary equipment*

ISO 5821, *Resistance welding — Spot welding electrode caps*

ISO 14373, *Resistance welding — Procedure for spot welding of uncoated and coated low carbon steels*

ISO 17677-1, *Resistance welding — Vocabulary — Part 1: Spot, projection and seam welding*

ISO 18278-1:2015, *Resistance welding — Weldability — Part 1: General requirements for the evaluation of weldability for resistance spot, seam and projection welding of metallic materials*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 669, ISO 14373, ISO 17677-1 and ISO 18278-1 and the following apply.

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

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

3.1

spot weld bonding

resistance spot welding through an adhesive or sealant

3.2

substrate

material upon the surface of which an adhesive is spread for weld bonding

3.3

prepared assembly

set of components (substrates and adhesives) positioned prior to welding

3.4

wearing sheet

sheet which is used to produce electrode wear through continuous spot welding

4 Weld bonding equipment

4.1 General

Methods to characterize resistance welding equipment can be found in ISO 669.

The mass and friction of the movable electrode assembly can be determined in accordance with ISO 18278-1.

4.2 Adhesive dispensing equipment

The adhesive dispensing equipment shall be defined by agreement between the contracting parties.

4.3 Storage chamber

The storage chamber shall have a temperature regulation system that is sufficient to maintain the properties of the adhesive or sealant, as required by the manufacturer of the adhesive or sealant.

4.4 Electrodes

The electrode materials shall be as defined in ISO 5182. Their geometry shall be defined according to ISO 5821.

4.5 Welding current

The type of welding current used (alternating current or direct current) shall be specified before testing and recorded. Constant current control settings shall be used.

When using AC resistance welding equipment, it shall be set so that welding current is not less than 30 % of R.M.S. value at full conduction angle.

4.6 Mechanical settings

The mechanical settings shall be chosen to limit the impact of the electrode meeting the sheet.

To limit the impact of the electrode an electrode approach speed of 0,15 m/s is recommended and/or the peak force should be less than 150 % of the nominal electrode force.

The machine squeeze time should be of sufficient duration to overcome electrode bounce effects and machine inertia so as to allow the electrode force to build up to the required value before the welding current is initiated.

4.7 Measurement of parameters

4.7.1 Temperature

The ambient temperature shall be measured.

4.7.2 Amount of adhesive applied

Measurement of the amount of adhesive applied shall be carried out as defined by the contracting parties.

For example, measurements can be performed using a calliper gauge, scale magnifier or by relative weighing.

4.7.3 Welding current and electrode force

Measurement of welding current and electrode force shall be in accordance with ISO 18278-1:2015, 5.3.

4.7.4 Electrode cooling water flow rate

Since water cooling significantly influences electrode life, the inlet water temperature should be maintained at 20 °C and shall not exceed 30 °C. A separate water supply should be used for each electrode, and the water flow rate for each electrode shall be a minimum of 4 l/min. The water cooling tube should be arranged to ensure that the water directly cools the electrode.

Dimensions of the water cooling holes and pipes shall comply with the relevant requirements of the appropriate ISO Standard for various electrode types. The distance between the back and working face of the electrode should not exceed the values given in ISO 5821 which specifies electrode dimensions.

Any deviations shall be recorded.

All machine and water cooling details shall be recorded in the format presented in [Clause 9](#).

4.8 Measurement of results

4.8.1 Weld diameter

After destructive testing, the weld diameter shall be measured according to ISO 17677-1.

4.8.2 Detection of expulsion

Occurrence of expulsion shall be determined by

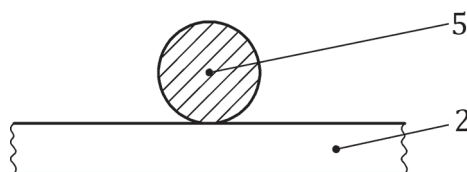
- the electrode displacement curve,
- the welding voltage signal,
- the welding force signal, or
- visually.

In the latter case, expulsion shall be confirmed by visual examination after destructive testing. For steel sheets, an expulsion is characterized by a very sharp deviation in the trace of an electrode displacement or welding voltage signal.

