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**Friction stir spot welding — Aluminium
— Part 2: Quality requirements, welding
procedures and welding personnel**

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Foreword

This Japanese Industrial Standard has been established by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee according to the proposal for establishment of Japanese Industrial Standard submitted by Japan Light Metal Welding Association (JLWA)/Japanese Standards Association (JSA) with a draft being attached, based on the provision of Article 12, paragraph (1) of the Industrial Standardization Act.

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JIS Z 3609 series consists of the following 2 parts under the general title *Friction stir spot welding — Aluminium —*:

Part 1: Vocabulary and welding processes

Part 2: Quality requirements, welding procedures and welding personnel

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Friction stir spot welding — Aluminium — Part 2 : Quality requirements, welding procedures and welding personnel

Introduction

This Japanese Industrial Standard has been prepared based on **ISO 18785-3** : 2018, Edition 1, and **ISO 18785-4** : 2018, Edition 1 and **ISO 18785-5** : 2018, Edition 1, with some modifications of the technical contents.

The dotted underlines indicate changes from the corresponding International Standards. A list of modifications with the explanations is given in Annex JA.

1 Scope

This Standard specifies quality requirements, welding procedure specification and its qualification, and qualification of welding personnel for friction stir spot welding (FSSW) process to be applied for aluminium and its alloys.

It specifies quality requirements related to FSSW but does not assign characteristic values to any specific semi-finished or finished product.

NOTE The International Standards corresponding to this Standard and the symbol of degree of correspondence are as follows.

ISO 18785-3 : 2018 *Friction stir spot welding — Aluminium — Part 3 : Qualification of welding personnel*

ISO 18785-4 : 2018 *Friction stir spot welding — Aluminium — Part 4 : Specification and qualification of welding procedures*

ISO 18785-5 : 2018 *Friction stir spot welding — Aluminium — Part 5 : Quality and inspection requirements* (Overall evaluation: MOD)

In addition, symbols which denote the degree of correspondence in the contents between the relevant International Standards and **JIS** are IDT (identical), MOD (modified), and NEQ (not equivalent) according to **ISO/IEC Guide 21-1**.

2 Normative references

Part or all of the provisions of the following standards, through reference in this text, constitute provisions of this Standard. The most recent editions of the standards (including amendments) indicated below shall be applied.

JIS Z 2305 *Non-destructive testing — Qualification and certification of NDT personnel*

NOTE Normative reference in the corresponding International Standard : ISO 9712 *Non-destructive testing — Qualification and certification of NDT personnel*

JIS Z 2343 (all parts) *Non-destructive testing — Penetrant testing*

NOTE Normative reference in the corresponding International Standard : ISO 3452 (all parts) *Non-destructive testing — Penetrant testing*

JIS Z 3090 *Visual testing method of fusion-welded joints*

NOTE Normative reference in the corresponding International Standard : ISO 17637 *Non-destructive testing of welds — Visual testing of fusion-welded joints*

JIS Z 3105 *Methods of radiographic examination for welded joints in aluminium*

NOTE The **JIS** cited above is not a corresponding standard to but equivalent to the normative reference in the corresponding International Standard in the contents relevant to this Standard.

JIS Z 3110 *Non-destructive testing of welded joints — Methods of radiographic testing for X- and gamma-ray techniques with digital detectors*

NOTE Normative reference in the corresponding International Standard : ISO 17636-2 *Non-destructive testing of welds — Radiographic testing — Part 2 : X-and gamma-ray techniques with digital detectors*

JIS Z 3136 *Specimen dimensions and procedure for shear testing resistance spot and embossed projection welded joints*

NOTE Normative reference in the corresponding International Standard : ISO 14273 *Resistance welding — Destructive testing of welds — Specimen dimensions and procedure for tensile shear testing resistance spot and embossed projection welds*

JIS Z 3137 *Specimen dimensions and procedure for cross tension testing resistance spot and embossed projection welded joints*

NOTE Normative reference in the corresponding International Standard : ISO 14272 *Resistance welding — Destructive testing of welds — Specimen dimensions and procedure for cross tension testing of resistance spot and embossed projection welds*

JIS Z 3144 *Routine test of resistance spot and projection welds*

NOTE The **JIS** cited above is not a corresponding standard to but equivalent to the normative reference in the corresponding International Standard in the contents relevant to this Standard.

