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Friction stir welding — Aluminium —

Part 5: Quality and inspection requirements

Soudage par friction-malaxage — Aluminium —
Partie 5: Exigences de qualité et de contrôle

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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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 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 IIW, *International Institute of Welding*, Commission III, *Resistance Welding, Solid State Welding and Allied Joining Process*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 121, *Welding and allied processes*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 25239-5:2011), which has been technically revised.

The main changes compared to the previous edition are as follows:

— the concept of three different acceptance levels for the assessment of weld quality has been added to Annex A;

— the following imperfections have been added to Table A.1: angular misalignment, joint area deformation, surface breaking cavity, solid inclusion, joint remnants and multiple imperfections;

— the requirements for personnel performing non-destructive testing and visual testing have been aligned with ISO 17637

A list of all parts in the ISO 25239 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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, Wayne Thomas at TWI invented friction stir welding (FSW), which is carried out entirely in the solid phase (no melting).

The increasing use of FSW has created the need for this document 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. This document focuses on the FSW of aluminium because, at the time of publication, the majority of commercial applications for FSW involved aluminium. Examples include railway carriages, consumer products, food processing equipment, aerospace structures, and marine vessels.

Friction stir welding — Aluminium —

Part 5: Quality and inspection requirements

1 Scope

This document specifies a method for determining the capability of a manufacturer to use the friction stir welding (FSW) process for the production of products of the specified quality. It specifies quality requirements, but does not assign those requirements to any specific product group.

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

This document does not apply to friction stir spot welding which is covered by the ISO 18785 series.

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 3452-1, *Non-destructive testing — Penetrant testing — Part 1: General principles*

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

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 9017, *Destructive tests on welds in metallic materials — Fracture test*

ISO 9712, *Non-destructive testing — Qualification and certification of NDT personnel*

ISO 17636 (all parts), *Non-destructive testing of welds — Radiographic testing*

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

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

ISO 25239-1, *Friction stir welding — Aluminium — Part 1: Vocabulary*

ISO 25239-3, *Friction stir welding — Aluminium — Part 3: Qualification of welding operators*

ISO 25239-4, *Friction stir welding — Aluminium — Part 4: Specification and qualification of welding procedures*

ISO/TR 25901 (all parts), *Welding and allied processes — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 25239-1 and ISO/TR 25901 (all parts) 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 Quality requirements

4.1 General

These requirements relate only to those aspects of product quality that can be influenced by FSW.

4.2 Welding personnel

4.2.1 General

Manufacturers shall have at their disposal sufficient competent personnel for the planning, performance and supervision of FSW production operations in accordance with specified requirements.

4.2.2 Welding operator

Welding operators shall be qualified in accordance with ISO 25239-3. Qualification records shall be kept up to date.

4.3 Inspection and testing personnel

4.3.1 General

Manufacturers shall have sufficient competent personnel for the planning, performance, and supervision of inspection and testing operations during the production of friction stir welded parts in accordance with specified requirements.

4.3.2 Personnel performing non-destructive testing (including visual testing)

Non-destructive testing of welds (including visual testing) and the evaluation of results for final acceptance shall be performed by qualified and capable personnel. It is recommended that the personnel be qualified in accordance with ISO 9712 or an equivalent standard at an appropriate level in the relevant industry sector.

4.3.3 Destructive testing personnel

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

4.4 Equipment

4.4.1 Suitability of equipment

The equipment shall be adequate for the application concerned.

Welding equipment (e.g. welding machines and FSW tools) shall be capable of producing welds that meet the acceptance levels specified in Annex A. Welding equipment shall be maintained in good condition and shall be repaired or adjusted when a welding operator, inspector or welding coordinator is concerned about the capability of the equipment to operate satisfactorily.

4.4.2 Reproducibility 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 in Annex A. Reproducibility tests shall be carried out when any of the following occurs:

— after installation of new or refurbished welding equipment;

— a critical component of the FSW machine is repaired or replaced after being damaged or after failing to operate properly;

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

— stationary equipment is moved from one location to another.

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

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

4.4.3 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 WPSs. 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:

— condition of guides and mechanized fixtures;

— condition of meters and gauges that are used for the operation of the welding equipment;

— condition of cables, hoses, and connectors;

— condition of the control systems in mechanized or automatic welding equipment;

— condition of thermocouples and other temperature measurement instruments;

— condition of clamps, jigs, and fixtures.

Before welding, clamps, jigs, and fixtures that contact the workpieces shall be clean and sufficiently free of contaminants (e.g. oil, grease, and dirt) that can have a detrimental effect on the weld.

Defective equipment shall not be used.

4.5 Welding procedure specification

The manufacturer shall ensure the WPS is used correctly in production.

4.6 Friction stir welding tool

4.6.1 Identification

The FSW tool that is used in production shall be permanently marked for identification prior to use.

4.6.2 Friction stir welding tool inspection

The correct tool geometry is critical for producing a quality friction stir weld. Therefore upon first use, the FSW tool shall be clean and sufficiently free of contaminants (e.g. oil, grease or dirt) that can have a

detrimental effect on weld quality. Because the FSW tool wears with use, it shall be inspected for wear at appropriate intervals and in accordance with a written procedure.

