ISO 5817:2023(E)

Fourth edition

2023-02

Welding — Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) — Quality levels for imperfections

Soudage — Assemblages en acier, nickel, titane et leurs alliages soudés par fusion (soudage par faisceau exclu) — Niveaux de qualité par rapport aux défauts

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

Published in Switzerland

Contents

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 Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 10, *Quality management in the field of welding*, 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 fourth edition cancels and replaces the third edition (ISO 5817:2014), which has been technically revised.

The main changes are as follows:

— editorial updates;

— actual throat thickness a_A, used in Table 1, nos 1.3, 1.4, 1.16 and 3.2;

— figures for Table 1, nos 1.4, 1.5, 1.6, 1.11, 1.14, 1.16, 1.19, 2.12, 2.13 and 4.1 changed or added;

— Table 1, no. 4.1: exclusion of several imperfections and change of acceptance criteria;

— Former Annex B deleted.

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

Introduction

This document is intended to be used as a reference in the drafting of application codes and/or other application standards. It contains a simplified selection of fusion weld imperfections based on the designations given in ISO 6520-1.

Some of the imperfections described in ISO 6520-1 have been used directly and some have been grouped together. The basic numerical referencing system from ISO 6520-1 has been used.

The purpose of this document is to specify dimensions of typical imperfections which might be expected in normal fabrication. It may be used within a quality system for the production of welded joints. It provides three sets of dimensional values from which a selection can be made for a particular application. The quality level necessary in each case should be specified by the application standard or the responsible designer in conjunction with the manufacturer, user and/or other parties concerned. The quality level shall be prescribed before the start of production, preferably at the enquiry or order stage. For special purposes, additional details may be prescribed. If the welds will be subsequently coated with a protective coating, lining or paint, the welds might require more thorough post weld treatment or surface finishing to achieve the requirements in ISO 8501-3.

The quality levels given in this document provide basic reference data and are not specifically related to any particular application. They refer to 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.

The main part of the document takes no account for fitness or design for purpose. Annex B gives a possibility to address design for purpose for fatigue applications.

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, testing and repair.

Although this document includes types of imperfection relevant to the fusion welding processes listed in Clause 1, only those which are applicable to the process and application in question need to be considered.

Imperfections are quoted in terms of their actual dimensions, and their detection and evaluation can require the use of one or more methods of non-destructive testing. The detection and sizing of imperfections is dependent on the testing methods and the extent of testing specified in the application standard or contract.

This document does not address the methods used for the detection of imperfections. However, ISO 17635 contains a correlation between the quality level and acceptance level for different NDT methods.

This document is directly applicable to visual testing of welds and does not include details of recommended methods of detection or sizing by non-destructive means. It should be considered that there are difficulties in using these limits to establish appropriate criteria applicable to non-destructive testing methods, such as ultrasonic testing (UT), radiographic testing (RT), eddy current testing (ET), penetrant testing (PT) and magnetic particle testing (MT) and that these will possibly need to be supplemented by requirements for inspection, examining and testing.

The values given for imperfections are for welds produced using normal welding practice. Requirements for smaller (more stringent) values as stated in quality level B may include additional manufacturing processes, e.g. grinding, TIG dressing.

Annex B gives additional requirements for welds subject to fatigue.

Welding — Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) — Quality levels for imperfections

1 Scope

This document specifies quality levels of imperfections in fusion-welded joints (except for beam welding) in all types of steel, nickel, titanium and their alloys. It applies to material thickness ≥ 0,5 mm. It covers fully penetrated butt welds and all fillet welds. Its principles can also be applied to partial-penetration butt welds.

Quality levels for beam-welded joints in steel are presented in ISO 13919-1.

Three quality levels are given in order to permit application to a wide range of welded fabrication. They are designated by symbols B, C and D. Quality level B corresponds to the highest requirement on the finished weld.

Several types of loads are considered, e.g. static load, thermal load, corrosion load, pressure load. Additional guidance on fatigue loads is given in Annex B.

The quality levels refer to production and good workmanship.

This document is applicable to:

a) non-alloy and alloy steels;

b) nickel and nickel alloys;

c) titanium and titanium alloys;

d) manual, mechanized and automatic welding;

e) all welding positions;

f) all types of welds, e.g. butt welds, fillet welds and branch connections;

g) the following welding processes and their sub-processes, as defined in ISO 4063:

- 11 metal arc welding without gas protection;
- 12 submerged arc welding;
- 13 gas-shielded metal arc welding;
- 14 gas-shielded arc welding with non-consumable tungsten electrode;
- 15 plasma arc welding;
- 31 oxyfuel gas welding (for steel only).

Metallurgical aspects, such as grain size and hardness, are not covered by this document.

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in the ISO 25901 series and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
quality level
description of the quality of a weld on the basis of type, size and amount of selected imperfections

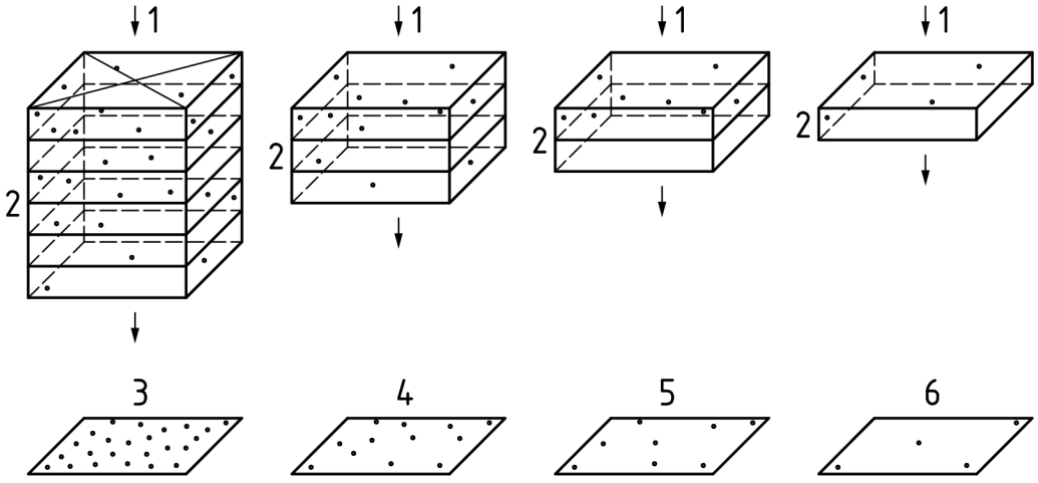
3.2
short imperfection
<welds 100 mm long or longer> imperfection whose total length is not greater than 25 mm in the 100 mm of the weld which contains the greatest number of imperfections

