

Design guideline to avoid hydrogen induced stress cracking in subsea duplex stainless steels

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This Workshop Agreement is based on contributions provided by representatives from key companies in the oil and gas industry in Norway

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Introduction

This guideline is based on the current industry practice and the experience gained by use of duplex stainless steels in sub-sea applications over the last 20 years and reflects the practice in several ongoing oil and gas projects including evaluation of known failure cases. The main body of the guideline covers the requirements, while best practice recommendations are provided as a supplement in the end.

Duplex stainless steels have shown susceptibility to HISC in subsea applications. Design, cathodic protection, material properties/microstructure, extent and type of coating and stress/strain level are factors influencing the risk for HISC. It is important to highlight that failures due to HISC have only occurred in very special cases, and have been due to over loading and sub-standard welds, see Annex D for an overview of known failures.

It is acknowledged that several research projects are ongoing and they may change the content of this guideline in the future.

The initiative for preparing this guideline was taken by the NORSOK material expert group K 114/EGM, *Materials*. With background in the severe failures cases there has been a need for a “quick fix” design guideline. A working group was established with representatives from the following companies:

- Aker Kvaerner Engineering & Technology
- Det Norske Veritas
- FMC Kongsberg Subsea
- Norsk Hydro
- Aker Kværner Subsea
- SINTEF
- Statoil
- Technip Offshore Norge
- Vetco Gray

The working group as such has been autonomous and the content of the guideline reflects the sum of experience and knowledge by the members within the group. Due to the need for a quick issuance the guideline is issued as NORSOK Workshop Agreement, for which the NORSOK procedure for industry hearing is not required. Further, it is anticipated that the guideline would have a limited lifetime until the matters for a safe design related to HISC for duplex materials have been documented by testing and implemented in recognized standards (e.g. ISO, API) and/or in a DNV Recommended Practice. Based on the mentioned reasons the guideline has been issued as a Workshop Agreement.

1 Scope

This guideline specifies design requirements in order to avoid HISC in duplex stainless steels in subsea applications when subjected to conventional cathodic protection, covering e.g.:

- manifold piping;
- pipelines, risers and associated components;
- umbilical end terminations.

2 Normative and informative references

The following standards include provisions and guidelines which, through reference in this text, constitute provisions and guidelines of this NORSOK standard. Latest issue of the references shall be used unless otherwise agreed. Other recognized standards may be used provided it can be shown that they meet or exceed the requirements and guidelines of the standards referenced below.

2.1 Normative references

DNV OS-F101, Submarine Pipeline Systems

2.2 Informative references

ASME VIII, Div.2, Appendix 4, Boiler and Pressure Vessel Code – Rules for Construction of pressure vessels

3 Terms, definitions, abbreviations and symbols

For the purposes of this NORSOK standard, the following terms, definitions and abbreviations apply.

3.1 Terms and definitions

3.1.1

can

verbal form used for statements of possibility and capability, whether material, physical or casual

3.1.2

duplex stainless steel (austenitic/ferritic stainless steel)

stainless steel whose microstructure at room temperature consists primarily of a mixture (50/50) of austenite and ferrite

3.1.3

hydrogen induced stress cracking

HISC

cracking that results from the presence of hydrogen in a metal and tensile stress (residual and/or applied)

3.1.4

may

verbal form used to indicate a course of action permissible within the limits of this NORSOK standard

3.1.5

shall

verbal form used to indicate requirements strictly to be followed in order to conform to this NORSOK standard and from which no deviation is permitted, unless accepted by all involved parties

3.1.6

should

verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required

3.2 Abbreviations

API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
CP	cathodic protection
DNV	Det Norske Veritas
FEA	finite element analysis
HISC	hydrogen induced stress cracking
ISO	International Organization for Standardization
SCF	stress concentration factor
SMYS	specified minimum yield strength
SNCF	strain concentration factor
ULS	ultimate limit state

3.3 Symbols

σ	is the stress (indexes are according to criteria, see Clause 5)
ϵ	is the strain (indexes are according to criteria, see Clause 5)
Y_F	is the load effect factor (1,1 for ULS load condition (b), safety class normal), see DNV OS-F101, Table 5-6.
Y_C	is the condition load effect factor for functional loads according to DNV OS-F101, Table 5-7
E	is the Youngs modulus (= 200 000 MPa for duplex steels).

4 Technical requirements

The technical requirements in order to avoid HISC in duplex stainless steels can be summarized as follows:

- Keep control over interface loads and imposed loads during service life.
- Definition of stresses and strains shall be as specified in Clause 5.
- Design shall fulfil the requirements outlined in Clause 6.
- CP system shall be in accordance with the requirements given in Clause 7.

5 Design acceptance criteria - Stress and strain assessment

5.1 General

HISC is a non ductile mode of failure by an interaction between stresses, the CP system, and a susceptible duplex stainless steel material. Only loads acting while the structure is submerged, and the CP system is active, are therefore relevant. All load contributions causing stress and strain shall be included. The designer should be aware that deformation loads such as thermal stresses, subsidence effects, and residual stress which may be partly or completely disregarded in design for ductile modes of failure, shall be included, and that careful considerations shall be given to all effects contributing to peak tensile stress.

The design requirements herein are aimed at avoiding HISC. They are a supplement to, and not a replacement for, the selected design code. In case of conflict between the selected design code and the requirements in this document, the most stringent requirement shall apply.

5.2 Introduction to stress/strain assessment

The objective of the stress and strain criteria is to ensure that the loading does not initiate significant creep in the material. The following three separate criteria are established, each applying to different type of locations:

1. Stress/strain requirement for smooth pipe section without welds.
2. Stress/strain requirement for components.
3. Stress/strain for welds.

As a first assessment a linear elastic stress screening criteria according to 5.5, 5.6 and 5.7 could be performed. The analysis is based on global stresses and it is not taking into account SCFs and residual stresses. If the criterion is satisfied no further analysis is required.

If the linear elastic stress screening criterion is not satisfied the design may be checked against the global and the local non-linear strain criteria (where SNCFs and residual stresses are included), see 5.5, 5.6 and 5.7.