JIS Z 3609-1 *Friction stir spot welding — Aluminium — Part 1 : Vocabulary and welding processes*

NOTE Normative reference in the corresponding International Standard : ISO 18785-1 *Friction stir spot welding — Aluminium — Part 1 : Vocabulary* and ISO 18785-2 *Friction stir spot welding — Aluminium — Part 2 : Design of weld joints*

ISO 17636-1 *Non-destructive testing of welds — Radiographic testing — Part 1 : X-and gamma-ray techniques with film*

ISO 17640 *Non-destructive testing of welds — Ultrasonic testing — Techniques,*

testing levels, and assessment

ISO 20807 *Non-destructive testing — Qualification of personnel for limited application of non-destructive testing*

3 Terms and definitions

For the purpose of this Standard, the terms and definitions given in **JIS Z 3609-1** apply.

4 Quality requirements

4.1 General

The requirements in **4.2** to **4.14** relate only to those aspects of product quality that may be influenced by FSSW.

4.2 Essential information of weld

The following shall be specified as appropriate for each weld :

- a) parent material specification(s), thickness(es), and temper(s);
- b) joint geometry/configuration;
- c) pre-weld surface condition, including any coatings and/or interface materials (sealant or adhesive);
- d) tool plunge side (hereafter including refill FSSW tool if refill FSSW is being applied);
- e) edge distance;
- f) orientation of asymmetric spot welds with respect to loading direction;

NOTE 1 It is shown that the following considerations are necessary for stitch FSSW (see **JIS Z 3609-1, 4.4**) and swing FSSW (see **JIS Z 3609-1, 4.6**) :

- whether the tool travel direction is parallel or perpendicular to the edge of the work piece;
- whether the tool advance or retract direction should coincide with the edge of the work piece [this makes a difference in the strength of the weld (see **JIS Z 3608, 4.1.4**)].

NOTE 2 It is shown that the following considerations are necessary for swept FSSW (see **JIS Z 3609-1, 4.5**) :

- pass shape (circular or elliptical) and size of the circle or ellipse;
- whether the tool advance or retract direction should coincide with the edge of the work piece;
- orientation of the longer diameter of the ellipse with respect to the edge of the work piece.

- g) weld finishing requirements.

4.3 Spot weld variables

4.3.1 Spot weld size

The diameter of a round spot weld, and if necessary, the major and minor dimensions of an elongated spot weld shall be listed on the engineering drawing.

4.3.2 Spot weld location

The location of the spot weld shall be controlled on the engineering drawing.

For an elongated spot weld, the orientation of the spot weld, in addition to location, shall be specified on the engineering drawing.

4.3.3 Spot weld strength

If specified, joint strength requirements listed on the engineering drawing shall be included in the WPS and are to be proven through designated destructive testing methods in accordance with c) to g) of 4.13.4. This can be done in conjunction with the qualification of the pWPS (see Clause 5).

4.4 Welding personnel

4.4.1 General

Manufacturers shall have at their disposal sufficient and competent personnel for the planning, performing and supervising of FSSW production operations in accordance with specified requirements.

4.4.2 Weld setter

Weld setters shall be qualified in accordance with Clause 6. Qualification records shall be kept up to date.

4.4.3 Welding operators

Welding operators shall, as a minimum, have received training in operation of welding equipment (including education regarding safety and other related matters) necessary for welding of the parts concerned. Welding operators do not need to be qualified.

4.5 Testing and inspection personnel

4.5.1 General

The manufacturer shall have sufficient and competent personnel for the planning, performing, and supervising of testing and inspecting operations during FSSW production operations in accordance with specified requirements.

4.5.2 Personnel performing non-destructive testing and visual testing

Non-destructive and visual testing personnel shall be qualified in accordance with JIS Z 2305 or ISO 20807 or equivalent.

When the use of an examination method not presently incorporated in these or equivalent standard(s) is specified, the manufacturer shall be responsible for developing the training program, written practice, examination, and practical demonstrations equivalent to the requirements of these standard(s). These shall establish the capability of the personnel performing the required examination.

4.5.3 Destructive testing personnel

Personnel performing destructive testing shall be trained for those test methods.

4.6 Equipment

4.6.1 Suitability of equipment

The equipment shall be adequate for the application concerned.

Welding unit (for example, welding equipment and FSSW tools) shall be capable of producing welds that do not exhibit any of the excessive imperfections given in Annex A. Acceptance levels shall be defined prior to commencing welding.

Welding equipment shall be maintained in good condition and shall be repaired or adjusted when a weld setter, welding operator, equipment inspector, or welding coordinator is concerned about the capability of the equipment to operate satisfactorily.

4.6.2 Equipment acquisition

After installation of new or refurbished equipment, tests shall be performed as agreed between the equipment manufacturer/supplier and user of the equipment. Such tests shall verify the equipment functions correctly.