3.3
short imperfection
< welds less than 100 mm long> imperfection whose total length is not greater than 25 % of the length of the weld

3.4
systematic imperfection
imperfection that is repeatedly distributed in the weld over the weld length to be tested, the size of a single imperfection being within the specified limits

3.5
projected area
area where imperfections distributed along the volume of the weld under consideration are imaged two-dimensionally

Note 1 to entry: In contrast to the cross-sectional area, the occurrence of imperfections is dependent on the weld thickness when exposed radiographically (see Figure 1).



Key

1	direction of rays	3	sixfold thickness	5	twofold thickness
2	four pores per volume unit	4	threefold thickness	6	onefold thickness

Figure 1 — Radiographic films of specimens with identical occurrence of pores per volume unit

3.6
cross-sectional area
area to be considered after fracture or sectioning

3.7
smooth transition
even surface with no irregularities or sharpness at the transition between the weld bead and the parent material and/or the adjacent welding bead(s)

3.8
fatigue class
FATx
classification reference to S-N curve

Note 1 to entry: x is the stress range in MPa at $2 \cdot 10^6$ cycles.

Note 2 to entry: Fatigue properties are described by S-N curves (stress-number of cycle-curves).

Note 3 to entry: See Annex B.

4 Symbols

a	nominal throat thickness of the fillet weld (see also ISO 2553)
a_A	actual throat thickness (throat thickness of the finalized weld) (see ISO/TR 25901-1)
A	area surrounding the gas pores
b	width of weld reinforcement
d	diameter of gas pore
d_A	diameter of area surrounding the gas pores
h	height or width of imperfection
i	penetration in fillet welds
l	length of imperfection in longitudinal direction of the weld
l_p	length of projected or cross-sectional area
r	radius of weld toe
s	nominal butt weld thickness
t	wall or plate thickness (nominal size)
w_p	width of the weld or width or height of the cross-sectional area
z	leg length of a fillet weld (see also ISO 2553)
α	angle of weld toe
β	angle of angular misalignment

5 Assessment of imperfections

Limits for imperfections in accordance with ISO 6520-1 are given in Table 1.

If, for the detection of imperfections, macro-examination is used, only those imperfections shall be considered which can be detected with a maximum of tenfold magnification. Excluded from this are micro lack of fusion (see Table 1, 1.5) and microcracks (see Table 1, 2.2).

Systematic imperfections are only permitted in quality level D, provided the other requirements of Table 1 are fulfilled.

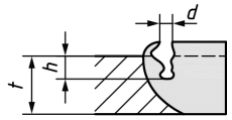
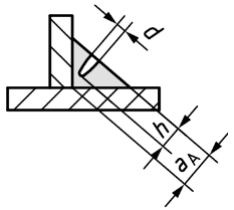
A welded joint should usually be assessed separately for each individual type of imperfection (see Table 1, 1.1 to 3.2).

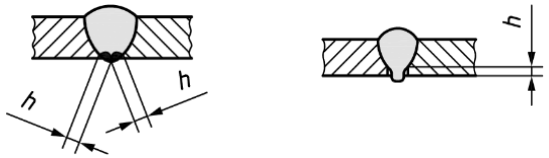
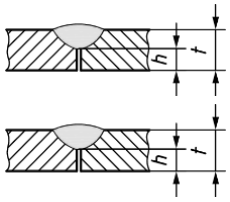
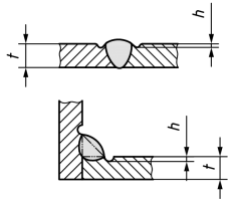
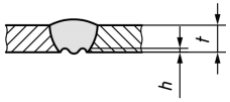
Different types of imperfection occurring at any cross-section of the joint need special consideration (see multiple imperfections in Table 1, 4.1).

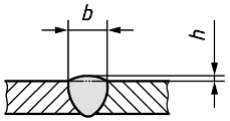
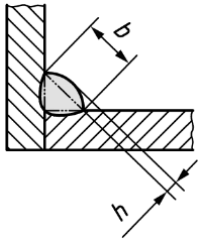
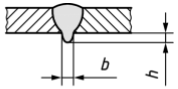
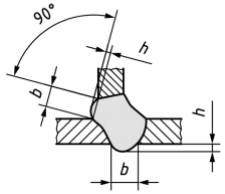
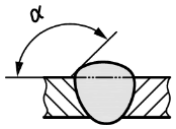
The limits for multiple imperfections (see Table 1) are only applicable for cases where the requirements for a single imperfection are not exceeded.

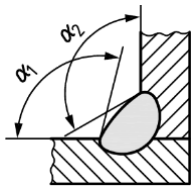
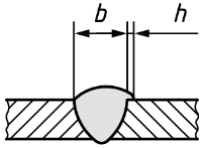
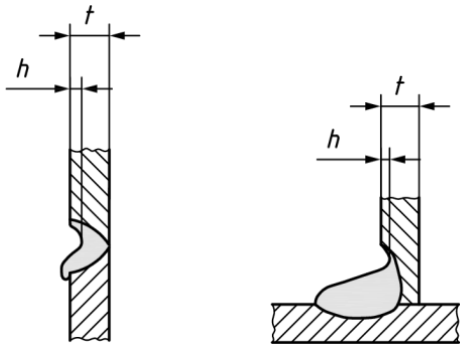
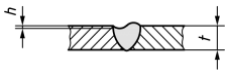
Any two adjacent imperfections separated by a distance smaller than the major dimension of the smaller imperfection shall be considered as a single imperfection.