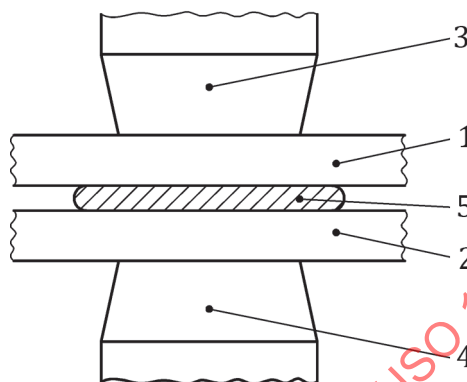
5 Assembly preparation

The weld bonding shall be set up according to the indications given in [Figure 1](#). The amount and pattern of adhesive applied shall be agreed between the contracting parties.

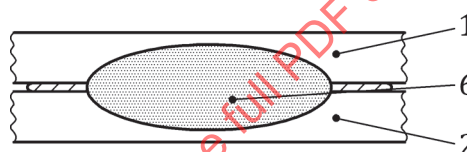
a) Just after adhesive application



b) Prepared assembly under application of electrode force, just before



c) After welding



Key

- | | | | |
|---|-----------------|---|-----------------|
| 1 | upper sheet | 4 | lower electrode |
| 2 | lower sheet | 5 | adhesive |
| 3 | upper electrode | 6 | nugget |

Figure 1 — Stages during spot weld bonding

To ensure reproducible test conditions, it is necessary to define the adhesive characteristics and dispensing conditions; see 9.1 a) to f).

6 Preliminary adjustments

6.1 Electrode alignment

Electrode alignment shall be checked. This may be accomplished by the methods suggested in Annex A.

Eccentricity (see ISO 669) should be less than 0,5 mm. This may be checked using the carbon imprint method where a sheet of paper is sandwiched between two carbon papers inserted between the two caps after which the electrode force is applied. Examples of carbon imprints obtained on the paper sheet after application of pressure are shown in Figure A.1.

Angular deflection (see ISO 669) should not exceed 5°. A method using a tube is described in Figure A.2.

6.2 Electrode conditioning

Electrodes shall not be conditioned.

7 Determination of the welding current range

7.1 Test specimens

The geometry of test specimens shall be defined for a given welding current range test. Recommended geometries are those for single spot specimens defined in relevant International Standards, especially cross-tension specimens (ISO 14272), tensile-shear specimens (ISO 14273), torsion specimens (ISO 17653), mechanized peel specimens (ISO 14270) or chisel/peel test specimens (ISO 10447). In the case of the chisel test, the specimens shall have a minimum size of 40 mm × 40 mm with at least 35 mm overlap.

The spot weld shall be aligned with the median line of the adhesive bead.

For non-conductive adhesives, shunting may be necessary to initiate current flow through the adhesive. Tensile-shear and cross-tension specimens welding procedures with shunt are shown in [Annex B](#).

Cross-tension, peel and chisel specimens are recommended to obtain accurate weld diameter measurements.

7.2 Welding parameters

Appropriate welding parameters shall be specified in the instructions or in the test order form. Proposed sets of welding parameters for steel assemblies are given in [Annex C](#).

7.3 Test procedure

Starting with a level sufficiently low to be under any welding condition, the welding current is increased in 200 A steps and never decreased. Three test specimens shall be prepared and welded for each current setting, two will be used for destructive testing and the third will be kept in reserve, for example, for metallographic analysis.

When splashing occurs, the test shall be continued until the welding current reaches 10 % above the current after splashing first occurred.

Destructive testing and measurement of the weld diameter shall be performed according to [4.8.1](#) and the information supplied in [7.1](#).

For the purpose of the welding current range determination, only the weld diameter is needed, therefore, adhesive curing is not required before destructive testing.

7.4 Current range criteria

The minimum weld diameter shall be specified in the instructions.

NOTE This minimum weld diameter can be equal to $3,5\sqrt{t}$, t being the thickness of the thinnest sheet of the assembly.

The upper end of the welding current range, $I_{\max}$, is defined as the maximum current setting for which at least two out of three spot welds show no splash and all current settings below satisfy the same condition.

