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Welding and allied processes — Process specification for laser-arc hybrid welding for metallic materials

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This document was prepared by Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 10, *Quality management in the field of welding*.

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Official interpretations of ISO/TC 44 documents, where they exist, are available from this page: https://committee.iso.org/sites/tc44/home/interpretation.html.

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Welding and allied processes — Process specification for laser-arc hybrid welding for metallic materials

1 Scope

This document outlines the equipment and operator qualification needed for laser-arc hybrid welding, and recommends butt, fillet and flange joint preparations and consumables suitable for use with this process.

It also gives an overview of the steps to take during equipment set-up, procedure specification, workpiece set-up immediately prior to welding, and after welding once inspecting and testing the welds.

This document applies to laser-arc hybrid welding of steels, aluminium and its alloys.

This document does not apply to hybrid processes where laser beam welding is hybridized with another welding process not using an electric arc as its heat source.

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.

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

ISO 14732:2013, *Welding personnel — Qualification testing of welding operators and weld setters for mechanized and automatic welding of metallic materials*

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

ISO 15614-14, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 14: Laser-arc hybrid welding of steels, nickel and nickel alloys*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 15607 and ISO 15614-14 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 Safety

The environment condition, operation and protective measures for laser-arc hybrid welding should be in accordance with the requirements of related standards (e.g. ISO 11553-1, ISO 13849-1, IEC 62061, IEC 60825-1 and IEC 60825-4).

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5 Welding operator qualification

The welding operator should receive necessary training and education and be competent to his/her job. An operator of an automated laser-arc hybrid welding process can be qualified through one of the different routes referred to ISO 14732:2013, Clause 4, relevant to automatic welding, namely:

a) qualification based on a welding procedure test in accordance with ISO 15614-14;

b) qualification based on a pre-production welding test in accordance with ISO 15613, ISO 15609-6 and ISO 15614-14;

c) qualification based on a production test or production sample test.

In addition, any method of qualification shall be supplemented by a test of the functional knowledge of the welding system, referring to ISO 14732:2013, Annex A.

Furthermore, any method of qualification may be supplemented by a discretionary test of knowledge related to welding technology, referring to ISO 14732:2013, Annex B.

6 Laser-arc hybrid welding equipment

The laser-arc hybrid welding equipment mainly includes laser generator, beam delivery system, arc welding power source and laser-arc hybrid welding head, high precise manipulator, high precise clamping device, seam tracking device, wire feeding unit, etc.

The equipment necessary to perform a laser-arc hybrid weld can include:

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a) laser beam safety enclosure;

b) laser source;

c) laser source chiller (commonly needed);

d) arc power source;

e) beam delivery means (e.g. optical fibre);

f) welding wire feeder/delivery means (if the arc welding process uses a consumable wire);

g) beam focusing optics, and cover slide (an appropriately anti-reflection coated optical flat) and cross jet for protection of those optics;

h) arc welding torch;

i) torch cooling (commonly needed);

j) current return lead(s);

k) equipment for setting the respective positions of the laser beam focusing optics and the arc welding torch (e.g. torch bracketry);

l) shielding gas delivery system to weld cap (commonly, through wire feeding delivery system to arc welding torch) and, in case of full penetration welding, weld root;

m) some form of automatic beam-to-work manipulation device, e.g. a welding robot;

n) equipment/system controls (optional: seam tracking and/or seam inspection and/or weld process monitoring and/or control devices).

Best practice is that all equipment be the subject of regular scheduled maintenance and calibration checks, irrespective of any other pre-, in- or post-welding monitoring carried out for quality assurance/ control purposes.

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All equipment shall fulfil the manufacturer’s guidelines.

7 Shielding gas

All the shielding gases used for laser-arc hybrid welding shall be in accordance with ISO 14175.

The recommended gas component and flow rates are given in Table 1.

Table 1 — Recommandation for gas component and flow rates

Base metal	Shielding gas	Gas flow rate L/min
Carbon steel	M20, M21, M22, M26	12 to 30
Stainless steel	M12, M13, M22, R1	
Aluminium alloy	I1, I2, I3	
NOTE When using CO_2 laser source, argon is replaced partly by helium with following condition: $P < 4$ kW than 30 % He; 4 kW $\leq P \leq$ 6 kW than 50 % He; $P > 6$ kW than 70 % He.		

8 Joint design and preparation

Generally, the single pass penetration that can be achieved by the laser-arc hybrid welding process is significantly greater than that achieved by electric arc welding, depending on factors such as the laser parameters used, welding speed, welding position, etc. Furthermore, the gap-bridging tolerance of the process is less than that of arc welding. As such, the groove type and size for this process should be designed taking both the penetration capability and gap-bridging tolerance of the laser in to account, e.g. butt joint grooves with significantly broader root faces can be welded, albeit close-fitting, square-edged root preparations are then needed.

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The special groove types have been proved to be useful in application.

The grooved types are based on ISO 9692-1 for steels and ISO 9692-3 for aluminium and aluminium alloys. It is possible, and sometimes with advantage for steel sructures, to use filler materials with lower strength because of the high cooling rates and reduced width of the laser hybrid weld seams.

