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Petroleum, petrochemical and natural gas industries — Test methods for quality control of microstructure of ferritic/austenitic (duplex) stainless steels

Industries du pétrole, de la pétrochimie et du gaz naturel — Méthodes d'essai de contrôle de la qualité de la microstructure des aciers inoxydables (duplex) austénitiques/ferritiques

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Foreword

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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).

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For an explanation on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*.

Introduction

The aim of this document is to establish common test methods for quality control of microstructure of ferritic/austenitic (duplex) stainless steels for the oil and gas industry, enabling the manufacturers to apply the same test procedures for their clients.

Duplex stainless steels have a dual phase microstructure consisting of ferrite and austenite. Ideally, these phases are present in equal proportions; although in alloys which are commercially available, the ferrite phase volume fraction can vary between 35 % and 65 % for products in the solution annealed condition. They are characterized by high-chromium (19 % to 33 %) and low-nickel contents compared with austenitic stainless steels.

Duplex stainless steels are prone to precipitation of intermetallic phases, carbides and/or nitrides possibly causing embrittlement and reduced corrosion resistance. The formation of intermetallic phases such as Sigma, σ, and Chi, χ, occurs depending on exposure time in the approximate temperature range 590 °C to 1 000 °C (1 094 °F to 1 832 °F) and decomposition of ferrite to Alpha Prime occurs in the range 300 °C to 540 °C (572 °F to 1 004 °F).

The microstructure of components or fabrication welds is affected by amongst others the thermal-mechanical history associated with hot working, solution annealing and with subsequent forming and welding. The destructive test methods with acceptance criteria specified herein are considered relevant to verify that exposure time at above stated temperature ranges have been within acceptable limits and to ensure that desired corrosion resistance and mechanical properties are obtained in final products.

Petroleum, petrochemical and natural gas industries — Test methods for quality control of microstructure of ferritic/austenitic (duplex) stainless steels

1 Scope

This document specifies quality control testing methods and test conditions for the characterization of microstructure in relation to relevant properties in ferritic/austenitic (duplex) stainless steel components supplied in the solution annealed condition and fabrication welds in the as welded condition.

This document supplements the relevant product and fabrication standards with respect to destructive testing methods including sampling of test specimens, test conditions and test acceptance criteria to show freedom from deleterious intermetallic phases and precipitates in duplex stainless steels. In addition, this document specifies the documentation of testing and test results by the testing laboratory.

NOTE 1 This document is based upon experience with duplex stainless steels in offshore oil and gas industry applications including topside and subsea hydrocarbon service, sea water service, as well as structural use.

NOTE 2 The austenite spacing is relevant to the susceptibility of duplex stainless steels to hydrogen-induced stress cracking (HISC) in subsea applications where cathodic protection is applied. This falls outside the scope of this document. Reference is made to DNV/GL RP-F112[4].

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 148-1, *Metallic materials — Charpy pendulum impact test — Part 1: Test method*

ISO 15614-1[1)], *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys)*

ASTM A 370, *Standard test methods and definitions for mechanical testing of steel products*

ASTM A 1058, *Standard test methods and definitions for mechanical testing of steel products — Metric*

ASTM A 1084, *Standard test method for detecting detrimental phases in lean duplex austenitic/ferritic stainless steels*

ASTM E 3, *Standard practice for preparation of metallographic specimens*

ASTM E 562, *Standard test method for determining volume fraction by systematic manual point count*

ASTM E 1245, *Standard practice for determining the inclusion or second-phase constituent content of metals by automatic image analysis*

ASTM G 48, *Standard test methods for pitting and crevice corrosion resistance of stainless steels and related alloys by use of ferric chloride solution*

1) For the purpose of this document, the following documents are considered equivalent: ASME Boiler and pressure vessel code, section IX Welding and brazing qualifications[2].

3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms and definitions apply.

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

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

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

NOTE For limitations in chemical composition of each specific material grade of duplex stainless steel, reference is made to the appropriate product standards or UNS number. For nominal chemical composition of duplex stainless steels and grouping of different types, used within this document, reference is made to Annex A.

3.1 Terms and definitions

3.1.1
centreline intermetallic stringer
group of *intermetallic phases* (3.1.4) aligned within the mid-thickness area due to alloy segregation

Note 1 to entry: They can be observed as both continuous and discontinuous precipitates.