4.7 Pre-weld joint preparation and fit-up

4.7.1 Joint preparation

The edge of each joint member shall be prepared in accordance with the WPS.

The joint condition shall be set in accordance with the WPS.

4.7.2 Pre-weld cleaning

Pre-weld cleaning shall be carried out in accordance with the WPS. Parent material shall be clean and sufficiently free of contaminants (e.g. oil, grease or dirt) that can have a detrimental effect on weld quality.

4.8 Preheating and interpass temperature control

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

4.9 Tack welds

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

4.10 Welding

All welding shall be done in accordance with a WPS.

4.11 Postweld heat treatment

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

The manufacturer shall be fully responsible for the specification and performance of any postweld heat treatment (e.g. 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 or specified requirements. A record of the heat treatment shall be made. The record shall demonstrate that this document has been followed and shall be traceable to the heat-treated part.

4.12 Inspection and testing

4.12.1 General

The location and frequency of applicable inspections and tests depends on the product standard and the type of construction.

4.12.2 Inspection and testing before welding

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

— suitability and validity of the welding operator's qualification certificate;

— suitability of the WPS;

— parent material alloy and temper;

— joint preparation (e.g. shape and dimensions);

— joint fit-up, jigging, and tacking;

— welding parameters set in accordance with the WPS;

— preheating and interpass temperature.

4.12.3 Inspection and testing during welding

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

4.12.4 Inspection and testing after welding

4.12.4.1 General

After welding, compliance with the relevant application standards or relevant requirements shall be verified by selecting from the following tests:

— visual testing;

— non-destructive testing;

— destructive testing;

— form, shape, and dimensions of the weldment;

— results and records of postweld operations (e.g. postweld heat treatment, ageing).

4.12.4.2 Visual testing

Visual testing shall be performed in accordance with ISO 17637.

4.12.4.3 Penetrant inspection

Penetrant inspection shall be performed in accordance with ISO 3452-1.

4.12.4.4 Radiographic testing

Radiographic testing shall be performed in accordance with ISO 17636 (all parts).

Ultrasonic examination can be used instead of radiographic testing when specified by the design specification or by relevant requirements.

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

4.12.4.5 Ultrasonic examination

Ultrasonic examination shall be performed in accordance with ISO 17640.

When immersion ultrasonic examination or phased-array ultrasonic examination is used, the design specification or relevant requirements shall determine the applicable standard(s) or requirements.

4.12.4.6 Service testing

Service testing can be used in conjunction with, or in lieu of, the testing methods listed in 4.12.4.3 (penetrant), 4.12.4.4 (radiographic) and 4.12.4.5 (ultrasonic), when specified by the design specification or relevant requirements.

4.12.4.7 Tensile testing

Tensile testing and the preparation of tensile test specimens shall be performed in accordance with ISO 4136.

4.12.4.8 Bend testing

Bend testing and the preparation of bend test specimens shall be performed in accordance with ISO 25239-4.

4.12.4.9 Hardness testing

Hardness testing shall be performed in accordance with ISO 9015-1 or ISO 9015-2, as applicable.

4.12.4.10 Fracture testing

Fracture testing shall be performed in accordance with ISO 9017.

4.12.4.11 Other destructive tests

Other destructive tests, procedures or techniques (e.g. impact tests, fatigue tests or macrographic and micrographic examination) not specifically addressed in this document can be used in conjunction with the tests stated herein. When one or more of these other testing methods is indicated, then they shall be carried out in accordance with the relevant International Standard.

4.12.5 Damaged and non-conforming welds

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

4.12.6 Weld geometry correction

Toe flash or other protruding material along the edges of a friction stir weld and excess penetration can be removed by a method that does not degrade parent metal properties. This operation shall be carried out in such a manner that the thickness of the weld and parent material remain within tolerance.

4.13 Identification and traceability

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

Annex A
(normative)

Imperfections, testing and examination, acceptance levels, and ISO 6520-1 reference number

The imperfections described in Table A.1 are based on designations given in ISO 10042 together with designations specific to friction stir welding.

The quality levels provide basic reference data and are not specifically related to any particular application. They refer to the types of welded joint in fabrication and not to the complete product or component itself. It is possible, therefore, that different quality levels are applied to individual welded joints in the same product or component.

It would normally be expected that for a particular welded joint the dimensional limits for imperfections can all be covered by specifying one quality level. In some cases, it can be necessary to specify different quality levels for different imperfections in the same welded joint.

The choice of quality level for any application should take account of design considerations, subsequent processing (e.g. surfacing), mode of stressing (e.g. static, dynamic), service conditions (e.g. temperature, environment) and consequences of failure. Economic factors are also important and should include not only the cost of welding but also of inspection, test and repair.

