
**Friction stir spot
welding — Aluminium —**

**Part 4:
Specification and qualification of
welding procedures**

Soudage par friction: malaxage par points — Aluminium —

Partie 4: Descriptif et qualification des modes opératoires de soudage



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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).

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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 the IIW, *International Institute of Welding*, Commission III, *Resistance welding, solid state welding and allied joining processes*.

Any feedback, question or request for official interpretation related to any aspect of this document should be directed to IIW via your national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

A list of all parts in the ISO 18785 series can be found on the ISO website.

Introduction

Welding processes are widely used in the fabrication of engineered structures. During the second half of the twentieth century, fusion welding processes, wherein fusion is obtained by the melting of parent material and usually a filler metal, dominated the welding of large structures. In 1991, friction stir welding (FSW), which is carried out entirely in the solid phase (no melting), was invented.

Friction stir spot welding (FSSW) processes are spot-like variants of the FSW process. Unlike FSW, there is minimal or no traverse motion of the tool. In basic FSSW, the joint is created by plunging a rotating tool into the work piece and retracting the tool out of the overlapping sheets. Other FSSW variants include additional tool movements. Frictional heat is generated from the contact between the tool and the material to be welded resulting in softening of this material. The softened material is stirred to form a metallurgical connection which is aided by the forge action applied by the tool shoulder contacting the upper sheet surface.

The increasing use of FSSW has created the need for a FSSW standard in order to ensure that welding is carried out in the most effective way and that appropriate control is exercised over all aspects of the operation. The ISO 18785 series focuses on the FSSW of aluminium because, at the time this document was developed, the majority of commercial applications for FSW involved aluminium. Examples include railway cars, consumer products, food processing equipment, automotive components, aerospace structures, and marine vessels.

To be effective, welded structures should be free from serious problems in production and in service. To achieve that goal, it is necessary to provide controls from the design phase through material selection, fabrication, and inspection. For example, poor design can create serious and costly difficulties in the workshop, on site, or in service. Incorrect material selection can result in welding problems such as cracking. Welding procedures need to be correctly formulated and approved to avoid imperfections. To ensure the fabrication of a quality product, management needs to understand the sources of potential trouble and introduce appropriate quality and inspection procedures, and supervision should be implemented to ensure that the specified quality is achieved.

The International Organization for Standardization (ISO) draws attention to the fact that it is claimed that compliance with this document may involve the use of patents concerning friction stir welding given in [Clauses 5](#) to [7](#).

ISO takes no position concerning the evidence, validity and scope of this patent right. The holders of this patent right have assured ISO that they are willing to negotiate licenses under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statement of the holder of this patent right is registered with ISO. Further information may be obtained from:

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Friction stir spot welding — Aluminium —

Part 4: Specification and qualification of welding procedures

1 Scope

This document specifies the requirements for the content of welding procedure specifications for the Friction Stir Spot welding (FSSW) of aluminium.

In this document, the term "aluminium" refers to aluminium and its alloys

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 10447, *Resistance welding — Testing of welds — Peel and chisel testing of resistance spot and projection welds*

ISO 14270, *Resistance welding — Destructive testing of welds — Specimen dimensions and procedure for mechanized peel testing resistance spot, seam and embossed projection welds*

ISO 14271, *Resistance welding — Vickers hardness testing (low-force and microhardness) of resistance spot, projection, and seam welds*

ISO 14272, *Resistance welding — Destructive testing of welds — Specimen dimensions and procedure for cross tension testing of resistance spot and embossed projection welds*

ISO 14273, *Resistance welding — Destructive testing of welds — Specimen dimensions and procedure for tensile shear testing resistance spot and embossed projection welds*

ISO 17653, *Resistance welding — Destructive tests on welds in metallic materials — Torsion test of resistance spot welds*

ISO 18785-1, *Friction stir spot welding — Aluminium — Part 1: Vocabulary*

ISO 18785-5, *Friction stir spot welding — Aluminium — Part 5: Quality and inspection requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 18785-1 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/>

4 Development and qualification of welding procedures

4.1 General

Qualification of welding procedures shall be performed prior to production welding.