3.1.2
fabrication
building of structures or equipment by cutting, bending, and assembling processes such as welding, riveting, threaded fasteners or other joining methods

3.1.3
ferritic/austenitic (duplex) steel
stainless steel (3.1.8) with a high-chromium mass fraction (19 % to 33 %) with or without molybdenum additions up to 5 %, and a nickel mass fraction intermediate to those of ferritic and austenitic stainless steels

3.1.4
intermetallic phase
solid-state compounds, containing two or more metallic elements, whose ordered structure differs from that of its constituents

Note 1 to entry: In duplex stainless steel, the most relevant phases are identified as σ-phase, χ-phase and R-phase.

3.1.5
lot
finite quantity of products from the same heat (or melt), same manufacturing process steps and same heat treatment load

Note 1 to entry: For continuous and semi-continuous furnaces, the lot definition should comply with the applicable product standards.

3.1.6
non-metallic precipitate
solid-state compounds, containing two or more elements, whose ordered structure differs from that of its constituents

Note 1 to entry: In duplex stainless steel, the relevant non-metallic precipitates are chromium carbides and nitrides.

3.1.7
pitting resistance equivalent number
PREN
number indicating the resistance of *stainless steel* (3.1.8) to pitting corrosion related to chemical composition and derived from one of the equations PREN = % Cr + 3,3 % Mo + 16 % N or PREN = % Cr + 3,3 × % (Mo + 0,5W) + 16 × % N (mass fraction)

Note 1 to entry: All PREN limits are absolute limits based upon the heat analysis. The calculated value is not to be rounded.

3.1.8
stainless steel
steel with at least 10,5 % mass fraction or more chromium, possibly with other elements added to secure special properties

3.1.9
type 20Cr duplex Group A
ferritic/austenitic *stainless steel* (3.1.8) alloys with 24,0 ≤ PREN < 28,0

3.1.10
type 20Cr duplex Group B
ferritic/austenitic *stainless steel* (3.1.8) alloys with 28,0 ≤ PREN < 30,0

3.1.11
type 22Cr duplex
ferritic/austenitic *stainless steel* (3.1.8) alloys with 30,0 ≤ PREN < 40,0 and Cr ≥ 19 % (mass fraction)

3.1.12
type 25Cr duplex
ferritic/austenitic *stainless steel* (3.1.8) alloys with 40,0 ≤ PREN < 48,0

3.1.13
type 27Cr duplex
ferritic/austenitic *stainless steel* (3.1.8) alloys with 48,0 ≤ PREN ≤ 55,0 and Cr ≤ 33,0 % (mass fraction)

3.2 Abbreviated terms

For the purposes of this document, the following abbreviated terms are used.

ASTM American society for testing and materials

CVN Charpy V-notch

HIP hot isostatically-pressed

NA not applicable

OD outside diameter

PREN pitting resistance equivalent number

QL quality level

T ruling section thickness

UNS unified numbering system

4 Sampling of test specimens

4.1 General

The test samples shall be made from a sacrificial product or from a prolongation/extension of a product in the final solution annealed condition with location of test specimens as defined in Table 1 representing the thickest product within the lot. Alternatively, a representative test block may be used when agreed with the purchaser.

Table 1 — Sampling of test specimens dependent of product

Product	Test sample	Product dimension	Test method	Test direction[a]	Thickness location
Plates, and seamless tubes, pipes and fittings	Prolongation of the product	All	CVN	Transverse	Mid-thickness
			Corrosion, Microstructure	Transverse	Full thickness[b]
Welded pipes and fittings	Prolongation or welded extension piece	All	CVN	Transverse	Mid-thickness
			Corrosion[c], Microstructure	Transverse	Full thickness[b]
Bars and long solid forgings without weld end	Prolongation	OD or section thickness <50 mm (2 in)	CVN	Longitudinal	Mid-thickness
			Corrosion, Microstructure	Transverse	Surface to centre[b]
		OD or section thickness ≥50 mm (2 in)	CVN	Longitudinal	1/4 thickness
			Corrosion, Microstructure	Transverse	Surface to centre[b]
Flanges and other hollow contour shaped forgings with weld end including tees	Sacrificial product or prolongation at weld end	All[d]	CVN	Both longitudinal and tangential to centre bore	Mid-thickness weld end
			Corrosion, Microstructure	Longitudinal or tangential	Full thickness[b] weld end
HIP products with weld end	Sacrificial product or prolongation at weld end with greatest wall thickness	All	CVN	Any direction	Mid-thickness weld end
			Corrosion, Microstructure	Any direction	Full thickness[b] weld end
HIP products without weld end[b]	Sacrificial product or prolongation at cross section with greatest wall thickness	Section thickness <50 mm (2 in)	CVN	Any direction	Mid-thickness
			Corrosion, Microstructure	Any direction	Surface to centre[b]
		Section thickness ≥50 mm (2 in)	CVN	Any direction	1/4 thickness
			Corrosion, Microstructure	Any direction	Surface to centre[b]
Castings	Sacrificial product or test block (see 4.2)	Test block thickness <50 mm (2 in)	CVN Corrosion, Microstructure	Any direction	Mid-thickness
		Test block thickness ≥50 mm (2 in)	CVN Corrosion, Microstructure	Any direction	Within hatched area (see Figure 1)

