INTERNATIONAL STANDARD

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Specification and qualification of welding procedures for metallic materials — Welding procedure specification —

Part 4: Laser beam welding

Descriptif et qualification d'un mode opératoire de soudage pour les matériaux métalliques — Descriptif d'un mode opératoire de soudage —

Partie 4: Soudage par faisceau laser

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Contents

Page

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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.

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.

ISO 15609-4 was prepared by Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 10, *Unification of requirements in the field of metal welding*.

This second edition cancels and replaces the first edition (ISO 15609-4:2004), which has been technically revised.

ISO 15609 consists of the following parts, under the general title *Specification and qualification of welding procedures for metallic materials — Welding procedure specification*:

— *Part 1: Arc welding*

— *Part 2: Gas welding*

— *Part 3: Electron beam welding*

— *Part 4: Laser beam welding*

— *Part 5: Resistance welding*

The following part is planned:

— Part 6: Laser arc hybrid welding

Requests for official interpretations of any aspect of this part of ISO 15609 should be directed to the Secretariat of ISO/TC 44/SC 10 via your national standards body, a complete listing of which can be found at www.iso.org.

Specification and qualification of welding procedures for metallic materials — Welding procedure specification —

Part 4: Laser beam welding

1 Scope

This part of ISO 15609 specifies requirements for the content of the welding procedure specification (WPS) for laser beam welding processes, including overlay welding. It is not applicable to other processes for cladding (e.g. thermal spraying).

This part of ISO 15609 is part of a series of standards, and details of this series are given in ISO 15607:2003, Annex A.

Variables listed in this part of ISO 15609 are those influencing the quality and properties of the welded joint. The dimensions mentioned in this part of ISO 15609 influence the metallurgical and mechanical qualities, the geometry of the structural member and other important performance properties.

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 4063, *Welding and allied processes — Nomenclature of processes and reference numbers*

ISO 6947, *Welds — Working positions — Definitions of angles of slope and rotation*

ISO 14175, *Welding consumables — Gases and gas mixtures for fusion welding and allied processes*

ISO 15607:2003, *Specification and qualification of welding procedures for metallic materials — General rules*

ISO/TR 25901:2007, *Welding and related processes — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 15607:2003, ISO/TR 25901:2007 and the following apply.

3.1
slope up
⟨beam welding⟩ controlled increase of the beam power at the beginning of the welding

[ISO/TR 25901:2007, definition 2.337]

3.2
slope down
controlled decrease of the beam power at the end of the welding

NOTE 1 Adapted from ISO/TR 25901:2007, definition 2.336.

NOTE 2 The slope down region is the region on the workpiece in which the effects of slope down occur. It can consist of one or two of the following areas, depending on the selected welding mode.

a) In full penetration welding, it can consist of

- a region where beam penetration is still complete, and
- a region where penetration is partial or decreasing.

b) In partial penetration welding, it can consist of

- a region where penetration decreases continuously.

3.3
working distance
⟨beam welding⟩ distance between the surface of the workpiece and a standard reference point of the equipment which is traceable to the true focusing lens or mirror centre

[ISO/TR 25901:2007, definition 2.472]

NOTE This is a practical reference distance only.

3.4
tacking pass
pass made to hold the parts to be welded in proper alignment until the final welds are made

NOTE 1 Adapted from ISO/TR 25901:2007, definition 2.370.

NOTE 2 This can be produced by a continuous or discontinuous pass with partial penetration.

3.5
pass
run
single operation of welding that is part of the production of a completed weld

NOTE 1 Adapted from ISO/TR 25901:2007, definition 2.312.

NOTE 2 The term “pass” is commonly used in beam welding.

3.6
cosmetic pass
pass for superficial remelting of the weld in order to enhance appearance

NOTE 1 Adapted from ISO/TR 25901:2007, definition 2.75.

NOTE 2 This pass can be performed with a defocused or oscillating beam.

3.7
overlap
⟨beam welding⟩ portion of the weld pass remelted prior to the slope down

[ISO/TR 25901:2007, definition 2.249]

NOTE For overlay welding, portion of a welding pass remelted by the adjoining pass.

3.8
back support
piece of metal or other auxiliary material placed against the workpiece on the back face of the joint in order to retain the molten weld metal

NOTE Adapted from ISO/TR 25901:2007, definition 2.24.

3.9
focal length
⟨beam welding⟩ distance between the centre of the focusing lens or mirror and the focal spot

[ISO/TR 25901:2007, definition 2.146]

NOTE In a thick lens or system of lenses, the principal plane is often inside the lens. For set-up purposes, operators often use the "back focal length", which is the distance from the front surface of a focusing lens or mirror system to the focal spot.