4.6.3 Validation tests for qualified machine welding settings

Reproducibility tests shall be performed to demonstrate that the welding equipment can repeatedly produce welds that meet the acceptance levels. Acceptance levels shall be within the specified limit of the relevant requirements or the design specification. Validation tests shall be carried out when any of the following occurs :

- a) an event occurs that changes the functionality of the machine;
- b) repair or preventative maintenance of the machine that changes the functionality of the machine;
- c) equipment is upgraded or modified;
- d) equipment is dislodged or moved in a manner for which it was not designed;
- e) stationary equipment is moved from one location to another.

The reproducibility test shall be performed in accordance with a WPS (see 4.7) that is used in production for that machine.

A representative number of acceptable welds, at least three, shall be made and found satisfactory.

4.6.4 Equipment maintenance

The manufacturer shall have a documented plan for equipment maintenance.

The plan shall ensure that maintenance checks are performed on the equipment that controls variables listed in the relevant WPS(s). The maintenance plan may be limited to those items that are essential for producing welds that meet the quality requirements of this document.

Examples of these items are as follows :

- a) condition of guides and mechanised fixtures;
- b) condition of meters and gages that are used for the operation of the welding equipment;
- c) condition of cables, hoses, and connectors;
- d) condition of the control systems in mechanised and/or automatic welding equipment;
- e) condition of thermocouples and other temperature measurement instrument;
- f) condition of clamping rings, jigs, and fixtures.

Before welding, clamping rings, jigs, and fixtures that contact the work pieces shall be sufficiently free of contaminants (for example, oil, grease, and dirt) that can have a detrimental effect on the weld.

4.7 Welding procedure specification (WPS)

The welding coordinator, or the person responsible designated by the manufacturer shall ensure the WPS is used correctly in production.

NOTE See 5.1.2 and Annex B for preliminary welding procedure specification (pWPS).

4.8 Tool

4.8.1 Identification

The FSSW tool that is used in production shall be indelibly printed or stamped with its drawing or part number.

4.8.2 FSSW tool inspection

Before welding, the FSSW tool shall be sufficiently free of contaminants (e.g. oil, grease or dirt) that can have a detrimental effect on weld quality.

The correct tool geometry is critical for producing a quality FSSW weld. Because the FSSW tool wears with use, it shall be inspected for wear at appropriate intervals and in accordance with a written procedure.

The manufacturer shall determine the useful life of the FSSW tool, i.e. maximum number of spots, which shall be recorded on the WPS.

4.9 Pre-weld joint preparation and fit-up

4.9.1 Joint preparation

The faying surface shall be prepared in accordance with the WPS.

If sealants, adhesives or surface coatings are to be used, composition and application details shall be included on the manufacturer's WPS.

4.9.2 Pre-weld cleaning

Pre-weld cleaning shall be carried out in accordance with the WPS. Parent material

shall be sufficiently free of oils, grease, dirt, and any other contaminants that can have a detrimental effect on weld quality.

4.10 Thermal control

Requirements for any thermal control, if required, of the weld and/or equipment shall be in accordance with a WPS.

4.11 Welding

All welding shall be done in accordance with a WPS.

4.12 Post-weld heat treatment

If post-weld heat treatment is required, then it shall be done in accordance with a WPS.

The manufacturer shall be fully responsible for the specification and performance of any post-weld heat treatment (for example, solution heat-treating, stress relieving, or ageing). The procedure shall be compatible with the parent material, welded joint, and weldment, in accordance with the product standard and/or specified requirements.

A record of the heat treatment shall be made during the heat treating process. The record shall demonstrate that this document was followed and shall be traceable to the heat treated part.

4.13 Testing and inspection

4.13.1 General

The location, frequency, and type of applicable tests and inspections depend on the product standard and type of construction. The FSSW testing and inspection standards are referenced in 4.13.2 to 4.13.6 below.

4.13.2 Testing and inspection before welding

Before the start of welding, the applicability and validity of the following shall be verified :

- a) weld setter's qualification certificate;
- b) WPS;
- c) FSSW tool;
- d) parent material alloy and temper;
- e) joint preparation (for example, shape and dimensions);
- f) joint fit-up, jiggling;
- g) welding parameters set in accordance with the WPS;
- h) thermal control method(s).

4.13.3 Testing and inspection during welding

During welding, the welding sequence may be checked at suitable intervals or by continuous monitoring.

4.13.4 Testing and inspection after welding

After welding, compliance with the relevant application standards or relevant requirements shall be verified. Testing and inspection after welding shall be in accordance with the WPS.

Examples of common imperfections are shown in Annex A.

Examples of conformance methods are described in the following.