[a] For definition of test directions, reference is made to ASTM A 370/ASTM A 1058.

[b] For products with large sections, the corrosion test specimen shall be taken transverse to the longitudinal axis with dimensions of approximately 6 mm × 25 mm (1/4 in × 1 in) by thickness. For very large sections, the thickness dimension of the specimen can be cut so that one-half to two-thirds of the product thickness is tested.

[c] For welded products, the test specimens for corrosion testing and microstructure examination shall include weld metal and the heat affected zone of parent metal. For products with wall thickness exceeding 25 mm, more than one (1) specimen can be taken to cover full thickness. In such a case, all specimens shall fulfil the specified criteria.

[d] When flange body thickness <50 mm (2 in) or weld end OD ≤100 mm (4 in), test specimens may be taken from the flange body mid-thickness in tangential direction.

For all products, the mid-length of the test specimens shall be located one T or minimum 50 mm to any second surface provided this is feasible within the size of the test sample/sacrificial product.

CVN testing is required when the wall thickness is ≥6 mm, wherever geometry permits.

For all products, the notch axis of CVN test specimens shall be positioned perpendicular to the closest outer surface.

For welded products, two (2) sets of three (3) CVN impact toughness test specimens shall be taken from mid-thickness of the component, one (1) with notch located in base material and the other notched in the weld metal.

For forgings, HIP products and fittings, dimensioned sketches shall be established showing type, size and orientation of test specimens to be taken from a prolongation of product or a sacrificial product.

4.2 Casting test blocks

Test blocks shall be integral or gated with the casting(s) they represent and shall accompany the castings through all heat treatment operations. During any heat treatment of products, which the test block represents, the test blocks shall be tack welded onto the casting and shall accompany the castings through all heat treatment operations. Alternatively, a sacrificial product may be used as a test sample.

The thickness of the test block shall be equal to the thickest section of the casting(s) represented. For flanged components, the largest flange thickness should be used as the ruling section.

Dimensions of test blocks and location of test specimens within the test blocks are shown in Figure 1 for integral and gated test blocks, respectively. All test specimens shall be taken within the cross hatched area. When the thickness T of the test block is ≤50 mm, the longitudinal axis of test specimens shall be located in the centre of the test block.

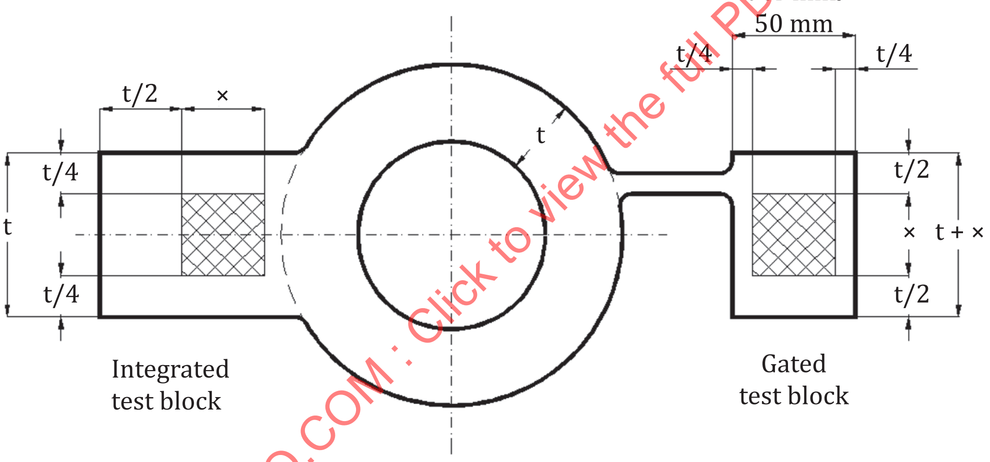


Figure 1 — Integral and gated test block for castings

4.3 Welds in the as welded condition

Test specimens for weld procedure qualification shall be taken in accordance with the requirements of ISO 15614-1 or applicable design code.

