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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

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).

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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.