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Friction stir welding of aluminium
General requirements
Part 5
Quality and inspection requirements

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Friction stir welding of aluminium - General requirements — Part 5: Quality and inspection requirements

Élément introductif — Élément central — Partie 5: Titre de la partie

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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 a patent concerning friction stir welding.

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ISO 25239-5 was prepared by Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 10, *Unification of requirements in the field of metal welding*.

ISO 25239 consists of the following parts, under the general title *Friction stir welding of aluminium - General requirements*:

— *Part 1: Vocabulary*

— *Part 2: Design of weld joints*

— *Part 3: Qualification of friction stir welding operators*

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

— *Part 5: Quality and inspection requirements*

Introduction

Welding processes are widely used in fabrication of engineered structures. During the second half of the twentieth century, welding of large structures was dominated by fusion welding processes wherein fusion is obtained by melting of the base metal and, usually, a filler metal. Friction stir welding, originating in the last decade of the twentieth century, is carried out entirely in the solid phase (no melting). There is an increasing need for friction stir welding standards. This standard focuses on friction stir welding of aluminium because, at the time this standard was created, the majority of commercial applications for friction stir welding involved aluminium. Examples include railway cars, consumer products, food processing equipment, aerospace, and marine vessels. Welding strongly influences the cost of fabrication and quality of such products. The increasing use of friction stir welding has created the need for a friction stir welding standard in order to assure that welding is carried out in the most effective way and that appropriate control is exercised over all aspects of the operation.

To this end, ISO is publishing this standard, which comprises five Parts. Part 1, entitled, Vocabulary, presents those terms and definitions specific to friction stir welding.

Part 2, entitled, *Design of Weld Joints*, presents the design requirements for friction stir weld joints in aluminium.

Part 3, entitled, *Qualification of friction stir welding operators*, specifies the requirements for the approval of welding operators for the friction stir welding of aluminium.

Part 4, entitled, *Specification and qualification of welding procedures*, specifies the requirements for the specification and qualification of welding procedures for the friction stir welding of aluminium.

Part 5, entitled, *Specification and qualification of welding procedures*, specifies a method to determine the capability of a manufacturer to use the friction stir welding process for production of aluminium products of the specified quality. It defines specific quality requirements but does not assign those requirements to any specific product group.

For welded structures to be effective and free from serious problems in production and in service, it is necessary to provide controls from the design phase through material selection and into fabrication and subsequent inspection. For example, poor design for welding may create serious and costly difficulties in the workshop, on site, or in service. Incorrect material selection may result in welding problems such as cracking. Welding procedures have to be correctly formulated and approved to avoid imperfections. Supervision should be implemented to ensure that the specified quality will be achieved.

To ensure effective welded fabrication, management should appreciate the sources of potential trouble and introduce appropriate quality and inspection procedures.

Friction stir welding of aluminium - General requirements — Part 5: Quality and inspection requirements

1 Scope

This Part specifies a method to determine the capability of a manufacturer to use the friction stir welding process for production of products of the specified quality. It defines specific quality requirements but does not assign those requirements to any specific product group.

In this standard, the term aluminium refers to aluminium and its alloys.

2 Normative references

The following referenced documents are indispensable for the application 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 3452 *Non-destructive testing – Penetrant inspection -- General principles*

ISO 4136 *Destructive tests on welds in metallic materials – Transverse tensile test*

ISO 5173 *Destructive tests on welds in metallic materials – Bend tests*

ISO 9015-1 *Destructive tests on welds in metallic materials – Hardness testing – Part 1: Hardness test on arc welded joints*

ISO 9015-2 *Destructive tests on welds in metallic materials – Hardness testing – Part 2: Microhardness testing of welded joints*

ISO 9712 *Non-destructive testing – Qualification and certification of personnel*

ISO 17636 *Non-destructive testing of welds – Radiographic testing of fusion-welded joints*

ISO 17637 *Non-destructive testing of welds – Visual testing of fusion-welded joints*

ISO 17640 *Non-destructive examination of welds – Ultrasonic examination of welded joints*

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

ISO 25239-1 *Friction stir welding of aluminium and its alloys – General requirements – Part 1: Vocabulary*

ISO 25239-2 *Friction stir welding of aluminium and its alloys – General requirements – Part 2: Design of weld joints*

ISO 25239-3 *Friction stir welding of aluminium and its alloys – General requirements – Part 3: Qualification of friction stir welding operators*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in Part 1 of this standard apply.

4 Quality Requirements

These requirements relate only to those aspects of product quality that may be influenced by friction stir welding.