The test specimens for microstructural examination shall comprise a cross section of the weld metal, heat affected zones and base metal of parts joined in full thickness.

The ferrite content shall be determined in the weld metal root and the last bead of the weld cap 2 mm (0,08 in) below the surface. For welds with thickness less than 5 mm (0,2 in), the ferrite content shall be determined through the full thickness.

In total, three sets of CVN test specimens shall be taken from the following positions from the weld cap area:

— weld metal;

— fusion line;

— fusion line +2 mm (0,08 in).

When the weld thickness exceeds 25 mm (1,0 in), two (2) additional sets of specimens shall be taken from the weld root area 2 mm from the internal surface, one (1) from the weld metal and one (1) from the fusion line +2 mm (0,08 in).

The corrosion test specimen shall include the external and internal surface and a cross sectional surface including the weld zones in full wall thickness. The test specimens shall have a dimension of full wall thickness by 25 mm (1,0 in) along the weld and 50 mm (2,0 in) across the weld. For products with great wall thickness, e.g. exceeding 25 mm (1,0 in), more than one (1) specimen can be taken to cover full thickness. In such a case, all specimens shall fulfil the specified criteria.

5 Test methods

5.1 General

Laboratory test methods for evaluation of the microstructure of duplex stainless steel are as follows:

a) metallographic microstructural examination;

  — check for presence of intermetallic phases and non-metallic precipitates;

  — determine ferrite content;

b) CVN impact toughness testing;

c) ferric chloride corrosion test.

There are several parameters of the material microstructure that can influence the test results and the use of all three test methods, as far as practical, is necessary to demonstrate acceptable quality.

This document specifies how test results should be documented by the test house. Material certification reporting requirements are outside the scope of this document.

5.2 Microstructural examination

5.2.1 General

Microstructural examinations shall be carried out by trained and experienced technicians.

5.2.2 Preparation of specimen

Metallographic preparation of duplex stainless steels shall be in accordance with ASTM E 3 and shall be polished to a metallographic finish suitable for light optical examination at minimum 400 × (200 × for casting) after etching.

With mechanical polishing, a 1 µm diamond final polish or equivalent shall be used as minimum. Preferably, a final oxide polish (e.g. colloidal silica/alumina) should be used.

Electro polishing may be used as an alternative to mechanical polishing.

The use of conductive mounts can affect the subsequent etching. Samples should consequently be mounted into a resin (thermo-setting or cold-setting).

5.2.3 Etching of specimens

The base case etchant to detect intermetallic phases and the ferrite balance electrolytic etching should be performed after final polishing using the following solution:

— 20 % to 40 % NaOH or KOH solution.

In the case that it is of interest to detect nitrides/carbides, the following combination of two (2) solutions in sequence with examination in between should be used (or using two test specimens):

1) 10 % oxalic acid solution or V2A etchant, followed by

2) 20 % to 40 % NaOH or KOH solution or, alternatively, see 5.3.

NOTE For guidance on effect of different etching solutions, reference is made to Annex B. Exact etching parameters (e.g. time, voltage, etc.) are typically established by trial and error, and can depend on factors such as cathode material and area, specimen surface area and alloying content.

5.2.4 Microstructural evaluation of test specimens

5.2.4.1 General

The microstructure shall be examined by optical microscopy at a magnification sufficient to observe the presence of any intermetallic phases and/or nitride/carbide precipitates. The entire metallographic specimen shall be examined in the as-etched condition; starting at low magnification and followed by progressively higher magnifications (screening).

The assessment of the microstructure shall be made with a magnification of minimum 400 × for all product forms, except for castings where a 200 × magnification shall be used.

The presence and location of intermetallic phases and/or nitride/carbide precipitates shall be noted and recorded with micrographs representative of the location(s) with the highest concentration of intermetallic phases and the locations with the highest concentration of nitride/carbide precipitates. If intermetallic phases and nitride/carbide precipitates are not detected, a representative micrograph at or near mid-wall thickness shall be recorded. Micrographs shall be reported at the actual magnification and shall include a scale bar.

5.2.4.2 Acceptance criteria

The following acceptance criteria for intermetallic phases and precipitates shall apply.