The lower end of the welding current range, $I_{\min}$, is defined as the minimum current setting for which both spot weld specimens which are destructively tested will have a diameter equal or greater than the defined minimum, and all current settings above until $I_{\max}$ satisfy the same condition.

7.5 Three sheet and multiple stack-ups

In such cases, each interface shall be considered individually. Therefore, the shape and number of test specimens shall be adapted to test each interface separately (i.e. in the case of instrumented testing, two specimens per interface and one in reserve for metallographic analysis).

The minimum weld diameters shall be defined for each interface of the stack-up, and the lower end of the welding current range is defined when every interface reaches its own minimum weld diameter condition.

The upper end of the welding current range is defined when every interface matches the no-splashing condition.

8 Estimation of electrode life

8.1 Test specimens

Two types of specimens are to be welded during this test:

- a) wearing sheets (e.g. dimensions 300 mm × 400 mm);
- b) test strips for weld testing. The size of these strips can be chosen depending on the means used for destructive testing; however, the overlap area shall be at least 40 mm × 300 mm. [Figure D.1](#) and [Figure D.2](#) give examples of a test strip and a device for simultaneously separating 10 spot welds. Since the first spot weld is not used in the analysis, it can be welded without adhesive, if shunting is necessary to initiate current flow.

8.2 Welding parameters

The welding current shall be set at $I_{\max}$ as determined during a welding current range test on the same stack-up, the other parameters being defined in the instructions or in the test order form. New electrodes shall be installed before this test.

NOTE Proposed sets of welding parameters for steel stack-ups are given in [Annex C](#).

8.3 Procedure

The test sequence is as follows:

- a) first test strip: 10 welds
If splashing occurs on three consecutive welds, the testing current shall be reduced by 100 A. If splashing still occurs on the three next welds, then the test shall be restarted at $I_{\max} - 200$ A;
- b) 40 welds continuously on wearing sheets;
- c) 10 welds on subsequent test strips;
- d) 40 welds continuously on wearing sheets;
- e) repeat c) and d) until 400 welds;
- f) 10 welds on a test strip;
- g) 90 welds continuously on wearing sheets;
- h) repeat f) and g) until ending conditions are reached.

The testing procedure shall be performed in a continuous mode, ideally on the same day.

For b), d) and g), a welding rate of 30 spots per minute is recommended for thin sheet material; see [Table C.1](#) for details in the case of steel sheets.

The test settings are given in [Table 1](#).

Table 1 — Settings for spot weld production

Weld pitch	30 mm
Edge distance	15 mm
Precision of weld positioning on the test strips	±5 mm

After welding, each test strip shall be tested destructively, and the weld diameters of the eight central spots shall be measured. The test shall be continued until at least four spots out of eight show a no-weld condition (weld diameter equal to zero). Other ending conditions may be defined.

The test shall be performed without tip dressing and current stepping control.

8.4 Test criteria, interpretation of results

Electrode life is defined as the last weld number of a test strip before reaching more than two welds out of eight below a minimum weld diameter defined by the contracting parties.

The electrode wear can be evaluated by

- the overall reduction in length of the electrodes, which can also be followed in-line by using displacement sensors,
- tip profile and diameter through carbon imprints or by using optical devices, or
- the change in mass of the electrode.

NOTE This minimum weld diameter can be equal to $3,5\sqrt{t}$, t being the thickness of the thinnest sheet of the assembly.

9 Test report

9.1 General

The test report shall include data about stack-up being welded (e.g. sheet thicknesses, materials, coatings) and welding parameters [e.g. machine type, machine reference, current type (alternating current or direct current), electrode type, electrode force, welding cycle, inlet cooling water temperature and flow rate]. See ISO 15609-5 for further details.