4.1 Welding personnel

4.1.1 General

Manufacturers shall have at their disposal sufficient and competent personnel for the planning, performing and supervising of the FSW production according to specified requirements.

4.1.2 Friction stir welding operator

FSW operators shall be qualified in accordance with Part 3 of this standard. All qualification records shall be maintained up to date.

4.2 Inspection and testing personnel

4.2.1 General

The manufacturer shall have sufficient and competent personnel for planning, performing, and supervising the inspection and testing of the FSW production according to specified requirements.

4.2.2 Non-destructive testing personnel and visual weld inspector

Non-destructive testing personnel shall be qualified per ISO 9712 or ISO 20807. When the use of an examination method not presently incorporated in these ISO standards is specified, the manufacturer shall be responsible for developing the training program, written practice, examination, and practical demonstrations equivalent to the requirements of these ISO standard(s). These shall establish the capability of the personnel performing the required examination.

4.2.3 Destructive testing personnel

Personnel performing destructive testing shall be trained for the method.

4.2.4 Vision test

Non-destructive testing and visual weld inspection personnel shall pass an eye examination as required in ISO 9712.

The eye examination shall be conducted by a trained technician using standard methods for determining visual acuity.

4.3 Equipment

4.3.1 Suitability of equipment

The equipment shall be adequate for the application concerned.

Welding equipment (for example, welding machines, friction stir welding tools) shall be capable of producing welds that meet the acceptance criteria specified in Annex A. Welding equipment shall be maintained in good condition and shall be repaired or adjusted when a friction stir welding operator, inspector, or welding coordination personnel has concern about the capability of the equipment to operate satisfactorily.

4.3.2 New equipment

After installation of new or refurbished equipment, appropriate tests of the equipment shall be performed. Such tests shall verify the correct function of the equipment.

4.3.3 Reproducibility tests for qualified machine welding settings

The reproducibility test shall be carried out to demonstrate that the welding equipment can repeatedly produce welds that meet the acceptance criteria in Annex A. Reproducibility tests shall be carried out when any of the following occurs:

— a critical component of the equipment is damaged, repaired, or replaced, or

— equipment is dislodged or moved in a manner for which it was not designed, or

— stationary equipment is moved from one location to another.

4.3.3.1 Test Requirements

The reproducibility test shall be carried out according to a WPS used in production on that machine.

A minimum of three test welds shall be made and found satisfactory.

4.3.4 Equipment maintenance

The manufacturer shall have a documented plan for the maintenance of equipment. The plan shall ensure maintenance checks of those items in the equipment that control variables listed in the relevant procedure specifications. The plan may be limited to those items that are essential for assuring the quality of the construction.

Examples of these items are as follows:

— condition of guides, mechanised fixtures etc.;

— condition of meters and gages etc. used for the operation of the welding equipment;

— condition of cables, hoses, connectors etc.;

— condition of control system in mechanised and/or automatic welding equipment;

— condition of thermocouples and other temperature measurement instruments;

— condition of clamps, jigs, and fixtures

Prior to welding, clamps, jigs, and fixtures that come into contact with the weldment shall be clean and sufficiently free of contaminants such as oil, grease, and dirt that could have a detrimental effect.

Defective equipment shall not be used.

4.4 Welding procedure specification

The manufacturer shall ensure that welding procedure specification it is used correctly in production.

4.5 Friction stir welding tool

4.5.1 Identification

The friction stir welding tool employed for production purposes shall be permanently identified prior to use.

4.5.2 Friction stir welding tool inspection

The friction stir welding shall be clean and sufficiently free of contaminants that could have a detrimental effect such as oil, grease, and dirt prior to welding. Tool geometry is critical for producing a quality friction stir weld. Because the friction stir welding tool wears with use, it shall be inspected for wear at appropriate intervals and according to a procedure.

4.6 Preweld joint preparation and fit-up

4.6.1 Joint Preparation

The edge of each joint member shall be prepared as specified in the WPS.

The root gap shall be in accordance with the qualified WPS.

4.6.2 Preweld cleaning

Preweld cleaning shall be carried out as indicated in the WPS. Parent material shall be free of surface oxides, protective finishes, adhesive, oils, grease, dirt, and any other contaminants found to be detrimental.

4.7 Preheating/Interpass temperature control

Requirements for preheating and interpass temperature control shall be in accordance with a qualified WPS.

4.8 Tack Welds

If tack welds are required, then they shall be made in accordance with a qualified WPS.

4.9 Welding

All welding shall be done in accordance with a qualified WPS.

4.10 Postweld heat treatment

If postweld heat treatment is required, then it shall be done in accordance with a qualified WPS.