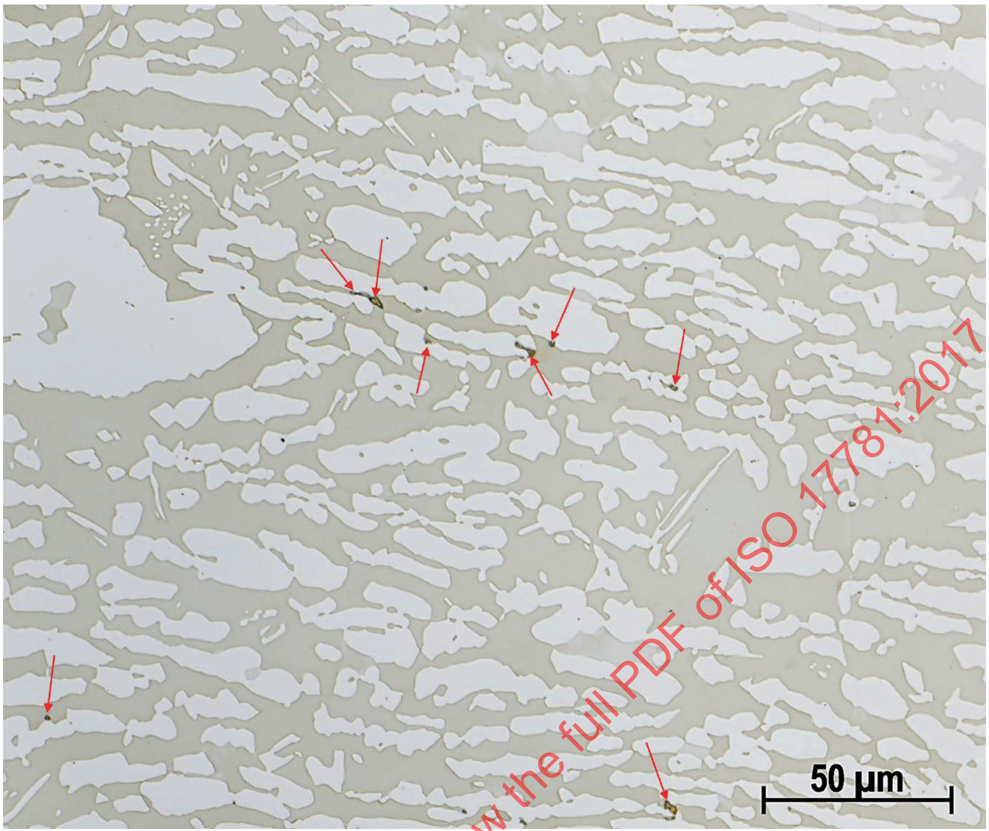
a) intermetallic phases

The microstructure shall basically be free from intermetallic precipitates. However, discrete/stand-alone intermetallic precipitates can be tolerated provided these are located in isolated areas and not homogeneously distributed throughout the test specimen, and that the maximum dimension of each precipitate does not exceed 10 µm.

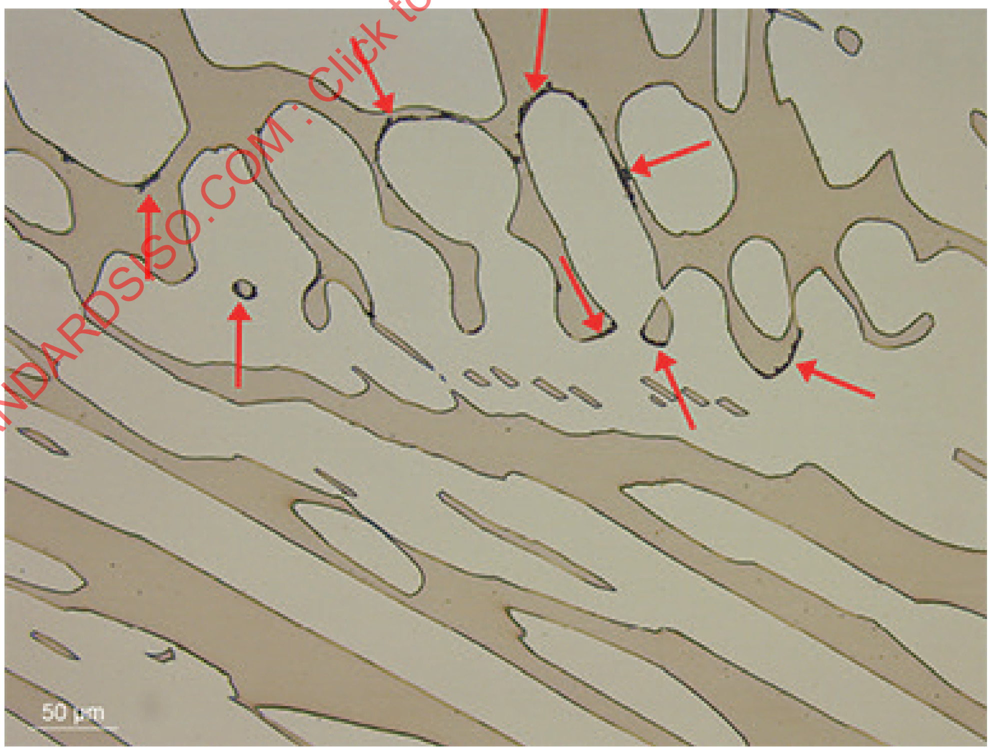
Micrographs included in Figure 2 are showing examples of microstructures representative of wrought and cast products containing such isolated areas with intermetallic precipitates to a level that can be considered borderline acceptable.