3.10
focal spot
⟨beam welding⟩ part of the beam beyond the focusing system where the beam comes to a minimum cross-sectional area

[ISO/TR 25901:2007, 2.147]

3.11
beam shaping
adapting of the geometry of the beam effective area and the power density distribution by suitable optical components

3.12
carrier gas
⟨overlay welding⟩ gas used to transport filler material to the molten pool

NOTE Typical carrier gases are nitrogen, helium and argon.

4 Technical content of welding procedure specification

4.1 General

The WPS shall provide all information required to make a weld.

The WPS may cover a certain range of thicknesses of the joined parts and may also cover a range of parent metals and even filler metals. Some manufacturers additionally prefer to prepare work instructions for each specific job as part of the detailed production planning.

Information listed below is adequate for most welding operations. For some applications, it is necessary to supplement or reduce the list. The relevant information shall be specified in the WPS.

Ranges and tolerances, according to the manufacturer's experience, shall be specified when appropriate.

An example of a typical WPS format is shown in Annex A.

4.2 Welding process

The welding process is 52, in accordance with ISO 4063.

4.3 Manufacturer

— identification of the manufacturer;

— identification of the WPS;

— reference to the welding procedure qualification record (WPQR) or other documents, as required.

4.4 Equipment

4.4.1 General

Identification of any equipment.

4.4.2 Laser welding equipment

— type of source (for example Nd:YAG or CO_2), model, make;

— nominal power;

— continuous wave or pulsed;

— number of lasers combined;

— manufacturer's or measured values for the beam quality parameters:

  — beam transverse electro-magnetic mode (TEM);

  — beam divergence;

  — wavelength;

  — beam polarization and orientation;

  — beam parameter product (BPP).

4.4.3 Beam delivery and focusing system

— method of transmission (fibres, mirrors, including beam collimators, if used);

— method of beam shaping (e.g. scanner, integrator, diffractive lenses);

— distance from beam source to focusing system, if necessary;

— beam diameter on entrance to focusing system;

— focusing optics;

— focal length;

— nominal focal spot size and method of measuring, if required;

— beam path protection system.

4.4.4 Process gas supply system

A description (schematic diagram) showing design, position of nozzle(s) for plasma suppression gas in relation to the joint, welding direction and welding point shall be specified.

Operation(s) and dimensions of the molten pool protection shall be specified.

In the case of overlay welding, the composition and flow rate of the gas stream carrying the powder metal shall be specified.

4.4.5 Filler material feeding system

Description (schematic) showing design, position of the filler material feeding system in relation to the joint, welding direction and welding point (if any).

4.5 Parent materials

4.5.1 Parent material type/grade

— the designation of the material(s) and any backing plates or supports used and any reference standard(s);

— the identification of the type of product (e.g. forged, cast, rolled, extruded).

A WPS may cover a group of materials.

4.5.2 Dimensions of materials

— the thickness range of the joint;

— the range of outside diameters, for circular workpieces.

4.6 Filler or other additional material(s)

— the designation and reference standard for any filler material(s) or other additional material(s) used in the joint;

— the dimensions of any filler material(s) or other additional material(s) used in the joint;

— any special cleaning or drying or handling instructions for any filler material(s) or other additional material(s) used in the joint;

4.7 Joint design

A sketch showing the joint design/configuration, dimensions and tolerances, including surface finish, or reference to another standard which provides this information.

4.8 Joint and surface preparation

4.8.1 Joint preparation

— the joint preparation method, cleaning, degreasing, etc.;

— the protection of joint preparation, if necessary.

4.8.2 Surface preparation

For overlay welding:

— the surface preparation method, cleaning, degreasing, etc.;

— the protection of the surface to be overlaid, if necessary.

4.9 Jigs, fixtures and tooling

The methods to be used for workpiece fixturing (including manual tack welding and arrangements for containment of the backing gas, if used).

4.10 Welding position

Applicable welding positions in accordance with ISO 6947.

4.11 Backing

Type(s) and dimensions, if any.

4.12 Welding technique

The welding technique sketch showing details of all welding passes (tacking pass, welding pass and cosmetic pass).

4.13 Welding parameters

4.13.1 Beam parameters

— the laser beam power at the workpiece;

— the pulse parameters, if pulsing is used, including

  — peak power,

  — pulse energy,

  — repetition rate,

  — pulse duration, and

  — pulse shape;

— the power ramping details (including slope down or slope up procedure, if used);

— the tacking pass details;

— the oscillation pattern, amplitude, frequency and dwell time, if applied;

— the laser beam orientation, polarization and position in relation to joint and welding direction:

  — angles (in two directions),

  — position in transverse direction, if relevant.

4.13.2 Mechanical parameters

— the travel speed;

— the travel speed ramping details, if necessary;

— the wire/filler feed rate, direction, position to be defined and angle, if any.

4.13.3 Plasma suppression gas, shielding and backing gas parameters

— the gas flow rate;

— the checking of gas purity;

— the purge procedure.