The manufacturer shall be fully responsible for the specification and the performance of any postweld heat treatment (for example, solution heat-treating, stress relieving, or aging). The procedure shall be compatible with the parent material, welded joint, construction, etc. and in accordance with the product standard and/or specified requirements. A record of the heat treatment shall be made during the process. The record shall demonstrate that this standard was followed and shall be traceable to the heat treated part.

4.11 Inspection and testing

4.11.1 General

Location and frequency of applicable inspections and tests will depend on the product standard and the type of construction (see 4.3.2 and 4.3.3).

NOTE: The manufacturer may carry out additional tests without restriction. Reporting of such tests is not required.

4.11.2 Inspection and testing before welding

Before the start of welding, the following shall be verified:

— suitability and validity of friction stir welding operator qualification certificate;

— suitability of welding procedure specification;

— parent material alloy and temper;

— joint preparation (for example, shape and dimensions);

— joint fit-up, jigging and tacking;

— preheating/interpass temperature

4.11.3 Inspection and testing during welding

During welding, the following shall be checked at suitable intervals or by continuous monitoring:

— essential welding parameters (for example, rotation speed, travel speed);

— welding sequence;

— control of distortion;

4.11.4 Inspection and testing after welding

After welding, compliance with relevant acceptance criteria shall be verified for conformance to the drawing requirements by one or more of the following.

— visual inspection;

— non-destructive testing;

— destructive testing;

— form, shape and dimensions of the construction;

— results and records of post-operations (for example, postweld heat treatment, ageing).

4.11.5 Damaged and nonconforming weld

If the repair of a damaged weld involves welding, then the repair shall be done using a qualified repair WPS. Repair shall bring the weldment into full conformance with the requirements of this specification.

4.11.6 Weld geometry correction

Flash, overlapping material or other protruding material along the edges of a friction stir weld may be removed by a method that does not degrade parent metal properties. This operation shall be carried out in such a manner that the weld and parent metal thickness will remain within drawing tolerances.

4.12 Identification and traceability

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

4.12.1 Traceability of welds

4.12.1.1 Interim identification

Each weld shall be traceable to the friction stir welding operator who made it. The friction stir welding operator shall identify his work by making a mark on the weldment or by marking the applicable shop planning paperwork. The interim identification shall remain next to or with the weld through final inspection. Marking methods and materials shall neither be detrimental to the parent metal nor interfere with subsequent operations.

4.12.1.2 Final identification

Each welded assembly, or the documentation accompanying each welded assembly, shall be marked as follows:

— date of welding (DD/MM/YYYY; e.g. 30/08/1953);

— welder's signature or individually assigned stamp or code;

— date of weld inspection (DD/MM/YYYY; e.g. 06/12/1991);

— weld inspector's signature or individually assigned stamp or code.

4.12.1.3 Visual inspection

Visual inspection shall be performed in accordance with ISO 17637.

4.12.1.4 Penetrant testing

Penetrant testing shall be performed in accordance with ISO 3452.

4.12.1.5 Radiographic testing

RT shall be carried out in accordance with ISO 17636.

Radiographic testing may be replaced by ultrasonic testing if required or accepted by the design specification.

When radiographic testing of lap joints or partial penetration butt welds is required, the design specification shall determine the acceptance criteria.

4.12.1.6 Ultrasonic inspection

Ultrasonic examination may be used instead of radiographic testing when specified by the drawing, or by the design specification or relevant requirements. Ultrasonic examination shall be in accordance with ISO/DIS 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.

4.12.1.7 Proof testing

Proof testing may be used in conjunction with or in lieu of the testing methods listed in 4.12.2.1, 4.12.2.2, and 4.12.2.3, when specified by the drawing, or by the design specification or relevant requirements.

4.12.1.8 Tensile tests

Test specimens and testing for transverse tensile tests of butt joints shall be in accordance with ISO 4136. Advancing and retreating sides of the test specimens shall be marked prior to testing.

4.12.1.9 Bend tests

Test specimens and bend tests of butt joints shall be in accordance with ISO 5173. The advancing and retreating sides of the test specimens shall be marked prior to testing.

For all parent materials, the bend angle shall be 180° using the calculated former diameter based upon the parent material elongation as indicated in ISO 25239-4 clause 6.3.3.4.

4.12.1.10 Hardness testing

Hardness testing shall be carried out in accordance with ISO 9015-1 or –2, as applicable**.**

4.12.1.11 Fracture tests

Fracture tests shall be carried out in accordance with ISO 9017.