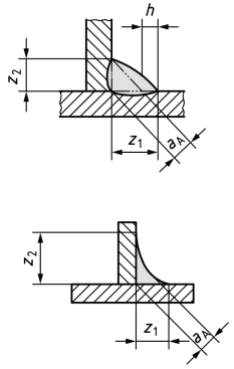
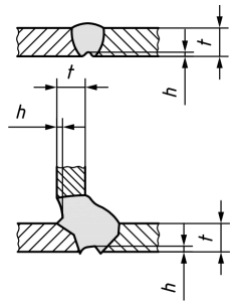
Table 1 — Limits for imperfections

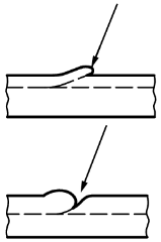
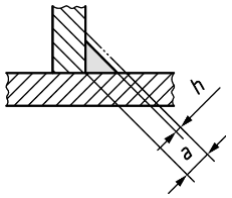
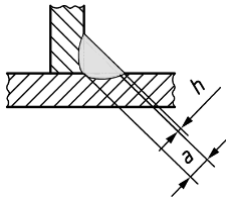
No.	Reference to ISO 6520-1	Imperfection designation	Remarks	t mm	Limits for imperfections for quality levels		
					D	C	B
1 Surface imperfections							
1.1	100	Crack		≥ 0,5	Not permitted	Not permitted	Not permitted
1.2	104	Crater crack		≥ 0,5	Not permitted	Not permitted	Not permitted
1.3	2017	Surface pore	On the weld face or the weld root Maximum dimension of a single pore	0,5 to 3	Butt welds $d \leq 0{,}3\ s$ fillet welds $d \leq 0{,}3\ a_A$	Not permitted	Not permitted
				> 3	Butt welds $d \leq 0{,}3\ s$, but max. 3 mm fillet welds $d \leq 0{,}3\ a_A$, but max. 3 mm	butt welds $d \leq 0{,}2\ s$, but max. 2 mm fillet welds $d \leq 0{,}2\ a_A$, but max. 2 mm	Not permitted
1.4	2025	End crater pipe	— butt welds  	0,5 to 3	Butt welds $h \leq 0{,}2$ s $d \leq 0{,}3\ s$ fillet welds $h \leq 0{,}2\ a_A$, $d \leq 0{,}3\ a_A$	Not permitted	Not permitted
			— fillet welds  	> 3	Butt welds $h \leq 0{,}2$ s, but max. 2 mm $d \leq 0{,}3\ s$, but max. 3 mm fillet welds $h \leq 0{,}2\ a_A$, but max. 2 mm $d \leq 0{,}3\ a_A$, but max. 3 mm	Butt welds $h \leq 0{,}1\ s$, but max. 1 mm $d \leq 0{,}2\ s$, but max. 2 mm fillet welds $h \leq 0{,}1\ a_A$, but max. 1 mm $d \leq 0{,}2\ a_A$, but max. 2 mm	Not permitted

No.	Reference to ISO 6520-1	Imperfection designation	Remarks	*t* mm	Limits for imperfections for quality levels		
					D	C	B
1.5	401	Lack of fusion (incomplete fusion)		≥ 0,5	Not permitted	Not permitted	Not permitted
	4014	Micro lack of fusion	Only detectable by micro examination (≥50 ×)	≥ 0,5	Permitted	Permitted	Not permitted
1.6	4021	Incomplete root penetration	Only for single side butt welds (full penetration) 	≥ 0,5	Short imperfections: $h \leq 0{,}2\ t$ but max. 2 mm	Not permitted	Not permitted
1.7	5011	Continuous undercut	Smooth transition is required. This is not regarded as a systematic imperfection.	0,5 to 3	Short imperfections: $h \leq 0{,}2\ t$	Short imperfections: $h \leq 0{,}1\ t$	Not permitted
	5012	Intermittent undercut (short imperfection)		> 3	$h \leq 0{,}2\ t$, but max. 1 mm	$h \leq 0{,}1\ t$, but max. 0,5 mm	$h \leq 0{,}05\ t$, but max. 0,5 mm
1.8	5013	Shrinkage grooves	Smooth transition is required. 	0,5 to 3	Short imperfections: $h \leq 0{,}1\ t + 0{,}2$ mm	Short imperfections: $h \leq 0{,}1\ t$	Not permitted
				> 3	Short imperfections: $h \leq 0{,}2\ t$, but max. 2 mm	Short imperfections: $h \leq 0{,}1\ t$, but max.1 mm	Short imperfections: $h \leq 0{,}05\ t$, but max. 0,5 mm

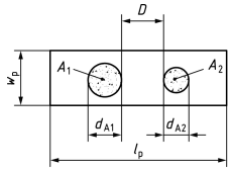
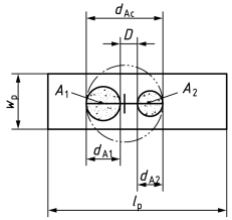
No.	Reference to ISO 6520-1	Imperfection designation	Remarks	t mm	Limits for imperfections for quality levels		
					D	C	B
1.9	502	Excess weld metal (butt weld)	Smooth transition is required between the capping run(s) and the plate surface and/or the adjacent welding bead(s) 	≥ 0,5	$h \leq 0{,}25\ b + 1$ mm, but max. 10 mm	$h \leq 0{,}15\ b + 1$ m m, but max. 7 mm	$h \leq 0{,}1\ b + 1$ mm , but max. 5 mm
1.10	503	Excessive convexity (fillet weld)	Smooth transition is required between the cap of the weld and the plate surface and/or the adjacent welding bead(s) 	≥ 0,5	$h \leq 0{,}25\ b + 1$ mm, but max. 5 mm	$h \leq 0{,}15\ b + 1$ m m, but max. 4 mm	$h \leq 0{,}1\ b + 1$ mm , but max. 3 mm
1.11	504	Excessive penetration	 	0,5 to 3	$h \leq 0{,}6\ b + 1$ m m	$h \leq 0{,}3\ b + 1$ mm	$h \leq 0{,}1\ b + 1$ mm
				> 3	$h \leq 1{,}0\ b + 1$ m m, but max. 5 mm	$h \leq 0{,}45\ b + 1$ m m, but max. 4 mm	$h \leq 0{,}2\ b + 1$ mm , but max. 3 mm
1.12	505	Incorrect weld toe	— butt welds  Not applicable for the root	≥ 0,5	$\alpha \geq 90°$	$\alpha \geq 110°$	$\alpha \geq 150°$
			— fillet welds	≥ 0,5	$\alpha \geq 90°$	$\alpha \geq 100°$	$\alpha \geq 110°$