The test report shall also include all information that facilitates interpretation, especially anomalies such as sticking of the electrodes to the sheet, etc. and the following information:

- a) substrate conditions (grade, thickness, coating, oiling, surface treatments, oxides, etc.);
- b) type of adhesive and applicable details;
- c) process by which the adhesive is applied (extruded, sprayed, etc.);
- d) amount of deposited adhesive (volume, diameter, weight, etc.) per specimen;
- e) pattern of deposited adhesive;
- f) deposition temperature of the adhesive, if relevant;
- g) storage conditions of the prepared test specimens before starting the spot welding operation:
 - 1) delay between preparation of the first substrate and its matching with the second substrate;

- 2) storage temperature of the prepared assemblies in the storage chamber;
- 3) time lapse and storage temperature between spot welding and mechanical testing;
- 4) any other relevant information.

9.2 Welding current range

The test report shall include the minimum and maximum welding currents, defining the welding current range.

In addition, for each individual spot weld, the following information shall be recorded:

- welding current;
- diameter of the weld and failure type obtained as defined in ISO 17677-1;
- maximum load in case of instrumented mechanical testing;
- splashing and electrode sticking (if any);
- any useful information about the degradation of the adhesive after weld bonding.

An example of a typical data sheet is given in [Annex E](#).

9.3 Electrode life

The test report shall include the electrode life obtained and the welding current used for the test.

In addition, the following information shall be recorded:

- individual weld diameter as a function of the number of spot welds on test strips;
- splashing and electrode sticking (if any);
- change in weld current during the test (if applied).

An example of a typical data sheet is given in [Annex E](#).

Annex A (informative)

Electrode alignment

There are many methods that can be used to check the alignment of electrodes. This annex shows two possibilities (see [Figure A.1](#) and [Figure A.2](#)).

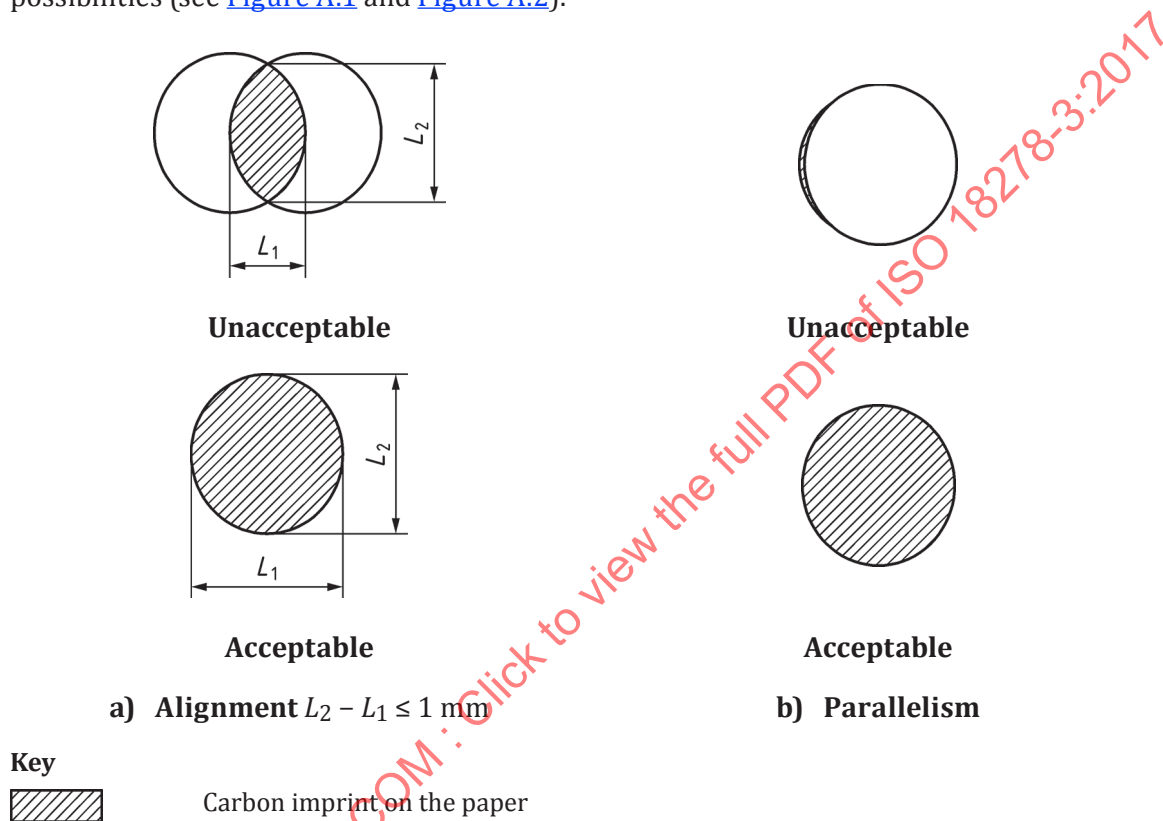


Figure A.1 — Acceptance criteria for the electrode alignment

The use of type C0 electrode caps (see ISO 5821) is recommended.