4.12.1.12 Other destructive tests

Other destructive tests, procedures, or techniques (for example, impact tests, fatigue tests or macro-/micrographic examination, etc.) not specifically addressed in this document may be used in conjunction with, or instead of those stated here, on the drawing, or in the contract. When one or more of these testing methods is indicated, then the engineering authority shall determine an approved standard or other requirement.

Annex A
(normative)

Imperfections, testing and examination, acceptance levels, and ISO 6520 reference number

Table A.1 — Imperfections, testing & examination, acceptance levels, and ISO 6520 reference number

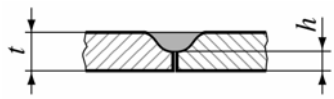
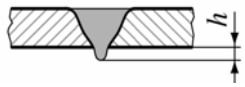
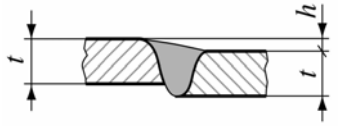
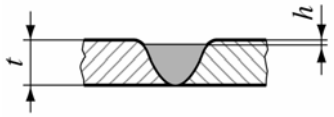
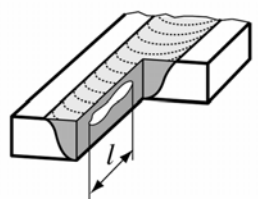
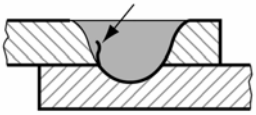
Designation of imperfection	Remarks	Testing and examination in Part 4 [a]	Acceptance levels in Part 4	Reference number in IS0 6520-1
Surface Imperfections				
Incomplete root penetration		ME	Not permitted	4021
Excess penetration		VT, ME	h ≤ 3 mm	504
Toe flash		VT, ME	[b]	[c]
Linear misalignment		VT, ME	h ≤ 0.2t max. 2 mm	507
Underfill		VT, ME	h ≤ 0.1t max. 0.5 mm	[c]
Irregular width	Excessive variation in width of the weld	VT	[b]	513
Irregular surface	Excessive surface roughness	VT	[b]	514

Table A.2 (*continued*) — Imperfections, testing & examination, acceptance levels, and ISO 6520 reference number

Designation of imperfection	Remarks	Testing and examination in Part 4 [a]	Acceptance levels in Part 4	Reference number in IS0 6520-1
Internal imperfections				
Elongated cavity (see Note 7)		ME	$h \leq 0.05t$ max. 0.5 mm	2105
Hooking		ME	[b]	[c]

NOTE 1 t: nominal thickness of the parent material

NOTE 2 h: height of an imperfection

NOTE 3 d: diameter of a cavity

NOTE 4 l: length of an elongated cavity in the longitudinal direction of the weld

NOTE 5 s: nominal butt weld thickness (penetration)

NOTE 6 VT: visual testing, ME: macroscopic testing

NOTE 7 An elongated cavity can also break through the workpiece surface.

[a] When required, non-destructive testing should be carried out in accordance with ISO 3452 (penetrant testing), ISO 17636 (radiographic testing), and ISO 17640 (ultrasonic examination).

[b] Acceptance levels shall be within the specified limit of the relevant requirements or the design specification.

[c] See Part 1.

[d] Testing and examination of other imperfections and their acceptance levels shall be in accordance with the relevant requirements or the design specification.

Bibliography

[1] ISO 857-1, *Welding and allied processes — Vocabulary — Part 1: Metal welding processes*

[2] ISO 3834-2, *Quality requirements for welding — Fusion welding of metallic materials — Part 2: Comprehensive quality requirements*

[3] ISO 9015-1, *Destructive tests on welds in metallic materials — Hardness testing — Part 1: Hardness test on arc welded joints*

[4] ISO 9015-2, *Destructive tests on welds in metallic materials — Hardness testing — Part 2: Microhardness testing of welded joints*

[5] ISO 9017, *Destructive tests on welds in metallic materials — Fracture test*

[6] ISO 9712, *Non-destructive testing — Qualification and certification of personnel*

[7] ISO 14731, *Welding coordination — Tasks and responsibilities*

[8] ISO 15607, *Specification and qualification of welding procedures for metallic materials — General rules*

[9] ISO 17671-1, *Welding — Recommendations for welding of metallic materials — Part 1: General guidance for arc welding*

[10] ISO 17640, *Non-destructive examination of welds — Ultrasonic examination of welded joints*

[11] ISO 20807, *Non-destructive testing — Qualification of personnel for limited applications of non-destructive testing*

[12] ISO 25239-4, *Friction stir welding of aluminium - General requirements — Part 5: Quality and inspection requirements*