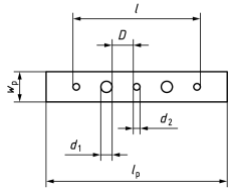
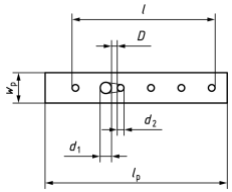
No.	Reference to ISO 6520-1	Imperfection designation	Remarks	*t* mm	Limits for imperfections for quality levels		
					D	C	B
			 $\alpha_1 \geq \alpha$ and $\alpha_2 \geq \alpha$				
1.13	506	Overlap		≥ 0,5	$h \leq 0{,}2\ b$	Not permitted	Not permitted
1.14	509	Sagging	Smooth transition is required 	0,5 to 3	Short imperfections: $h \leq 0{,}25\ t$	Short imperfections: $h \leq 0{,}1\ t$	Not permitted
				> 3	Short imperfections: $h \leq 0{,}25\ t$, but max. 2 mm	Short imperfections: $h \leq 0{,}1\ t$, but max. 1 mm	Short imperfections: $h \leq 0{,}05\ t$, but max. 0,5 mm
	511	Incompletely filled groove					
1.15	510	Burn through	—	≥ 0,5	Not permitted	Not permitted	Not permitted
	512		In cases where an asymmetric fillet weld has not been prescribed.	≥ 0,5			

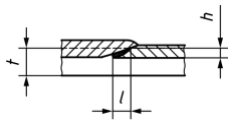
No.	Reference to ISO 6520-1	Imperfection designation	Remarks	t mm	Limits for imperfections for quality levels		
					D	C	B
1.16		Excessive asymmetry of fillet weld (excessive unequal leg length)	 $h = \lvert Z_1 - Z_2 \rvert$		$h \le 0{,}2\ a_A + 2$ mm	$h \le 0{,}15\ a_A + 2$ mm	$h \le 0{,}15\ a_A + 1{,}5$ mm
1.17	515	Root concavity	Smooth transition is required. 	0,5 to 3	$h \le 0{,}1\ t + 0{,}2$ mm	Short imperfections: $h \le 0{,}1\ t$	Not permitted
				> 3	Short imperfections: $h \le 0{,}2\ t$, but max. 2 mm	Short imperfections: $h \le 0{,}1\ t$, but max. 1 mm	Short imperfections: $h \le 0{,}05\ t$, but max. 0,5 mm
1.18	516	Root porosity	Spongy formation at the root of a weld due to bubbling of the weld metal at the moment of solidification (e.g. lack of gas backing)	≥ 0,5	Acceptance depends on application, e.g. material, corrosion protection	Not permitted	Not permitted

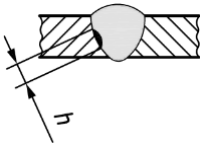
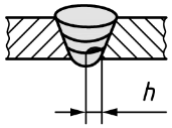
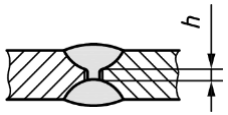
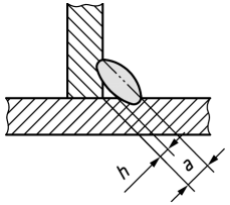
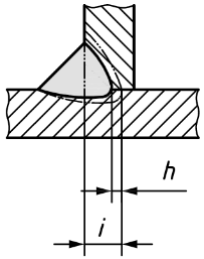
No.	Reference to ISO 6520-1	Imperfection designation	Remarks	*t* mm	Limits for imperfections for quality levels		
					D	C	B
1.19	517	Poor restart		≥ 0,5	Permitted The limit depends on the type of imperfection which occurred due to the restart	Not permitted	Not permitted
1.20	5213	Insufficient throat thickness	Not applicable to processes with proof of greater depth of penetration 	0,5 to 3	Short imperfections: $h \leq 0{,}1\ a + 0{,}2$ mm	Short imperfections: $h \leq 0{,}2$ mm	Not permitted
				> 3	Short imperfections: $h \leq 0{,}1\ a + 0{,}3$ mm, but max. 2 mm	Short imperfections: $h \leq 0{,}1\ a + 0{,}3$ mm, but max. 1 mm	Not permitted
1.21	5214	Excessive throat thickness	The actual throat thickness of the fillet weld is too large. 	≥ 0,5	Permitted	$h \leq 0{,}2\ a + 1$ mm, but max. 4 mm	$h \leq 0{,}15\ a + 1$ mm, but max. 3 mm
1.22	601	Stray arc	—	≥ 0,5	Permitted, if the properties of the parent metal are not affected	Not permitted	Not permitted