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

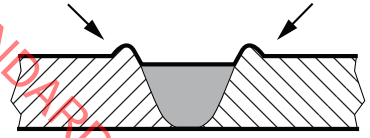
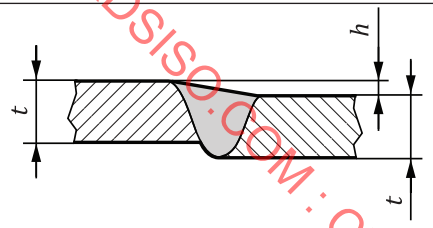
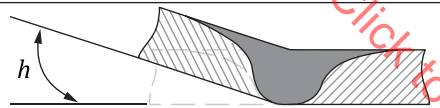
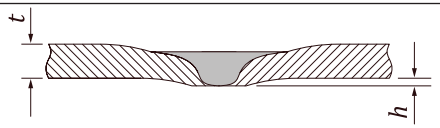
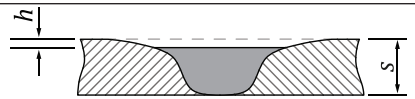
ISO 6520-1 :2007 reference number	Designation of imperfection	Remarks	Testing and examination to ISO 25239-4[a]	Acceptance levels[a]		
				D	C	B
Surface imperfections Type I (not affecting weld section thickness)[d]						
—[c]	Toe flash		VT, ME	—[b]		
507	Linear misalignment		VT, ME	$h \leq 0{,}3t$ or 4 mm, whichever is less	$h \leq 0{,}2t$ or 2 mm, whichever is less	$h \leq 0{,}1t$ or 1 mm, whichever is less
508	Angular misalignment		VT, ME	Not applicable	$h \leq 3°$	$h \leq 2°$
—[c]	Joint area deformation		VT, ME	$h \leq 0{,}5t$ or 4 mm whichever is less	$h \leq 0{,}4t$ or 2 mm whichever is less	—[b]
514	Irregular surface	Excessive surface roughness	VT	—[b]		
	Surface imperfections Type II (affecting weld section thickness)[d]					
—[c]	Underfill		VT, ME	—[b]	$h \leq 0{,}2 + 0{,}1s$	$h \leq 0{,}1s$
—	Cavity	Surface breaking cavity	VT, ME	Not permitted		

Table A.1 *(continued)*

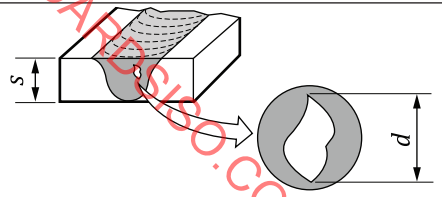
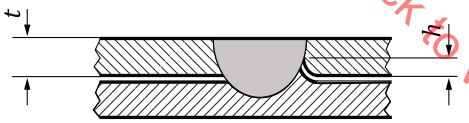
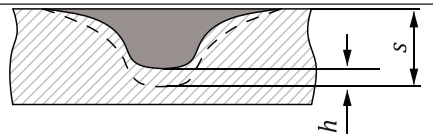
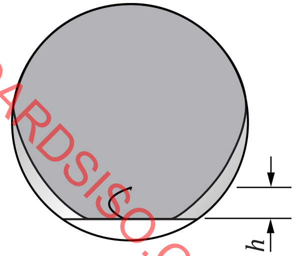
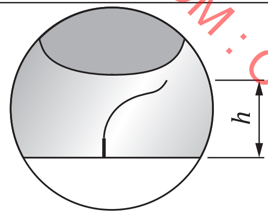
ISO 6520-1 :2007 reference number	Designation of imperfection	Remarks	Testing and examination to ISO 25239-4[a]	Acceptance levels[a]		
				D	C	B
Internal imperfections						
200	Cavity	 two adjacent cavities with a distance smaller than "*d*" from the smaller cavity should be considered as a single cavity.	ME, RT, UT	—[b]	$d \leq 0{,}2s$ or 4 mm whichever is less	Not permitted
—[c, e]	Hook		ME	—[b]	$h \leq 0{,}2 + 0{,}1t$ (to be considered only if it reduces the loaded cross-section of the joint)	$h \leq 0{,}1t$ (to be considered only if it reduces the loaded cross-section of the joint)
402	Incomplete penetration	 penetration that is less than that required or specified	ME, RT, UT	—[b]	$h \leq 0{,}2s$	Not permitted
300	Solid inclusion	multiple inclusions found in one cross section will be summed up: $l = l_1 + l_2 + \ldots$ inclusions smaller than 0,2 mm should not be considered	ME, RT, UT	—[b]	$l \leq 0{,}2s$	Not permitted

Table A.1 *(continued)*

ISO 6520-1:2007 reference number	Designation of imperfection	Remarks	Testing and examination to ISO 25239-4[a]	Acceptance levels[a]		
				D	C	B
Root flaws (see ISO 25239-1:2020, Figure 7)[d]						
—[c]	bonded joint remnant	 Applies only if invoked by the engineering drawing	ME, bend test	—[b]		
—[c]	unbonded joint remnant		ME, bend test, PT, UT	$h \leq 0{,}2t$ Short, non-systematic imperfections	—[b]	Not permitted