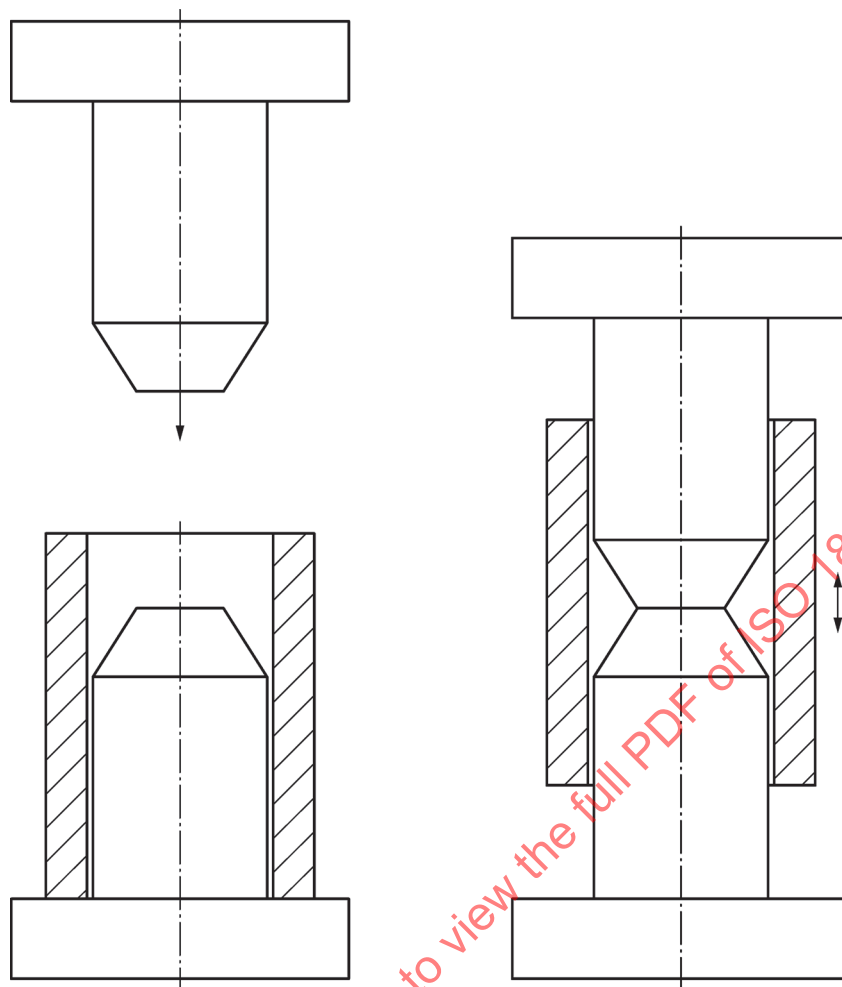


Figure A.2 — Tube method

Annex B (informative)

Specimens with current shunt

B.1 Cross-tension specimens

Cross-tension prepared assemblies can be positioned for welding in an insulating template as described in ISO 14272.

All cutting burrs should be first removed from the coupons to avoid any unwanted shunting, and corner cutting is also recommended (see [Figure B.1](#)).