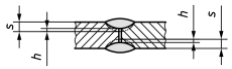
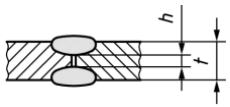
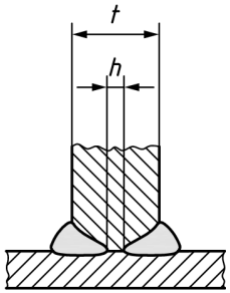
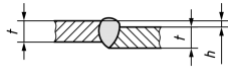
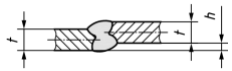
No.	Reference to ISO 6520-1	Imperfection designation	Remarks	*t* mm	Limits for imperfections for quality levels		
					D	C	B
1.23	602	Spatter	—	≥ 0,5	Acceptance depends on application, e.g. material, corrosion protection	Acceptance depends on application, e.g. material, corrosion protection	Acceptance depends on application, e.g. material, corrosion protection
1.24	610	Temper colours (visible oxide film)	—	≥ 0,5	Acceptance depends on application, e.g. material, corrosion protection	Acceptance depends on application, e.g. material, corrosion protection	Acceptance depends on application, e.g. material, corrosion protection
2 Internal imperfections							
2.1	100	Crack	All types of cracks except microcracks and crater cracks	≥ 0,5	Not permitted	Not permitted	Not permitted
2.2	1001	Microcrack	A crack usually only visible under the microscope (≥50 ×)	≥ 0,5	Permitted	Acceptance depends on type of parent metal with particular reference to crack sensitivity	Acceptance depends on type of parent metal with particular reference to crack sensitivity
2.3	2011 2012	Gas pore Uniformly distributed porosity	The following conditions and limits for imperfections shall be fulfilled. See also Annex A for information.				
			a1) Maximum dimension of the area of the imperfections (inclusive of systematic imperfection) related to the projected area. The porosity in the project area depends on the numbers of layers (volume of the weld).	≥ 0,5	For single layer: ≤ 2,5 % For multi-layer: ≤ 5 %	For single layer: ≤ 1,5 % For multi-layer: ≤ 3 %	For single layer: ≤ 1 % For multi-layer: ≤ 2 %
			a2) Maximum dimension of the cross-sectional area of the imperfections (inclusive of systematic imperfection) related to the fracture area (only applicable to test pieces: production test, welder or procedure qualification tests)	≥ 0,5	≤ 2,5 %	≤ 1,5 %	≤ 1 %
			b) Maximum dimension for a single pore for	≥ 0,5			

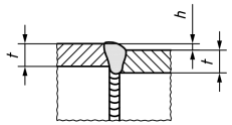
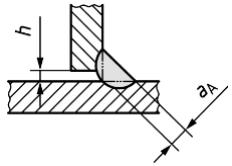
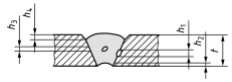
No.	Reference to ISO 6520-1	Imperfection designation	Remarks	t mm	Limits for imperfections for quality levels		
					D	C	B
			— butt welds — fillet welds		$d \leq 0{,}4\ s$, but max. 5 mm $d \leq 0{,}4\ a_A$, but max. 5 mm	$d \leq 0{,}3\ s$, but max. 4 mm $d \leq 0{,}3\ a_A$, but max. 4 mm	$d \leq 0{,}2\ s$, but max. 3 mm $d \leq 0{,}2\ a_A$, but max. 3 mm
2.4	2013	Clustered (localized) porosity	  Reference length for l_p is 100 mm. The total gas pore area within the cluster is represented by a circle of diameter d_A surrounding all the gas pores. The requirement for a single gas pore shall be met by all the gas pores within this circle. A permitted porous area shall be local. The possibility of the pore cluster masking other imperfections shall be taken into consideration. If D is less than d_{A1} or d_{A2}, whichever is smaller, then the total gas pore area is represented by a circle of diameter d_{AC}, where $d_{AC} = d_{A1} + d_{A2} + D$. Systematic cluster porosity is not permitted. d_A corresponds to d_{A1}, d_{A2} or d_{AC}, whichever is applicable.	≥ 0,5	$d_A \leq 25$ mm or $d_{A,\,max} \leq w_p$	$d_A \leq 20$ mm or $d_{A,\,max} \leq w_p$	$d_A \leq 15$ mm or $d_{A,\,max} \leq w_p/2$
2.5	2014	Linear porosity	— butt welds	≥ 0,5	$h \leq 0{,}4\ s$, but max. 4 mm	$h \leq 0{,}3\ s$, but max. 3 mm	$h \leq 0{,}2\ s$, but max. 2 mm

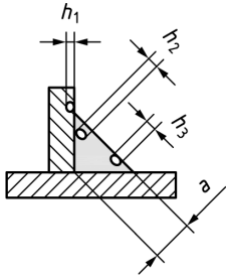
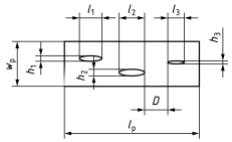
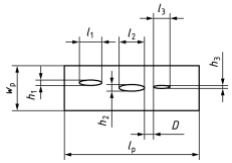
No.	Reference to ISO 6520-1	Imperfection designation	Remarks	t mm	Limits for imperfections for quality levels		
					D	C	B
					$l \leq s$, but max. 75 mm	$l \leq s$, but max. 50 mm	$l \leq s$, but max. 25 mm
			— fillet welds	≥ 0,5	$h \leq 0{,}4\ a$, but max. 4 mm $l \leq a$, but max. 75 mm	$h \leq 0{,}3\ a$, but max. 3 mm $l \leq a$, but max. 50 mm	$h \leq 0{,}2\ a$, but max. 2 mm $l \leq a$, but max. 25 mm
			Case 1 ($D > d_2$)  Case 2 ($D < d_2$)  Reference length for l_p is 100 mm. For case 1: $d_1 = h$ For case 2: $d_1 + d_2 + D = h$				
2.6	2015 2016	Elongated cavity Worm hole	— butt welds	≥ 0,5	$h \leq 0{,}4\ s$, but max. 4 mm $l \leq s$, but max. 75 mm	$h \leq 0{,}3\ s$, but max. 3 mm $l \leq s$, but max. 50 mm	$h \leq 0{,}2\ s$, but max. 2 mm $l \leq s$, but max. 25 mm
			— fillet welds	≥ 0,5	$h \leq 0{,}4\ a$, but max. 4 mm	$h \leq 0{,}3\ a$, but max. 3 mm	$h \leq 0{,}2\ a$, but max. 2 mm