The manufacturer shall prepare a preliminary welding procedure specification (pWPS) and shall ensure that it is applicable for production using experience from previous production jobs and/or the general fund of knowledge of welding technology.

A pWPS shall be used as the basis for the establishment of a welding procedure qualification record (WPQR). The pWPS shall be tested in accordance with one of the methods listed in [Clause 5](#) (welding procedure test), or [Clause 7](#) (pre-production welding test). [Clause 5](#) shall be used when the production part or joint geometry is accurately represented by a standardized test piece or pieces, as specified in [5.2](#). However, [Clause 5](#) shall be used when the production part or joint geometry is not accurately represented by the standardized test pieces, as specified in [5.2](#). The information required in a pWPS is given in [4.2](#).

For some applications, it may be necessary to supplement or reduce the list. All relevant information shall be specified in the WPS.

Once a pWPS has been qualified, the manufacturer shall prepare a Welding Procedure Specification (WPS) covering a range of parent material thicknesses, including tolerances, as well as a range of aluminium alloys.

An example of a pWPS form is shown in [Annex A](#).

4.2 Technical content of a pWPS

The following information, as a minimum, shall be included in a pWPS.

4.2.1 Manufacturer information

- identification of manufacturer;
- identification of pWPS.

4.2.2 Composition of parent material

- designation of the material(s) and reference standard(s);
- when coatings are applied the following may include: type, thickness, number of faces, control document.

4.2.3 Dimensions of material

- thickness of materials comprising the welded joint.

4.2.4 Welding method

Process parameters are unique to each process variant (see corresponding annexes for details).

- basic (includes probe-less) FSSW (see [Annex A](#));
- refill FSSW (see [Annex A](#) and [Annex B](#));
- swing FSSW (see [Annex A](#) and [Annex B](#));
- swept FSSW (see [Annex A](#) and [Annex B](#));

- stitch FSSW (see [Annex A](#) and [Annex B](#)).

4.2.5 Machine specifications

- type or model;
- manufacturer;
- auxiliary equipment.

4.2.6 Tool identification

- material;
- drawing or drawing number or identification number.

4.2.7 Clamping processes and conditions

- method and type of jiggling, fixtures, rollers and backing support (dimensions and material);
- tool and fixture heating/cooling (internal, external, cooling medium), if applicable;
- tacking arrangement.

4.2.8 Joint design

- overlap;
- edge distance;
- joint stack-up;
- sealant and/or adhesive (type, grade, location, dimension);
- tool plunge side.

NOTE A sketch of the welded joint can be used to show the joint design/configuration.

4.2.9 Joint preparation and cleaning methods

- cleaning procedure (degreasing, wire brushing, chemical etching, etc.);
- pre-weld heat treatment procedure, if applicable.

4.2.10 Welding technique

- mechanized, automatic welding;
- procedures to minimize distortion, indentation, contamination, corrosion, etc.

Operator protection shall be taken into consideration.

4.2.11 Post-weld processing

- stress relieving (or other methods to correct distortion);
- removal of flash, or any other mechanical post weld processing of the weldment;
- post-weld heat-treatment (temperature range and minimum time for post-weld heat treatment or ageing shall be specified or reference shall be made to other standards which specify this information).

5 Qualification based on a welding procedure test

5.1 General

The welded assembly, to which the welding procedure will relate to in production, shall be represented by actual components, subscale test components or by preparing a standardized test piece in accordance with 5.2.

If required by the application standard, the direction of plate rolling shall be marked on the test piece.

5.2 Standardized test piece

The joint geometry and dimensions of standardized test pieces shall be in accordance with the appropriate document: ISO 10447, ISO 14270, ISO 14271, ISO 14272, ISO 14273 or ISO 17653.

5.3 Welding of components, subscale test components or test specimens

Preparation and welding of actual components, subscale test components or standardized test pieces shall be carried out in accordance with a pWPS, and under the general conditions of production welding (parameters, equipment, etc.) which they shall represent.