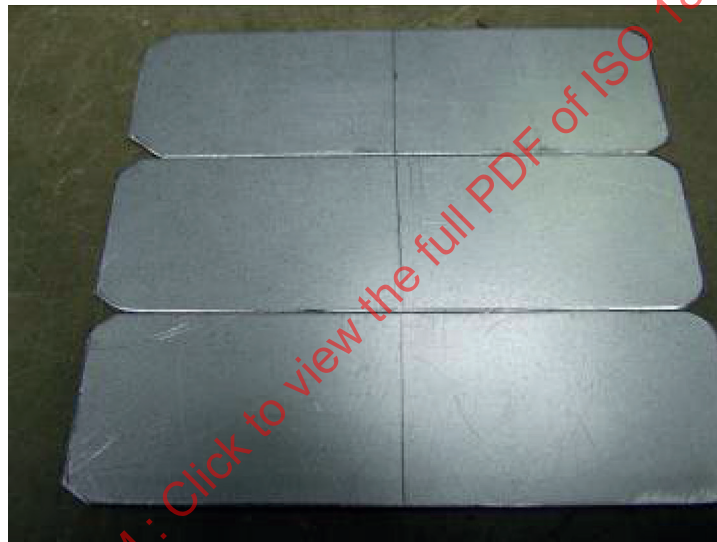


Figure B.1 — Prepared coupons for spot weld bonding

To ensure shunting during welding, copper bars with corresponding holes should be laid below the lower coupon and above the upper coupon, and electrically linked through a shunt cable (see [Figure B.2](#)). A clamping system should maintain the prepared assembly and the copper bars together during welding.

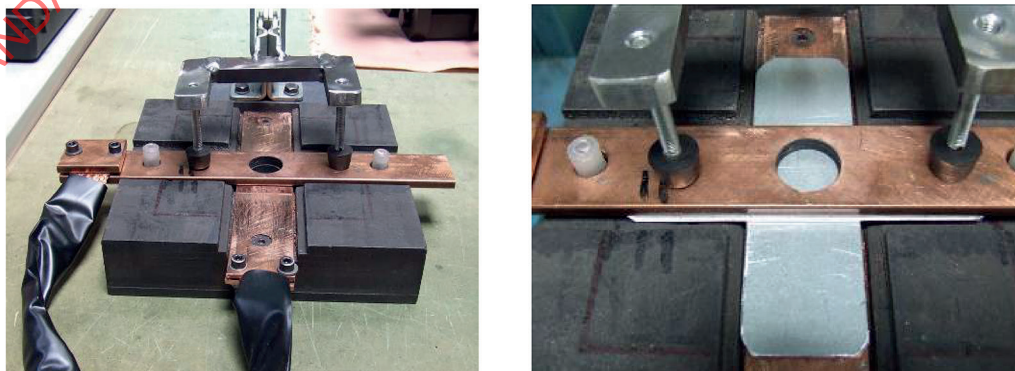


Figure B.2 — Electrically linked copper bars to ensure shunting during spot weld bonding of cross-tension specimens

B.2 Tensile-shear specimens

Tensile-shear specimens defined in ISO 14273 should be obtained through cutting after welding.

Two sheets should be prepared with a width equal to the individual coupon length, l_t , defined in ISO 14273, and a length being a multiple of the individual coupon width, b , defined in ISO 14273; see [Figure B.3](#).