The butt joint preparations for laser-arc hybrid welding are recommended in Table 2 (for single side welding) and Table 3 (for double side welding). The fillet and flange joint preparations for laser-arc hybrid welding are recommended in Table 4.

The butt joint grooves can be prepared by a mechanical process (machining) or high precision cutting process (e.g. laser cutting or waterjet cutting), provided that a dimensional accuracy suitable for the limited gap bridging tolerance of the hybrid welding process can be insured. As a guide, a maximum butt joint gap tolerance is of the order of 5 % to 10 % of material (or, in thicker materials, root face) thickness, depending on factors such as the material being welded, welding position and resulting weld quality required.

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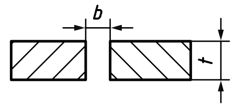
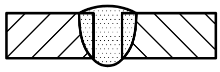
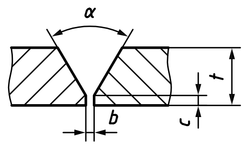
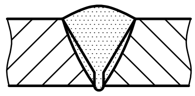
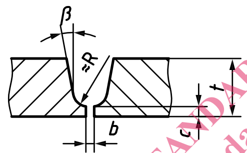
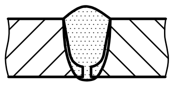
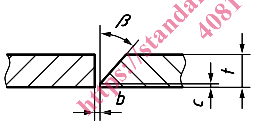
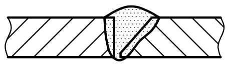
Table 2 — Butt joint preparations for single side welding

No.	Material thickness t mm	Symbol in accordance with ISO 2553	Cross-section	Dimensions: Angle α or β	Dimensions: Root gap b mm	Dimensions: Thickness of root face c mm	Weld illustration
1	1< t ≤ 5	||		—	0 ≤ b ≤ 0,3	—	
2	5 < t ≤ 10			—	0 ≤ b ≤ 0,3	—	
3	10 < t ≤ 16			—	0 ≤ b ≤ 0,3	—	
4	16 < t ≤20			—	2 ≤ b ≤ 3	—	
5	5 < t ≤ 15	V		3° ≤ α ≤ 20°	0 ≤ b ≤ 0,3	2 ≤ c ≤ 8	
6	t > 16			30° ≤ α ≤ 45°	0 ≤ b ≤ 1	2 ≤ c ≤ 8	
7	16< t ≤ 25			30° ≤ α ≤ 45°	0 ≤ b ≤ 0,1	10 ≤ c ≤ 16	
8	t > 25			45° ≤ α ≤ 60°	0 ≤ b ≤ 0,1	14 ≤ c ≤ 16	
9	t > 15	Y		8° ≤ β ≤ 12°	0 ≤ b ≤ 0,1	2 ≤ c ≤ 8	
10	t > 25			2 mm ≤ R ≤ 4 mm	0 ≤ b ≤ 0,1	14 ≤ c ≤ 16	
11	5< t ≤ 12	/		15° ≤ β ≤ 30°	0 ≤ b ≤ 1	2 ≤ c ≤ 8	
12	t > 12			15° ≤ β ≤ 30°	0 ≤ b ≤ 1	2 ≤ c ≤ 8	
13	16< t ≤ 25			15° ≤ β ≤ 30°	0 ≤ b ≤ 0,1	14 ≤ c ≤ 16	
14	t > 25			15° ≤ β ≤ 30°	0 ≤ b ≤ 0,1	14 ≤ c ≤ 16	

Note 1 All of the grooves are suitable to single pass and mult-pass welding.

Note 2 The grooves in No. 2, 3, 4, 7, 8, 9, 10, 13, 14, 17 and 18 are subject to high-power laser beam;

Note 3 The groove in No. 4 is filled with pre-posited cut wire (pieces of wire with the length of several mm) and backing plate is required.

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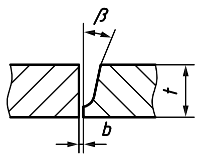
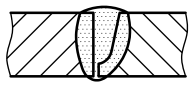
Table 2 *(continued)*

No.	Material thickness t mm	Symbol in accordance with ISO 2553	Cross-section	Dimensions Angle α or β	 Root gap b mm	 Thickness of root face c mm	Weld illustration
15	$5 < t \le 12$			$15° \le \beta \le 30°$ $2\ mm \le R \le 4\ mm$	$0 \le b \le 1$	$2 \le c \le 8$	
16	$t > 12$			$15° \le \beta \le 30°$ $2\ mm \le R \le 6\ mm$	$0 \le b \le 1$	$2 \le c \le 8$	
17	$16 < t \le 25$			$15° \le \beta \le 30°$ $2\ mm \le R \le 4\ mm$	$0 \le b \le 0{,}1$	$14 \le c \le 16$	
18	$t > 25$			$15° \le \beta \le 30°$ $2\ mm \le R \le 6\ mm$	$0 \le b \le 0{,}1$	$14 \le c \le 16$	

Note 1 All of the grooves are suitable to single pass and mult-pass welding.

Note 2 The grooves in No. 2, 3, 4, 7, 8, 9, 10, 13, 14, 17 and 18 are subject to high-power laser beam;

Note 3 The groove in No. 4 is filled with pre-posited cut wire (pieces of wire with the length of several mm) and backing plate is required.

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