In case centreline intermetallic stringers are present, this shall be reported and acceptance of the product shall be based upon CVN and corrosion test results.

For welds tested in the as welded condition, the microstructure shall be free from intermetallic phases. Discrete/stand-alone intermetallic particles are acceptable given the maximum dimension of these is ≤10 µm, alternatively, the acceptance criteria of ISO 15156-3 shall apply.



a) Wrought microstructure etched in 20 % NaOH shown at 500 × magnification



b) Cast microstructure etched in 40 % KOH shown at 200 × magnification

Figure 2 — Micrographs showing examples of borderline acceptable discrete/stand-alone intermetallic particles for wrought products and castings

b) non-metallic precipitates

If carbide or nitride precipitates are observed, the findings shall be reported and documented, and the acceptance shall be based upon the corrosion and CVN impact toughness test (see Table 2 and 5.5).

NOTE Nitrides precipitate along grain boundaries and within the ferrite phase (see References [5], [6], [7] and [8]). Such precipitation can decrease resistance to hydrogen embrittlement in components under cathodic protection. Avoidance of hydrogen embrittlement subsea is principally achieved by appropriate design to limit service stresses/strains (see DNV/GL RP-F112[4]), but excessive nitride precipitation is to be avoided. While determination of the nitride phase balance is impractical, the presence of nitrides in the ferrite phase reduces the CVN impact toughness property, increases micro hardness in the ferrite phase and reduces the breakthrough pitting corrosion potential (see Reference [7]). Quality control to avoid excessive nitrides is therefore best achieved by meeting the impact and corrosion properties given in this specification and applying appropriate design criteria where hydrogen embrittlement is a credible threat (see DNV/GL RP-F112[4]).

5.2.4.3 Reporting

The microstructural examination test report issued by the test laboratory shall, as a minimum, include the following information:

— reference to examination procedure;

— identification of the test specimens;

— location and orientation of extracted specimen(s);

— specimen size;

— etching method(s) used;

— magnification used for examination;

— relevant micrographs;

— statement of findings/presence of intermetallic phases and precipitates. If intermetallic phases or precipitates are identified, a micrograph with a scale bar from a view with the most densely populated area shall be included together with a description of their distribution over the examined specimen (s);

— statement whether the acceptance criteria are fulfilled;

— name/signature/identification of technician.

5.3 Ferrite content measurement

5.3.1 Test standard and conditions

The ferrite content shall be determined by either point counting according to ASTM E 562 or by image analysis according to ASTM E 1245.

The ferrite content measurement shall cover the section thickness as stated in Table 1 at views equally spaced over the section thickness and the mean ferrite content value shall be reported.

The relative accuracy shall be 20 % maximum.

To expose the ferrite phase, the specimen shall be etched in 20 % to 40 % NaOH or KOH solution, Beraha's etchant (ASTM E 407, number 212[3]) or an alternative acceptable etchant as mentioned in Annex B.

5.3.2 Acceptance criteria

The ferrite content, in percentage by surface/volume fraction, shall be as stated below for all duplex grades:

— 35 % to 60 % in base material;

— 35 % to 65 % in solution heat treated weld metals;

— 30 % to 70 % for welds in the as welded condition.

5.3.3 Reporting

The ferrite content examination test report issued by the test laboratory shall, as a minimum, include the following information:

— procedure reference and method of counting;

— location of extracted specimen;

— specimen size and etching agents used;

— magnification used during examination;

— digital micrographs with scale bar showing typical microstructure including their location;

— ferrite content; mean value of all examined views;

— the type and size of grid used, if applicable, number of fields examined and relative accuracy;

— statement whether the acceptance criteria are fulfilled;

— name/signature/identification of technician.