No.	Reference to ISO 6520-1	Imperfection designation	Remarks	*t* mm	Limits for imperfections for quality levels		
					D	C	B
					l ≤ *a*, but max. 75 mm	*l* ≤ *a*, but max. 50 mm	*l* ≤ *a*, but max. 25 mm
2.7	202	Shrinkage cavity	—	≥ 0,5	Short imperfections permitted, but not breaking of the surfaces: butt welds: *h* ≤ 0,4 *s*, but max. 4 mm fillet welds: *h* ≤ 0,4 *a*, but max. 4 mm	Not permitted	Not permitted
2.8	2024	Crater pipe	 The larger value of *h* or *l* will be measured	0,5 to 3	*h* or *l* ≤ 0,2 *t*	Not permitted	Not permitted
				> 3	*h* or *l* ≤ 0,2 *t*, but max. 2 mm	Not permitted	Not permitted
2.9	300 301	Solid inclusion Slag inclusion	— butt welds	≥ 0,5	*h* ≤ 0,4 *s*, but max. 4 mm *l* ≤ *s*, but max. 75 mm	*h* ≤ 0,3 *s*, but max. 3 mm *l* ≤ *s*, but max. 50 mm	*h* ≤ 0,2 *s*, but max. 2 mm *l* ≤ *s*, but max. 25 mm
	302 303	Flux inclusion Oxide inclusion	— fillet welds	≥ 0,5	*h* ≤ 0,4 *a*, but max. 4 mm *l* ≤ *a*, but max. 75 mm	*h* ≤ 0,3 *a*, but max. 3 mm *l* ≤ *a*, but max. 50 mm	*h* ≤ 0,2 *a*, but max. 2 mm *l* ≤ *a*, but max. 25 mm
2.10	304	Metallic inclusion other than copper	— butt welds	≥ 0,5	*h* ≤ 0,4 *s*, but max. 4 mm	*h* ≤ 0,3 *s*, but max. 3 mm	*h* ≤ 0,2 *s*, but max. 2 mm
			— fillet welds	≥ 0,5	*h* ≤ 0,4 *a*, but max. 4 mm	*h* ≤ 0,3 *a*, but max. 3 mm	*h* ≤ 0,2 *a*, but max. 2 mm

No.	Reference to ISO 6520-1	Imperfection designation	Remarks	*t* mm	Limits for imperfections for quality levels		
					D	C	B
2.11	3042	Copper inclusion	—	≥ 0,5	Not permitted	Not permitted	Not permitted
2.12	401	Lack of fusion (incomplete fusion)		≥ 0,5	Short imperfections permitted: butt welds: $h \leq 0{,}4\ s$, but max. 4 mm fillet welds: $h \leq 0{,}4\ a$ but max. 4 mm	Not permitted	Not permitted
	4011	Lack of side-wall fusion					
	4012	Lack of inter-run fusion					
	4013	Lack of root fusion					
2.13	4021	Incomplete root penetration	 T-joint (fillet weld)	> 0,5	Short imperfections: $h \leq 0{,}2\ a$, but max. 2 mm	Not permitted	Not permitted
	402	Lack of penetration	 T-joint (partial penetration)	≥ 0,5	Short imperfections: $h \leq 0{,}2\ s$ or $h \leq 0{,}2\ i$, but max. 2 mm	Short imperfections: $h \leq 0{,}1\ s$ or $h \leq 0{,}1\ i$, but max. 1,5 mm	Not permitted

No.	Reference to ISO 6520-1	Imperfection designation	Remarks	*t* mm	Limits for imperfections for quality levels		
					D	C	B
			 Butt joint (partial penetration)				
			 Butt joint (full penetration)	≥ 0,5	Short imperfections: $h \leq 0{,}2\ t$, but max. 2 mm	Not permitted	Not permitted
			 T-joint (full penetration)				
3 Imperfections in joint geometry							
3.1	507	Linear misalignment	The limits relate to deviations from the correct position. Unless otherwise specified, the correct position is that when the centrelines coincide (see also Clause 1). *t* refers to the smaller thickness.				
	5071	Linear misalignment between plates		0,5 to 3	$h \leq 0{,}25\ t + 0{,}2$ mm	$h \leq 0{,}15\ t + 0{,}2$ m m	$h \leq 0{,}1\ t + 0{,}2$ m m
				> 3	$h \leq 0{,}25\ t$ but max. 5 mm	$h \leq 0{,}15\ t$, but max. 4 mm	$h \leq 0{,}1\ t$, but max. 3 mm
			This applies for longitudinal welds in plates and hollow sections				

No.	Reference to ISO 6520-1	Imperfection designation	Remarks	t mm	Limits for imperfections for quality levels		
					D	C	B
	5072	Linear misalignment between tubes	 This applies for circumferential welds in tubes and hollow sections	≥ 0,5	$h \leq 0{,}5\ t$, but max. 4 mm	$h \leq 0{,}5\ t$, but max. 3 mm	$h \leq 0{,}5\ t$, but max. 2 mm
3.2	617	Incorrect root gap for fillet welds	Gap between the parts to be joined. Gaps exceeding the appropriate limit may, in certain cases, be compensated for by a corresponding increase in the throat thickness. 	0,5 to 3	$h \leq 0{,}1\ a_A + 0{,}5$ mm	$h \leq 0{,}1\ a_A +$ 0,3 mm	$h \leq 0{,}1\ a_A +$ 0,2 mm
				> 3	$h \leq 0{,}3\ a_A + 1$ mm, but max. 4 mm	$h \leq 0{,}2\ a_A + 0{,}5$ mm, but max. 3 mm	$h \leq 0{,}1\ a_A + 0{,}5$ mm, but max. 2 mm
4 Multiple imperfections							
4.1	None	Multiple imperfections in any cross-section which reduce the cross-section	502 Excess weld metal 503 Excessive convexity 504 Excessive penetration, 505 Incorrect weld toe, 506 Overlap, 512 Excessive asymmetry of fillet weld (excessive unequal leg length) and 5214 Excessive throat thickness are excluded  $h_1 + h_2 + h_3 + h_4 = \sum h$	0,5 to 3 > 3	Not permitted Maximum total height of imperfections: $\Sigma\ h \leq 0{,}4\ t$ or $\leq 0{,}4\ a$	Not permitted Maximum total height of imperfections: $\Sigma\ h \leq 0{,}3\ t$ or $\leq 0{,}3\ a$	Not permitted Maximum total height of imperfections: $\Sigma\ h \leq 0{,}2\ t$ or $\leq 0{,}2\ a$

No.	Reference to ISO 6520-1	Imperfection designation	Remarks	t mm	Limits for imperfections for quality levels		
					D	C	B
			 $h_1 + h_2 + h_3 = \sum h$				
4.2	None	Projected or cross-sectional area in longitudinal direction	Case 1 ($D > l_3$)  $h_1 \times l_1 + h_2 \times l_2 + h_3 \times l_3 = \Sigma h \times l$ Case 2 ($D < l_3$)  $h_1 \times l_1 + h_2 \times l_2 + (\frac{h_2 + h_3}{2}) \times D + h_3 \times l_3 = \Sigma h \times l$	≥ 0,5	Σ $h \times l \leq 16$ %	Σ $h \times l \leq 8$ %	Σ $h \times l \leq 4$ %
			The sum of the areas Σ $h \times l$ shall be calculated as a percentage to the evaluation area $l_p \times w_p$ (case 1).				