4.13.4 Run geometry and sequence for overlay welding

For overlay welding, the sequence of runs shall be specified, including

— the width and the height of the single run, and

— the distance or percentage of the overlap.

4.13.5 Other parameters

Other parameters include

— the working distance,

— the shape and dimensions of the beam on the workpiece, and

— the location and orientation of the shielding gas nozzle with respect to the workpiece.

4.14 Preheating and post-weld heat treatment

If preheating and/or post-weld heat treatment are required, the temperature and the time at temperature shall be included on the WPS, along with any other instructions related to the heat treatment. If the laser beam is to be used for preheating or post-weld heat treatment, the relevant parameters shall be recorded on the WPS.

4.15 Operations after welding

Any mechanical and/or chemical treatment.

Annex A
(informative)

Examples of welding procedure specification

A.1 Laser beam welding

Welding procedure specification (WPS) identification:

Manufacturer:

WPQR No.:

Equipment identification:
— laser source and beam implant system:
— beam quality [K, M^2 or BPP value (see ISO/TR 17671-6)]:
— beam polarization:
— beam delivery system:
— beam focusing system:
— plasma suppression gas system:
— shielding gas system:
— filler material(s) feeding system:

Parent material specification:
1:
2:

— material thickness (mm):
1:
2:
— outside diameter (mm):

Filler or other additional material: — designation: — dimensions: — handling:

Joint type: — sheet or plate ☐ — cylindrical ☐ — axial ☐
— radial ☐
— other ☐

Joint design	Welding technique

Jigs, fixtures and tooling: Yes ☐ No ☐

☐ Mechanically fixed:

☐ Tack weld; process:

Back support: Yes ☐ No ☐

Backing gas:

Preparation:			
Procedure:			
	Tacking pass	**Welding pass**	**Cosmetic pass**
Welding position:			
Welding technique:			
Beam power at workpiece — continuous (W): — pulse parameters: — peak power (W): — energy (J): — frequency: — duration (ms): — shape:			
Power ramping details — slope up (mm or deg): — overlap (mm or deg): — slope down (mm or deg): — slope profile:			
Oscillation — pattern: — amplitude: — frequency: — dwell time:			
Beam orientation angle — longitudinal: — transverse: — (position):			
Travel speed (m/min):			
Travel speed ramping:			
Filler metal — designation: — feed rate:			
Plasma suppression gas — classification and type: — flow rate (l/min):			
Shielding gas — classification and type: — flow rate: — purge procedure:			
Working distance (mm):			

Shielding gas nozzle — location (mm): — diameter (mm): — orientation:			
— Preheating: [a] — Post-weld heat treatment: [a]			
Operations after welding: [a]			
[a] If required.			

.....
Manufacturer
(name, signature, date)

A.2 Laser beam cladding

WPS identification:

Manufacturer:

WPQR N°:

Equipment identification:
— laser source and beam implant system:
— beam quality (K, M^2 or BPP value):
— beam polarization:
— beam delivery system:
— beam focusing system:
— plasma suppression gas system:
— shielding gas system:
— filler material(s) feeding system:

Parent material specification: 1:
2:

— material thickness (mm): 1: — outside diameter (mm):
2:

Filler or other additional material: — designation: — dimensions: — handling:

Joint type: — sheet or plate ☐ — cylindrical ☐ — axial ☐
— radial ☐
— other ☐

Layer geometry (including ranges for thickness, width and overlap)

Jigs, fixtures and tooling: Yes ☐ No ☐

☐ Mechanically fixed:

☐ Tack weld; process:

Back support: Yes ☐ No ☐

Backing gas:

Preparation:		
Procedure:		
	Buffer layer	**Claddings runs**
Welding position:		
Welding technique:		
Beam power at workpiece — continuous (W): — pulse parameters: — peak power (W): — energy (J): — frequency: — duration (ms): — shape:		
Oscillation — pattern: — amplitude: — frequency: — dwell time:		
Beam orientation angle — longitudinal: — transverse: — (position):		
Travel speed (m/min):		
Filler metal — designation: — feed rate: — feed ramp rate:		

Shielding gas — classification and type: — flow rate: — purge procedure:		
Carrier gas — nomination: — rate of flow (l/min):		
Working distance (mm):		
Shielding gas nozzle — location (mm): — diameter (mm): — orientation:		
— Preheating: [a] — Post-weld heat treatment: [a]		
Operations after welding: [a]		
[a] If required.		

.....
Manufacturer
(name, signature, date)

Bibliography

[1] ISO 11145, *Optics and photonics — Lasers and laser-related equipment — Vocabulary and symbols*

[2] ISO/TR 17671-6, *Welding — Recommendations for welding of metallic materials — Part 6: Laser beam welding*

[3] EN 1011-6, *Welding — Recommendations for welding of metallic materials — Part 6: Laser beam welding*

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