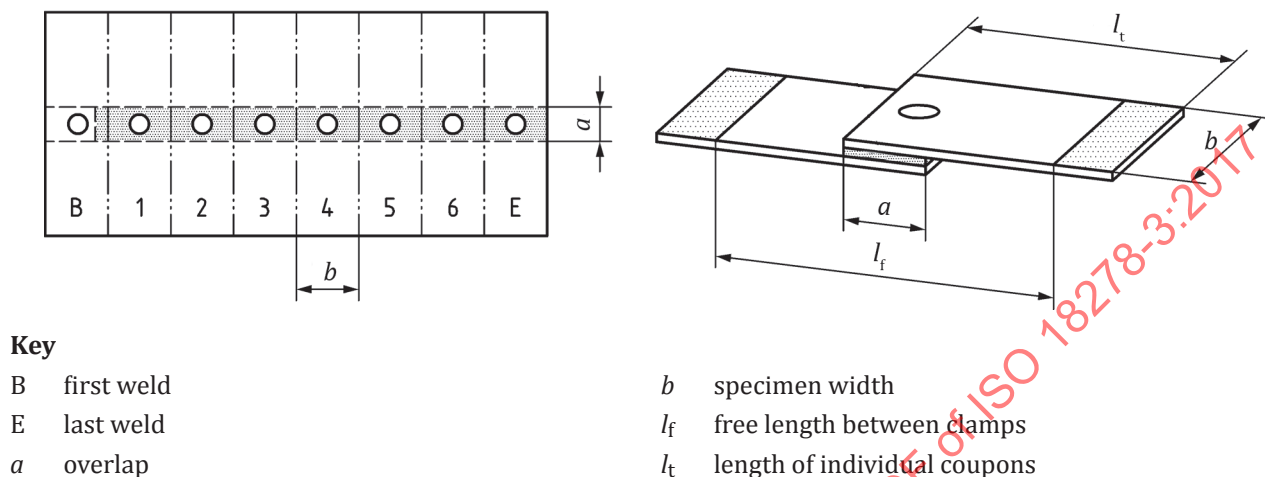


Figure B.3 — Tensile-shear specimen's geometry using non-conductive adhesives

The adhesive should be applied only along a part of the sheet, with a zone without adhesive. The first weld is therefore made without adhesive, and acts as a shunt weld for the weld bonding of the subsequent welds.

Annex C (informative)

Specific conditions for steel sheet customer qualification

C.1 Purpose

For the qualification of a new grade of steel or a new coating, the customer can ask the producer to characterize the weldability of its product. The general conditions of the method can be applied together with the following specific conditions.

C.2 Single side coatings

In the case of single side coated sheets, the coating position in the stack up should be reported (external coating, internal coating, alternating coating).

C.3 Welding parameters

The electrodes shall be of type A 2/2 material as defined in ISO 5182. Welding parameters for different steel sheet configurations are specified in [Table C.1](#). [Table C.2](#) gives maximum electrode diameter, electrode force, welding time and hold time which can be used for high-strength steels (UTS ≥ 600 MPa) if nominal parameters from [Table C.1](#) give unsatisfactory results.

C.4 Minimum weld diameter

The minimum weld diameter is used to evaluate the lower end of the welding range and the end of electrode life. It can be defined as [Formula C.1](#):

$$x \times \sqrt{t} \tag{C.1}$$

where

t is the thinner sheet thickness;

x is the coefficient to be defined (usually between 3 and 4,5).

Table C.1 — Welding parameters for steel sheets

Sheet thickness ^a mm	Electrode type acc. to ISO 5821 mm	Electrode force ^c kN		Number of impulses	Weld time ms			Hold time ms	Welding rate for electrode life test welds per min
					Individual weld time ^{b, c}		Cool time		
0,5 to 0,54	F1 16x6	1,70	2,10	1	100 + X	120 + X	—	120	30
0,55 to 0,64	F1 16x6	1,90	2,30	1	120 + X	140 + X	—	120	30
0,65 to 0,74	F1 16x6	2,10	2,60	1	140 + X	160 + X	—	140	30
0,75 to 0,84	F1 16x6	2,30	3,00	1	160 + X	180 + X	—	140	30
0,85 to 0,94	F1 16x6	2,50	3,50	1	180 + X	200 + X	—	160	30
0,95 to 1,09	F1 16x6	2,70	3,50	1	200 + X	220 + X	—	180	30
1,10 to 1,34	F1 16x6	3,00	4,00	1	240 + X	280 + X	—	200	30
1,35 to 1,64	F1 16x6	4,00	4,50	1	300 + X	340 + X	—	260	30
1,65 to 1,89	F1 20x8	4,50	5,00	3	140 + X	160 + X	40	320	20
1,90 to 2,24	F1 20x8	4,50	5,00	4	120 + X	140 + X	40	360	20
2,25 to 2,74	F1 20x8	5,00	6,00	5	120 + X	140 + X	40	460	20
2,75 to 3	F1 20x8	5,50	6,50	5	140 + X	160 + X	40	520	20

NOTE This table is compiled using 50 Hz.

^a When welding two sheets of unequal thickness, the thinner sheet determines the welding parameters. When welding a three sheets stack to up, the thinner of the two thicker sheets determines the weld parameters.