No.	Reference to ISO 6520-1	Imperfection designation	Remarks	*t* mm	Limits for imperfections for quality levels		
					D	C	B
			If *D* is smaller than the shorter length of one of the neighbouring imperfections, the full connection of the two imperfections shall be applied to the sum of imperfections (case 2). See also Annex A for information.				

Annex A
(informative)

Examples of determination of percentage (%) porosity

Figures A.1 to A.9 give a presentation of different percentage porosities. This should assist the assessment of porosity on projected areas (radiographs) or cross-sectional areas.

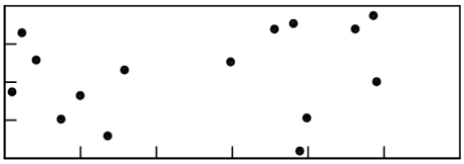


Figure A.1 — 1 surface per cent, 15 pores, *d* = 1 mm

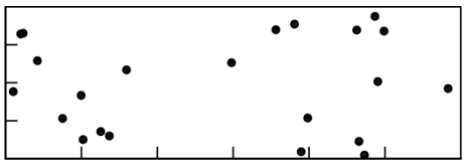


Figure A.2 — 1,5 surface per cent, 23 pores, *d* = 1 mm

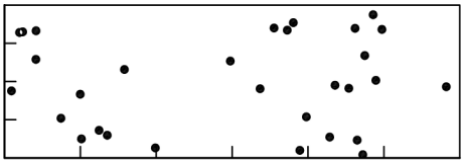


Figure A.3 — 2 surface per cent, 30 pores, *d* = 1 mm

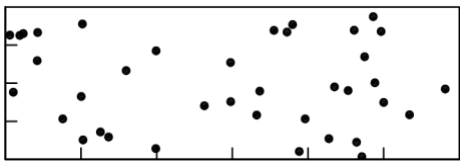


Figure A.4 — 2,5 surface per cent, 38 pores, *d* = 1 mm

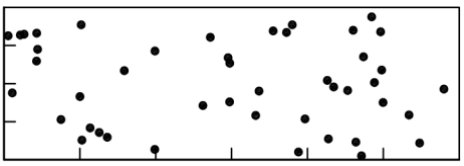


Figure A.5 — 3 surface per cent, 45 pores, *d* = 1 mm

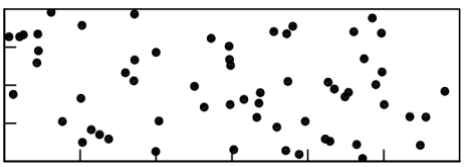


Figure A.6 — 4 surface per cent, 61 pores, *d* = 1 mm

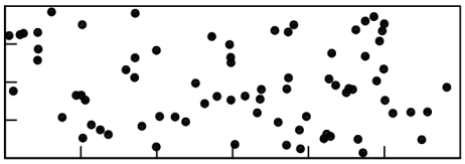


Figure A.7 — 5 surface per cent, 76 pores, *d* = 1 mm

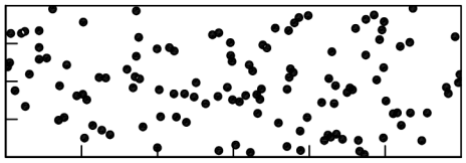


Figure A.8 — 8 surface per cent, 122 pores, *d* = 1 mm

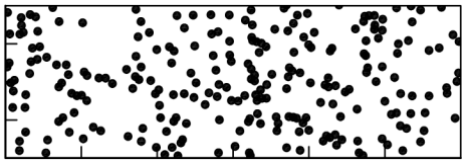


Figure A.9 — 16 surface per cent, 244 pores, *d* = 1 mm

Annex B
(informative)

Additional criteria for welds in steel subject to fatigue

B.1 General

This annex gives additional criteria to meet fatigue class (FAT) levels.

In several areas of application, the codes refer to mean minus two standard deviations, which corresponds to a survival probability of 97,7 %. Referring to a survival probability of 95 % at a two-sided confidence level of the mean of 75 % (one-sided 87,5 %, sometimes 95 %), considering the usual scatter of fatigue tests, the difference in terms of stress is less than 2 % and thus may be neglected.

For welds subject to fatigue load, Table 1 should be supplemented with additional criteria according to B.2 to B.5.

B.2 Quality levels

The additional criteria for quality levels B and C is to adjust the limits for imperfections to FAT 90 for quality level B, giving B90, and FAT 63 for quality level C, giving C63.

A quality level B125 representing FAT 125 is represented by additional criteria to level B for some imperfections. Level B125 is generally not achieved as welded.

Fillet welds are excluded from level B125.

Annex B does not apply to level D.

Additional criteria do not apply to Level D.

NOTE Level C63 covers FAT 63 and lower, level B90 covers FAT 90 and lower, and level B125 covers FAT 125 and lower.

Table B.1 contains additional criteria for levels C and B for welds subject to fatigue load. In the column for level B125, additional criteria to level B are presented. If no limits are presented, level B125 equals the level B.

B.3 Smooth transition

For smooth transition in Table 1, the transition radius according to Table B.1, 1.12, applies.

B.4 Partial penetration butt welds and fillet welds

For partial penetration butt welds and fillet welds, the designed value of penetration should be considered together with the limits for imperfection to apply to the respective quality level.

NOTE If no value for the penetration is present, limits for imperfections can be disregarded since the fatigue life will be governed by the design root crack.