5.4 Charpy V-notch impact toughness test

5.4.1 Test standard and conditions

CVN impact toughness testing shall be carried out according to ISO 148-1 (KV_8), ASTM A 370 or ASTM A 1058 at a temperature specified in Table 2 or lower.

NOTE The use of a hammer with smaller notch radius is considered conservative and therefore acceptable.

5.4.2 Acceptance criteria

The minimum absorbed energy of full size specimens is specified in Table 2. Two quality levels are defined. Selection of the quality level shall be made by the end user or purchaser.

NOTE Quality level II is in line with the acceptance level applied to the type 22/25 Cr duplex SS grades for more than 20 years and is the recommended level for most oil and gas applications. Quality level I is intended for special applications only. Selection of Quality level I can limit the availability of products with large cross sections.

Table 2 — Minimum absorbed energy requirements for Charpy V-notch impact toughness testing

Type of duplex	Temperature[a]	Product	Quality level	Minimum mean absorbed energy (J)[b]		Minimum single absorbed energy (J)[b]	
				Longitudinal	Transverse	Longitudinal	Transverse
20Cr Group A	Room temperature, maximum of 28 °C/82 °F	Plates, pipes[c] and fittings	NA	105	70	80	55
		Bars		105	NA	80	NA
		Forgings, castings and HIP products		70		55	
		Welds in as welded condition		45		35	
20Cr Group B/ 22Cr/25Cr/27Cr	−46 °C/ −50 °F	Plates, pipes[c] and fittings	QL I	85	60	65	45
			QL II	65	45	50	35
		Bars	QL I	85	NA	65	NA
			QL II	65	NA	50	NA
		Forgings, castings and HIP	QL I	60		45	
			QL II	45		35	
		Welds in as welded condition	QL I	50		40	
			QL II	35		27	

[a] Testing at lower temperature than specified should be considered acceptable.

[b] The reduction factors of energy requirements for sub-size specimens shall be 5/6 and 2/3 for 7,5 and 5 mm wide specimen respectively.

[c] This includes welded pipes and associated weld metal in the solution annealed condition.

5.4.3 Reporting

The CVN test report from the test laboratory shall, as a minimum, include the following information:

— standard of testing;

— test temperature;

— test location, direction and notch orientation of test specimen and specimen size;

— absorbed energy values;

— statement whether the acceptance criteria are fulfilled.

5.5 Corrosion test

5.5.1 Test standard and conditions

A ferric chloride corrosion test in accordance with ASTM G 48, Method A shall be carried out for type 22Cr duplex and higher alloyed grades. For leaner duplex grades, an inhibited $FeCl_3$ + $NaNO_3$ test solution in accordance with ASTM A 1084 shall be used. The test method and test temperature for the different duplex grades base material and welds in the as welded condition shall be as stated in Table 3.

The test exposure time shall be 24 h for both tests methods.

Test temperature tolerance shall be ±1 °C (±1,5 °F).

Table 3 — Corrosion testing for different grades of duplex stainless steel

Material grade	Test standard	Minimum test temperature base material (°C/°F)	Minimum test temperature welds in as weld condition (°C/°F)
Type 20Cr Group A	ASTM A 1084	18/64	Not applicable
Type 20Cr Group B	ASTM A 1084	30/86	Not applicable
Type 22Cr	ASTM G 48	25/77	22/72
Type 25Cr	ASTM G 48	50/122	35/95
Type 27Cr	ASTM G 48	60/140	40/104

5.5.2 Preparation of test specimens

The whole specimen shall be pickled before being weighed and tested. Pickling shall be performed in an acid solution following the guidance of ASTM A 380. An example for such a procedure is for 5 min at 60 °C in a solution of 20 % HNO_3 + 5 % HF (volume fraction).

Where it is agreed to test non-pickled specimens, the test conditions are considered more aggressive and the test should be accepted if passing the acceptance criteria.

5.5.3 Acceptance criteria

All surfaces of the test specimens shall be considered in the test.

The acceptance criteria shall be as follows.

— No pitting at 20 × magnification.

— The weight loss shall be less than 1,0 g/m^2 for products in the solution annealed condition.

— The weight loss shall be less than 4,0 g/m^2 for welds in the as welded condition.

Penetrant testing is recommended to judge if pitting is present or not.