- a) **Visual testing**, performed in accordance with **JIS Z 3090**.
- b) ~~Macroscopic examination~~, performed with reference to **JIS Z 3139, 6.1** after giving the section an appropriate polishing and etching, to examine the weld profile and identify internal imperfections.
- c) **Tensile shear testing**, performed in accordance with **JIS Z 3136**.
- d) **Cross tension testing**, performed in accordance with **JIS Z 3137**.
- e) ~~Chisel and/or peel testing~~, performed in accordance with **JIS Z 3144, 6.1** and/or **6.2**.
- f) ~~Torsion testing~~, performed in accordance with **JIS Z 3144, 6.3**.
- g) **Hardness testing**, performed with reference to **JIS Z 3139, 6.2**.
- h) **Penetrant testing**, performed in accordance with **JIS Z 2343** series.
- i) **Radiographic testing**, performed in accordance with ~~JIS Z 3105, JIS Z 3110 or ISO 17636-1~~. When radiographic testing of lap joints, the design specification shall determine the acceptance levels.
- j) **Ultrasonic testing**, performed in accordance with **ISO 17640**. When immersion ultrasonic examination and/or phased-array ultrasonic examination is used, then the design specification or relevant requirements shall determine the applicable standard(s) or requirements.
- k) **Other tests**, not specifically addressed in this document (for example, fatigue tests or microstructure inspection) may be performed as necessary.

4.13.5 Repair of welds

If the repair of a damaged weld involves welding, then it shall be performed in accordance with a WPS. Repair shall bring the weld into full conformance with the requirements of this specification.

4.13.6 Weld flash correction

Flash, overlapping material or other protruding material along the edges of a FSSW weld may be removed by a method that does not degrade parent material properties. This operation shall be carried out in such a manner that the weld and parent material thickness remain within user-specified tolerance.

4.14 Identification and traceability

Identification and traceability of a weld to a WPS shall be maintained throughout the manufacturing process.

5 Welding procedure specification and its qualification

5.1 Development of welding procedure specification

5.1.1 General

For preparing a welding procedure specification (WPS) prior to production welding, the manufacturer shall

- a) prepare a preliminary welding procedure specification (pWPS) based on experience from previous production jobs and/or the general fund of knowledge of welding technology;
- b) ~~perform either of the following tests according to pWPS and record the testing and inspection results in welding procedure qualification record (WPQR) :~~
 - ~~welding procedure test~~ (see 5.2), normally used when the production part or joint geometry is accurately represented by a standardized test material specified in 5.2.2;
 - ~~pre-production welding test~~ (see 5.3), normally used when the production part or joint geometry is not accurately represented by the standardized test material.

NOTE A typical example of a WPQR form is shown in Annex D.

- c) ~~have the prepared WPQR inspected by an examiner or examining body, and if receiving satisfactory results, prepare a welding procedure specification (WPS) covering, if necessary, a range of parent material thicknesses, including tolerances, as well as a range of aluminium alloys (see 6.1.3.4);~~
- d) ~~if receiving unsatisfactory results in step c), modify the pWPS to resolve the inadequacies and repeat steps a) to c).~~

5.1.2 Technical content of pWPS

A pWPS shall contain all the information necessary for development of a welding procedure specification. The following information, as a minimum, shall be included in a pWPS; addition and deletion of some of the following items may be required depending on the product concerned. An example of a pWPS form is shown in Annex B.

- a) Manufacturer information
 - 1) identification of manufacturer;
 - 2) identification of pWPS.
- b) Composition of parent material
 - 1) ~~alloy and temper~~;
 - 2) material thickness;
 - 3) ~~determination of faying surface~~;
 - 4) type and ~~composition~~, and thickness of the coating;
 - 5) title of relevant standard(s).

c) Welding method

- 1) Welding conditions [welding parameters [see i) 2)] specific to each of the following variants]
 - Basic FSSW (including probe-less FSSW) : see Annex B
 - Refill FSSW : see Annex B and **C.1.**
 - Stitch FSSW : see Annex B and **C.2.**
 - Swept FSSW : see Annex B and **C.3.**
 - Swing FSSW : see Annex B and **C.4.**
- 2) Control method
 - Force control or position control

d) Joint design

- 1) joint geometry (see **JIS Z 3609-1**, Table 2 for example);
- 2) joint stack-up;
- 3) joint overlap;
- 4) edge distance;
- 5) number of weld spots;
- 6) dimensions of weld spots;
- 7) sealant and/or adhesive (type, grade, location, dimension, etc.);
- 8) tool plunge side.

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

e) Joint preparation and cleaning method

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

f) Machine specifications

- 1) type or model;
- 2) manufacturer;
- 3) auxiliary equipment.

g) Tool identification

- 1) material;
- 2) heat treatment conditions;
- 3) hardness;
- 4) drawing or drawing number or identification number.