For the quality levels to apply to FAT, the penetration depth of the inner side of the weld (root side), which is governed by information on the drawing, should be determined by appropriate analysis methods and in later stages assessed using inspection.

B.5 Designation

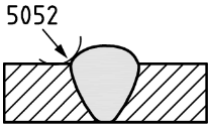
To indicate that the quality criteria include the criteria in Annex B, the designation for levels B and C is supplemented with the character FAT.

EXAMPLE 1 ISO 5817-C63.

EXAMPLE 2 ISO 5817-B90.

EXAMPLE 3 ISO 5817-B125.

Table B.1 — Additional criteria to Table 1 for welds subject to fatigue load

No.	Reference to ISO 6520-1	Imperfection designation	t mm	Limits for imperfections for quality levels		
				C 63[c]	B 90[c]	B 125
1.5	401	Micro lack of fusion	≥ 0,5	[a]	[a]	[a]
1.7	5011 5012	Continuous undercut Intermittent undercut	> 3	[a]	[a]	Not permitted
1.8	5013	Shrinkage groove	> 3	[a]	[a]	Not permitted
1.9	502	Excess weld metal (butt weld)	≥ 0,5	[a]	[a]	h ≤ 0,2 mm + 0,1 b, max. 2 mm
1.10	503	Excessive convexity (fillet weld)	≥ 0,5	[a]	[a]	[b]
1.11	504	Excessive penetration	0,5 to 3	[a]	[a]	h ≤ 0,2 mm + 0,05 b
			> 3	[a]	[a]	h ≤ 0,2 mm + 0,05 b, but max. 1 mm
1.12	505	Incorrect weld toe, weld toe angle for fillet welds	≥ 0,5	[a]	[a]	[a]
—	5052	Incorrect weld toe, weld toe radius 	> 3	[b]	r ≥ 1 mm	r ≥ 4 mm
1.14	509 511	Sagging Incompletely filled groove	> 3	[a]	[a]	Not permitted
1.16	512	Excessive asymmetry of fillet weld (excessive unequal leg length)	≥ 0,5	[a]	[a]	[b]
1.17	515	Root concavity	> 3	[a]	[a]	Not permitted
1.23	602	Spatter	≥ 0,5	[a]	[a]	Not permitted
2.3	2011 2012	Gas pore Uniformly distributed porosity	≥ 0,5	[a]	[a]	For single layer: ≤ 1 % for multi-layer: ≤ 2 % d ≤ 0,1 s, max. 1 mm
2.4	2013	Clustered (localized) porosity	≥ 0,5	[a]	≤ 3 %[d] d ≤ 0,2 s, d ≤ 0,2 a, d ≤ 2,5 mm	≤ 2 %[d] d ≤ 0,1 s, max. 0,5 mm
2.5	2014	Linear porosity	≥ 0,5	[a]	[a]	For single layer: ≤ 1 %[d] for multi-layer: ≤ 2 %[d] d ≤ 0,1 s, max. 1 mm
2.6	2015 2016	Elongation cavity Wormholes	≥ 0,5	[a]	h ≤ 0,2 s or 0,2 a max. h = 2 mm	[a]

No.	Reference to ISO 6520-1	Imperfection designation	t mm	Limits for imperfections for quality levels		
				C 63[c]	B 90[c]	B 125
					as welded: max. l = 2,5 mm; stress relieved: l ≤ 20 mm	
2.9	300 301 302 303	Solid inclusion Slag inclusion Flux inclusion Oxide inclusion	≥ 0,5	[a]	h ≤ 0,2 s or 0,2 a max. h = 2 mm as welded: max. l = 2,5 mm stress relieved: l ≤ 20 mm	Not permitted
3.1	5071	Linear misalignment between plates	≥ 0,5	[a]	h ≤ 0,1 t max. 3 mm	h ≤ 0,05 t max. 1,5 mm
	5072	Linear misalignment between tubes (this applies for circumferential welds in tubes and hollow sections)	≥ 0,5	[a]	h ≤ 0,5 t max. 1 mm	[a]
3.3	508	Angular misalignment[b]	≥ 0,5	β ≤ 2°	β ≤ 1°	β ≤ 1°

[a] Same values as given for quality levels B and C, respectively, in Table 1.

[b] Not specified.

[c] Values identical with IIW-Doc. XIII-2323–10. The values are proved by IIW for a material thickness of 10 mm and above. Lower material thicknesses may be applicable.

[d] The limit of imperfection corresponds to the ratio between the sum of the different pore areas and the evaluation area. If the distance between two pore areas is less than the diameter of the smallest pore area, an envelope surrounding both pore areas is relevant as one area of imperfection. If the distance between two pores is smaller than the diameter of one of the neighbouring pores, the full connected area of two pores is the sum of the imperfection areas.

Bibliography

[1] ISO 2553, *Welding and allied processes — Symbolic representation on drawings — Welded joints*

[2] ISO 4063, *Welding and allied processes — Nomenclature of processes and reference numbers*

[3] ISO 6520-1, *Welding and allied processes — Classification of geometric imperfections in metallic materials — Part 1: Fusion welding*

[4] ISO 8501-3, *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 3: Preparation grades of welds, edges and other areas with surface imperfections*

[5] ISO 13919-1, *Electron and laser-beam welded joints — Requirements and recommendations on quality levels for imperfections — Part 1: Steel, nickel, titanium and their alloys*

[6] ISO 17635, *Non-destructive testing of welds — General rules for metallic materials*

[7] IIW-Catalogue. *Reference radiographs for the assessment of weld imperfections in accordance with ISO 5817.* Düsseldorf: DVS Media Verlag

[8] Hobbacher, A., ed. *Recommendations for fatigue design of welded joints and components*. IIW document XIII-1823-0. Welding Research Council New York, WRC-Bulletin 520, 2009

[9] Hobbacher, A., Kassner, M. *On relation between fatigue properties of welded joints, quality criteria and groups in ISO 5817*. IIW-document XIII-2323-10

[10] Karlsson, N., Lenander, P.H. *Analysis of fatigue life in two weld class systems*. Master thesis in Solid Mechanics, LITH-IKP-EX-05/2302-SE, Linköpings University, Sweden, 2005