5.5.4 Reporting

The corrosion test report from the test laboratory shall, as a minimum, include the following information:

— reference standard of testing;

— location of extracted specimen;

— specimen size and surface treatment/condition;

— test temperature and duration of test;

— magnification used during examination;

— weight of specimen before and after testing and weight loss in g/m^2;

— statement on presence of pitting;

— statement whether the acceptance criteria are fulfilled;

— name/signature/identification of technician.

Annex A
(informative)

Chemical compositions of duplex stainless steels

Table A.1 shows the chemical compositions of duplex stainless steels. Only the alloying elements are included in Table A.1. Maximum levels of impurity elements are not included, except for carbon. The grouping of alloys is based upon their nominal compositions and the group definitions in this document. This means that some alloys may also belong to another group dependent of the actual alloying content.

Table A.1 — Chemical compositions of duplex stainless steels

Composition range given in mass percent

UNS No.[a]	EN No.[a]	C[b]	Cr[b]	Ni[b]	Mo[b]	N[b]	Mn[b]	Cu[b]	W[b]
Type 20Cr Group A duplex, 24,0 ≤ PREN < 28,0									
S32001	1.4482	0,03	19,5 to 21,5	1,0 to 3,0	0,6	0,05 to 0,17	4,0 to 6,0	1,0	c
S32101	1.4162[d]	0,04	21,0 to 22,0	1,35 to 1,7	0,1 to 0,8	0,20 to 0,25	4,0 to 6,0	0,1 to 0,8	c
S32202	1.4062[d]	0,03	21,5 to 24,0	1,0 to 2,8	0,45	0,18 to 0,26	2,00	c	c
S82011	—	0,03	20,5 to 23,5	1,0 to 2,0	0,1 to 1,0	0,15 to 0,27	2,0 to 3,0	0,5	c
	1.4655	0,03	22,0 to 24,0	3,5 to 5,5	0,1 to 0,6	0,05 to 0,20	2,00	1,0 to 3,0	c
Type 20Cr Group B duplex, 28,0 ≤ PREN < 30,0									
S32003	—	0,03	19,5 to 22,5	3,0 to 4,0	1,5 to 2,0	0,14 to 0,20	2,00	c	c
S32304	1.4362	0,03	21,5 to 24,5	3,0 to 5,5	0,05 to 0,6	0,05 to 0,20	2,5	0,05 to 0,60	c
S31500	1.4424	0,03	18,0 to 19,0	4,25 to 5,25	2,5 to 3,0	0,05 to 0,1	c	c	
S81921		0,03	19,0 to 22,0	2,0 to 4,0	1,0 to 2,0	0,14 to 0,20	2,0 to 4,0	c	c
Type 22Cr duplex, 30,0 ≤ PREN < 40,0 and Cr ≥ 19,5 %									
J92205		0,03	21,0 to 23,5	4,5 to 6,5	2,5 to 3,5	0,10 to 0,30	1,50	1,0	c
S31803	1.4462	0,03	21,0 to 23,0	4,5 to 6,5	2,5 to 3,5	0,08 to 0,20	2,00	c	c
S32205	1.4462	0,03	22,0 to 23,0	4,5 to 6,5	3,0 to 3,5	0,14 to 0,20	2,00	c	c
S31200	—	0,03	24,0 to 26,0	5,5 to 6,5	1,2 to 2,0	0,14 to 0,20	2,00	c	c
S32404	—	0,04	20,5 to 22,5	5,5 to 8,5	2,0 to 3,0	0,20 to 0,30	2,00	1,0 to 2,0	
S32506	—	0,03	24,0 to 26,0	5,5 to 7,2	3,0 to 3,5	0,08 to 0,20	1,00	-	0,05 to 3,0
S32808	—	0,03	27,0 to 27,9	7,0 to 8,2	0,8 to 1,2	0,30 to 0,40	1,10	c	2,1 to 2,5
S32900	1.4460	0,08	23,0 to 28,0	2,5 to 5,0	1,0 to 2,0	c	1,0	c	
S82011		0,03	20,5 to 23,5	1,0 to 2,0	0,10 to 1,0	0,15 to 0,27	2,0 to 3,0	0,5	c
S82122		0,03	20,5 to 21,5	1,5 to 2,5	0,60	0,15 to 0,20	2,0 to 4,0	0,5 to 1,5	c
S82551		0,03	24,5 to 26,5	4,5 to 6,5	0,75 to 2,00	0-10 to 0,35	1,5	2,0 to 3,0	c

a The chemical composition given by the UNS Nos. and EN steel Nos. are similar, but not equivalent.

b Single values denote a maximum allowable.

c Chemical element not voluntarily added and with commonly obtained residual level.

d These grades are patented.