^b Add X = 40 ms to the individual weld time when at least one coating is present at one faying interface of the assembly.

^c When sheets with differing UTS are welded together, choose the highest UTS of the assembly to set weld time and electrode force.

NOTE This table is compiled using 50 Hz.

^a When welding two sheets of unequal thickness, the thinner sheet determines the welding parameters. When welding a three sheets stack to up, the thinner of the two thicker sheets determines the weld parameters.

^b Add X = 40 ms to the individual weld time when at least one coating is present at one faying interface of the assembly.

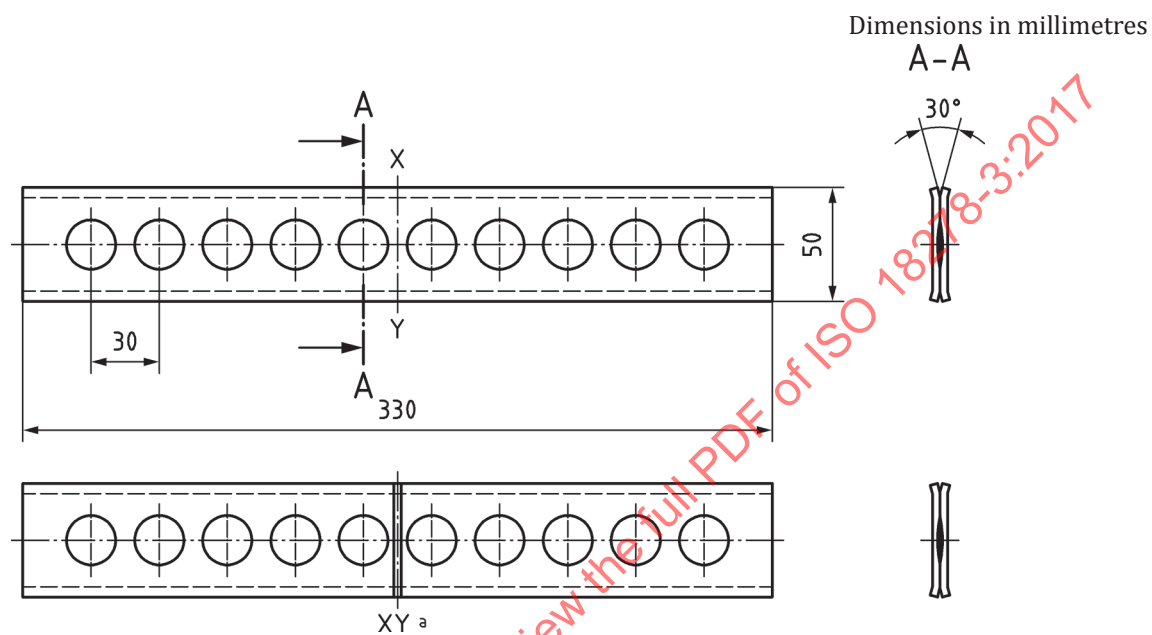
^c When sheets with differing UTS are welded together, choose the highest UTS of the assembly to set weld time and electrode force.

**Table C.2 — Optional maximum welding parameters for advanced high-strength steel sheets
(UTS ≥ 600 MPa)**

Sheet thickness mm	Maximum electrode face diameter mm	Maximum electrode force kN	Maximum weld time ms	Maximum hold time ms
0,5 to 0,54	6	2,10	240	240
0,55 to 0,64	6	2,30	240	240
0,65 to 0,74	6	2,60	320	320
0,75 to 0,84	6	3,00	320	320
0,85 to 0,94	6	3,80	320	320
0,95 to 1,09	6	4,00	400	400
1,10 to 1,34	6	4,50	500	500
1,35 to 1,64	8	5,50	800	500
1,65 to 1,89	8	6,00	900	500
1,90 to 2,24	8	6,50	1 100	500
2,25 to 2,74	10	7,00	1 200	600
2,75 to 3	10	7,50	1 400	700
These parameters are maximum values that may be used in case of unsatisfactory results obtained for standard parameters given in Table C.1 .				

Annex D (informative)

Specimens for destructive testing



a Cut centre.

Figure D.1 — Example of test strip