Welding and testing of the test pieces shall be witnessed by an examiner or examining body and the details of this shall be established before any qualification is undertaken.

6 Examination and testing

6.1 Visual testing

6.1.1 General

Test pieces shall be visually examined in accordance with ISO 18785-5.

6.1.2 Re-testing

If any test piece fails visual testing, an additional test piece shall be welded, under the same conditions as the original, and subjected to the same examination. If visual testing of the additional test piece fails, the welding procedure test has failed.

6.2 Destructive testing

6.2.1 General

Test specimens shall be cut from the actual components, standardized test pieces, or subscale test components.

Depending on the joint geometry and loading conditions, the shape and dimensions of the test pieces and test specimen and the test procedures shall be in accordance with the appropriate document: ISO 10447, ISO 14270, ISO 14271, ISO 14272, ISO 14273, or ISO 17653.

6.2.2 Re-testing

If any test specimen fails to comply with the requirements for destructive testing, two further test specimens shall be tested for each one that failed.

Additional test specimens shall be taken from the same test piece if there is sufficient material or from a new test piece welded under the same conditions as the original. Each additional test specimen shall

be subjected to the same tests as the initial test specimen that failed. If either of the additional test specimens fails to comply with the requirements, then the welding procedure test has failed.

6.3 Macrosection

Test specimens shall be prepared and etched to produce cross-sections in order to clearly show the stir zone and, if necessary, the weld profile.

6.4 Range of qualification

6.4.1 General

All the conditions of validity stated below shall be met independently of each other.

Additions, deletions or changes outside the ranges specified shall require a new welding procedure test to be performed.

6.4.2 Related to the manufacturer

A qualification of a WPS obtained by a manufacturer is valid for welding in workshops or sites under the same technical and quality control of that manufacturer.

Welding is under the same technical and quality control when the manufacturer who qualified the WPS retains complete responsibility for all welding carried out to it.

6.4.3 Related to the material

All tests shall be carried out with materials that are representative of those used in production. The following characteristics shall be consistent for the production and test materials:

- thickness;
- alloy and temper;
- surface condition and treatments if required.

Any modification shall be established before any qualification is undertaken.

6.4.4 Common to all welding procedures

6.4.4.1 Welding process

The qualification only applies to the welding procedure used in the welding procedure test.

Any variations in the welding parameters shall be within the range of machine performance specified in the WPS.

6.4.4.2 Type of control method

The WPS is only qualified for the type of control method used in the welding procedure qualification.

6.4.4.3 Type of weld equipment

The WPS is only qualified for the weld equipment of the same machine specifications used in the welding procedure qualification (see [4.2.5](#)).

6.4.4.4 Welding tools

The WPS is only qualified for the tool identification used in the welding procedure qualification (see [4.2.6](#)).

6.4.5 Other variables

The range of qualification for other variables shall be specified in the WPS.

7 Qualification based on pre-production welding test

7.1 General

The pre-production welding test shall be carried out in accordance with the relevant subclauses of [Clause 6](#), unless modified by [7.2](#) to [7.5](#).

Fulfilling the requirements of this document may also qualify the welding personnel (see ISO 18785-3).

7.2 Test pieces

Preparation and welding of test pieces shall be performed under the general conditions of production welding. The test pieces shall be designed such that their shapes and dimensions simulate the actual welding conditions of the structure. This includes welding positions and other essential items (for example, stress conditions, heating effects, limited access, and edge condition).

When actual components are used, jigs and fixtures shall be those that will be used in production.

7.3 Examination and testing of test pieces

The test pieces shall be tested in accordance with the relevant part of [Clause 6](#).

The following tests, as a minimum, shall be performed:

- visual testing (100 %);
- macroscopic examination (the number depends on the geometry of the structure).

7.4 Range of qualification

Any WPS issued in accordance with this document is limited to the type of joint used in the pre-production welding test.

The range of qualification is generally in accordance with [6.2](#) for welding.

7.5 Welding procedure qualification record

A standard format for the WPQR shall be used. An example of a WPQR form is shown in [Annex C](#).

Annex A

(informative)

Example format for a welding procedure specification

Manufacturer:	Date:
Address:	Manufacturer's pWPS No.:
Welding operator:	Manufacturer's WPQR No.:
Weld setter:	Customer:
Weld variant:	Governing specification:
Welding:	Weld program:
Material details	
Alloy 1:	Alloy 2:
— Temper:	— Temper:
— Thickness:	— Thickness:
— Coating:	— Coating:
— Coating details:	— Coating details:
Joint and quality details	
Joint configuration:	Joint drawing No.:
Joint preparation:	Clamping details:
Sealant/adhesive details:	Anvil material/condition:
Spot dimension:	Testing requirement(s):
Weld equipment details	
Machine manufacturer:	Tool design:
Model:	Tool drawing number:
Auxiliary equipment:	Tool material:
Fixture heating/cooling:	Tool heating/cooling:
Weld parameters	
RPM:	Plunge depth:
Plunge speed:	Dwell:
Control method:	Commanded value:
Welding time (s):	
Post-weld operations	
Flash removal:	Heat treatment:
Other requirements:	
Approved by:	Title:
	Date:

Annex B (informative)

Additional variables to be considered in WPS's for FSSW variants

B.1 Refill FSSW

Clamping ring force:	Shoulder or probe plunge:
Shoulder rotation speed:	Shoulder rotation direction:
Probe rotation speed:	Probe rotation direction:
Shoulder plunge position/force:	Shoulder plunge speed:
Probe plunge position/force:	Probe plunge speed:

B.2 Stitch FSSW

Length of travel:	Weld width:
Travel speed:	Tool tilt:

B.3 Swept FSSW

Plunge location (centre/on path):	Periphery path rotation (°):
Diameter of the tool path, d_t :	Exit path rotation (°):
Major and minor axes for elliptical paths:	Exit path pitch/diameter:
Travel speed:	Tool tilt:

B.4 Swing FSSW

Swing radius/pivot axis:	Perpendicular spacing:
Swing length:	Longitudinal spacing:
Swing width:	Swing speed/travel speed:
Swing radius:	Swing angle/swing length:
Dwell time before swing:	Dwell time after swing:

Annex C (informative)

Example welding procedure qualification record forms

C.1 Welding procedure qualification — Test certificate

Manufacturer:	Date of welding:
Address:	
Welding operator:	Manufacturer's pWPS No.:
Weld setter:	Manufacturer's WPQR No.:
Weld variant:	Examiner/examining body:
Governing specification:	Examining body reference No:
Material details	
Alloy 1:	Alloy 2:
— Thickness:	— Thickness:
Joint details	
Joint configuration:	Joint Drawing No.:
Joint preparation:	Clamping details:
Welding equipment details	
Machine manufacturer:	Tool design:
Model:	Tool drawing number:
Other information:	
The signature below certifies that the welds were prepared welded and tested satisfactorily in accordance with the requirements and standards listed above.	
Examiner of examining body signature:	
Examiner of examining body printed name:	
Date of issue:	Location:

C.2 Record of weld test

Manufacturer:	Date of welding:
Address:	
Welding operator:	Manufacturer's pWPS No.:
Weld setter:	Manufacturer's WPQR No.:
Weld variant:	Examiner/examining body:
Governing specification	Examining body reference No:
Material details	
Alloy 1:	Alloy 2:
— Thickness:	— Thickness:
Joint details	
Joint configuration:	Joint drawing No.:
Joint preparation:	Clamping details:
Welding equipment details	
Machine manufacturer:	Tool design:
Model:	Tool drawing number:
Post-weld operations	
Flash removal:	Heat treatment:
Other information:	

Test details

Weld ID	Quality test	Pass/Fail	Remarks
1	Visual inspection		
2	Visual inspection		
3	Visual inspection		

Manufacturer signature:	
Manufacturer printed name:	
Date:	Location:
Examiner of examining body signature:	
Examiner of examining body printed name:	
Date:	Location: