INTERNATIONAL STANDARD

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Petroleum and natural gas industries — Drilling and production equipment — Marine drilling riser couplings

Industries du pétrole et du gaz naturel — Équipement de forage et de production — Connecteurs de tubes prolongateurs pour forages en mer

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 13625 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 4, *Drilling and production equipment*.

This corrected version of ISO 13625:2002 incorporates correction of the French title.

Introduction

This International Standard is based upon API[1)] Specification 16R, first edition, January 1997[1].

Users of this International Standard should be aware that further or differing requirements could be needed for individual applications. This International Standard is not intended to inhibit a vendor from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application. This can be particularly applicable where there is innovative or developing technology. Where an alternative is offered, the vendor will need to identify any variations from this International Standard and provide details.

1) American Petroleum Institute, 1220 L Street NW, Washington D.C. 20005, USA.

Petroleum and natural gas industries — Drilling and production equipment — Marine drilling riser couplings

1 Scope

This International Standard specifies requirements and gives recommendations for the design, rating, manufacturing and testing of marine drilling riser couplings. Coupling capacity ratings are established to enable the grouping of coupling models according to their maximum stresses developed under specific levels of loading, regardless of manufacturer or method of make-up. This International Standard relates directly to API RP 16Q, which provides guidelines for the design, selection, and operation of the marine drilling riser system as a whole.

2 Normative references

The following referenced documents are indispensable for the application 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, *Steel — Charpy impact test (V-notch)*

ISO 6506-1, *Metallic materials — Brinell hardness test — Part 1: Test method*

ISO 6507-1, *Metallic materials — Vickers hardness test — Part 1: Test method*

ISO 6508-1, *Metallic materials — Rockwell hardness test — Part 1: Test method (scales A, B, C, D, E, F, G, H, K, N, T)*

ISO 6892, *Metallic materials — Tensile testing at ambient temperature*

ISO 10423:2001, *Petroleum and natural gas industries — Drilling and production equipment — Wellhead and christmas tree equipment*

ASME [2], *Boiler and Pressure Vessel Code, Section V*

ASME, *Boiler and Pressure Vessel Code, Section VIII*

ASTM [3] E 94, *Standard Guide for Radiographic Examination*

ASTM E 165, *Standard Test Method for Liquid Penetrant Examination*

ASTM E 709, *Standard Guide for Magnetic Particle Examination*

ASTM E 747, *Standard Practice for Design, Manufacture and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology*

2) American Society of Mechanical Engineers, 1950 Stemmons Freeway, Dallas, Texas 75207, USA.

3) American Society of Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103-1187, USA.

3 Terms, definitions and abbreviations

3.1 Terms and definitions

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

NOTE A comprehensive list of definitions pertaining to marine drilling riser systems is contained in API RP 16Q[2].

3.1.1
auxiliary line
external conduit (excluding choke and kill lines) arranged parallel to the riser main tube for enabling fluid flow

EXAMPLE Control system fluid line, buoyancy control line, mud boost line.

3.1.2
breech-block coupling
coupling which is engaged by partial rotation of one member into an interlock with another

3.1.3
buoyancy
devices added to the riser joints to reduce their submerged weight

3.1.4
choke and kill lines
C&K lines
external conduits, arranged parallel to the main tube, used for circulation of fluids to control well pressure

NOTE Choke and kill lines are primary pressure-containing members.

3.1.5
collet-type coupling
coupling having a slotted cylindrical element joint mating coupling members

3.1.6
dog-type coupling
coupling having dogs which act as wedges mechanically driven between the box and pin for engagement

3.1.7
flange-type coupling
coupling having two flanges joined by bolts

3.1.8
indication
visual sign of cracks, pits, or other abnormalities found during liquid penetrant and magnetic particle examination

3.1.8.1
linear indication
indication in which the length is equal to or greater than three times its width

3.1.8.2
relevant indication
any indication with a major dimension over 1,6 mm (1/16 in)

3.1.8.3
rounded indication
indication that is circular or elliptical with its length less than three times the width

3.1.9
marine riser coupling
means of quickly connecting and disconnecting riser joints

NOTE The coupling box or pin (depending on design type) provides a support for transmitting loads from the suspended riser string to the riser-handling spider while running or retrieving the riser. Additionally, the coupling can provide support for choke and kill and auxiliary lines, and load reaction for buoyancy.

3.1.10
marine drilling riser
tubular conduit serving as an extension of the well bore from the well control equipment on the wellhead at the seafloor to a floating drilling rig

3.1.11
preload
compressive bearing load developed between box and pin members at their interface; this is accomplished by elastic deformation induced during make-up of the coupling

3.1.12
rated load
nominal applied loading condition used during coupling design, analysis and testing, based on a maximum anticipated service loading

NOTE Under the rated working load, no average section stress in the riser coupling exceeds allowable limits established in this International Standard.

3.1.13
riser coupling box
female coupling member

3.1.14
riser joint
section of riser pipe having ends fitted with a box and a pin, typically including integral choke and kill and auxiliary lines

3.1.15
riser main tube
basic pipe from which riser joints are fabricated

3.1.16
riser coupling pin
male coupling member

3.1.17
stress amplification factor
SAF
K_{SAF}
factor equal to the local peak alternating stress in a component (including welds) divided by the nominal alternating stress in the pipe wall at the location of the component

NOTE This factor is used to account for the increase in the stresses caused by geometric stress amplifiers which occur in riser components.

3.1.18
threaded coupling
coupling having matching threaded members to form engagement

3.2 Abbreviations

The following abbreviations are used in this International Standard.

BOP	Blowout preventer
C&K	Choke and kill
LP	Liquid penetrant
MP	Magnetic particle
NDE	Non-destructive examination
QTC	Qualified test coupon
SAF	Stress amplification factor

4 Design

4.1 Service classifications

4.1.1 Design information

The coupling manufacturer shall provide design information for each coupling size and model which defines load capacity rating. These data are to be based on design load (see 4.5) and verified by testing (see 8.2).

4.1.2 Size

Riser couplings are categorized by riser main tube size . The riser pipe outer diameter and wall thickness (or wall thickness range) for which the coupling is designed shall be documented.

4.1.3 Rated load

The rated loads listed in here provide a means of general classification of coupling models based on stress magnitude caused by applied load. To qualify for a particular rated load, neither calculated nor measured stresses in a coupling shall exceed the allowable stress limits of the coupling material when subjected to the rated load. The allowable material stresses are established in 4.6.

The rated loads are as follows:

a) 2 220 kN (500 000 lbf);

b) 4 450 kN (1 000 000 lbf);

c) 5 560 kN (1 250 000 lbf);

d) 6 670 kN (1 500 000 lbf);

e) 8 900 kN (2 000 000 lbf);

f) 11 120 kN (2 500 000 lbf);

g) 13 350 kN (3 000 000 lbf);

h) 15 570 kN (3 500 000 lbf).

4.1.4 Stress amplification factor

The calculated SAF values for the coupling shall be documented at the pipe-to-coupling weld and at the locations of highest stress in the pin and box. SAF is a function of pipe size, and wall thickness. It is calculated as follows:

$$K_{SAF} = \frac{\sigma_{LPA}}{\sigma_{NAS}}$$

where

σ_{LPA} is local peak alternating stress;

σ_{NAS} is nominal alternating stress in pipe.

4.1.5 Rated working pressure

Riser couplings shall be designed to provide a pressure seal between joints. The manufacturer shall document the rated internal working pressure for the coupling design.

4.2 Riser loading

4.2.1 General

A drilling riser's ability to resist environmental loading depends primarily on tension. Environmental loading includes the hydrodynamic forces of current and waves and the motions induced by the floating vessel's dynamic response to waves and wind.

The determination of a riser's response to the environmental loading and determination of the mechanical loads acting upon, and developed within, the riser require specialized computer modelling and analysis. (For the general procedure used to determine riser system design loads and responses, see API RP 16Q[2].

Additional sources of applied load that are not included in the rated load may significantly affect the coupling design and shall be included in design calculations.

4.2.2 Loads induced by choke and kill and auxiliary lines

Riser couplings typically provide support for choke and kill and auxiliary lines. This support constrains the lines to approximate the curvature of the riser pipe. Loads can be induced on the coupling from pressure in the lines, imposed deflections on the lines and the weight of the lines. The manufacturer shall document those loads induced by choke and kill and auxiliary lines for which the coupling has been designed.

4.2.3 Loads induced by buoyancy

Riser couplings may provide support for buoyancy, which induces loads on the couplings. The manufacturer shall document the buoyancy thrust loads for which the coupling has been designed.

4.2.4 Loads induced during handling

Temporary loads are induced by suspending the riser from the handling tool or spider or both. The manufacturer shall document the riser handling loads for which the coupling is designed and how these loads are applied.

4.3 Determination of stresses by analysis

Design of riser couplings for static loading (see 4.6) and determination of the stress amplification factors (see 4.7) require detailed knowledge of the stress distribution in the coupling. This information is acquired by finite element analysis and subsequently validated by prototype strain gauge testing. A finite element analysis of the riser coupling shall be performed and documented. The analysis shall provide accurate or conservative peak stresses, and shall include any deleterious effects of loss of preload from wear, friction and manufacturing tolerances. Suggestions for the analysis can be found in Annex A. The following shall be documented and included in the analysis:

a) hardware and software used to perform the analysis;

b) grid size;

c) applied loads;

d) preload losses;

e) material considerations.

4.4 Stress distribution verification test

After completion of the design studies, a prototype (or multiple prototypes) of the riser coupling shall be tested to verify the stress analysis. The testing has two primary objectives: to verify any assumptions which were made about preloading, separation behaviour and friction coefficients, and to substantiate the analytical stress predictions.

Strain gauge data shall be used to measure preload stresses as they relate to make-up load or displacement. Friction coefficients shall be varied (including at least two values) in order to establish sensitivity.

The coupling design load shall be applied in order to verify any assumption made in the analysis regarding separation.

Strain gauges shall be placed as near as physically possible to at least five of the most highly stressed regions, as predicted by the finite element analyses performed in accordance with 4.3, and in five locations away from stress concentrations. Rosettes shall be used. All strain gauge readings and the associated loading conditions shall be recorded such that they may be retained as part of the coupling design documentation.

Normal design qualification tests may be performed simultaneously with this stress distribution verification testing (see 8.2).

NOTE It is often difficult to acquire sufficient strain data to totally correlate with the analytical results. High-stress areas may be inaccessible and are sometimes so small that a strain gauge gives an average rather than the peak value. The testing serves to verify the pattern of strain in regions surrounding the critical points.

4.5 Coupling design load

The coupling design load represents the maximum load-carrying capacity of the coupling. The manufacturer shall establish the design load for each coupling design, based on the methods and criteria given in this International Standard. Neither calculated nor measured stresses in a coupling shall exceed the allowable stress limits of the coupling material when subjected to the design load. The allowable material stresses are established in 4.6. The coupling's rated load (see 4.1.3) shall be less than or equal to the coupling's design load.

For simplicity, the design loading condition is taken to be axisymmetric tension. In using this simplification, riser bending moment is converted to equivalent tension, T_{EQ}. The coupling design load can be specified either as an axisymmetric tension of magnitude, T_{design}, or it may be considered to be any combination of tension (T) and bending moment (M) so that

$$T + \frac{Mc}{I}A = T + M\frac{32t(d_o - t)^2}{d_o^4 - (d_o - 2t)^4} = T + T_{EQ} = T_{design} \qquad (2)$$

where

c is the mean radius of riser pipe;

I is the moment of inertia of riser pipe;

A is the cross-sectional area of riser pipe;

d_o is the outside diameter of riser pipe;

t is the wall thickness of riser pipe.

Using this relationship, the maximum calculated riser pipe stress at the middle of the pipe wall caused by pure bending is treated in the same manner as that caused by pure tension. To classify a particular coupling design, only the axisymmetric tensile load (T_{design}) case need be considered.

While the coupling design load provides a means of grouping coupling models regardless of manufacturer or method of make-up, it does not include all loads affecting coupling design. Additional loads (see 4.2) shall also be included in the evaluation of coupling designs.

4.6 Design for static loading

4.6.1 General

The design of a riser coupling for static loading requires that it support the design load and preload, if any, while keeping the maximum cross-sectional stresses within specified allowable limits.

4.6.2 Riser coupling stresses

For all riser coupling components except bolts, stress levels shall be kept below the values provided in Annex C.

For load-carrying bolts in bolted-flange couplings, the manufacturer shall document the design-allowable stress levels in the bolts. Acceptance criteria for these bolt stresses shall be based on recognized codes and standards.

4.7 Stress amplification factor

Field experience suggests that the most likely cause of a riser coupling failure is propagation of a fatigue crack that has been initiated at a point of stress concentration. It is, therefore, incumbent upon the designer to endeavour to minimize the conditions leading to the initiation and propagation of fatigue cracks. The SAF is intended to provide the coupling user with information needed to estimate fatigue damage for a particular application, without extensive fatigue testing of the coupling. The SAF is a function of the double amplitude range of alternating stress.

It is important to note that the SAF value depends largely on the exhaustiveness of the finite element analysis and the validity of assumptions in the analysis. Assumptions such as load distribution, the correctness of preloading in field service and finite element size at critically stressed points necessitate individual evaluation for each design case.

The following procedure shall be used for an individual coupling design:

a) select the rated load from 4.1.3;

b) perform finite element analysis in accordance with 4.3 to determine maximum equivalent combined stresses for the loads

   1) L_1 = nominal preload plus 0,2 × rated load,

   2) L_2 = nominal preload plus 0,4 × rated load,

3) L_3 = nominal preload plus 0,6 × rated load,

4) L_4 = nominal preload plus 0,8 × rated load,

5) L_5 = minimum preload plus 0,2 × rated load,

6) L_6 = minimum preload plus 0,4 × rated load,

7) L_7 = minimum preload plus 0,6 × rated load, and

8) L_8 = minimum preload plus 0,8 × rated load;

c) verify the finite element analysis by strain gauge test of prototype in accordance with 4.4;

d) identify high-stress points in the structure and the pipe–to–coupling weld. For each, record the local peak stresses L_1 to L_8 (using von Mises' theory, explained in more detail in Annex C) for loading conditions L_1 to L_8;

e) calculate the SAFs for the pin and for the box of the coupling. If SAF varies with load or preload, document this variation.

4.8 Design documentation

For each size, model and service classification, the following documentation shall be retained by the manufacturer for a period of at least ten years after the manufacture of the last unit of that size, model and service classification:

a) design loads (tensile, bending, loads from auxiliary lines and others) in accordance with 4.2;

b) finite element analysis performed in accordance with 4.3;

c) results of tests performed in accordance with 4.4 and 8.2;

d) results of SAF and peak stress calculations in accordance with 4.7.

5 Material selection and welding

5.1 Material selection

5.1.1 General

Material selection for each component of the riser coupling shall include consideration of the type of loading, the temperature range, the corrosive conditions, strength requirements, durability, toughness and the consequences of failure. Documentation of these design parameters shall be retained by the riser system manufacturer throughout the design life of the riser system. All materials used shall conform to a written specification covering chemical composition, physical and mechanical properties, method and process of manufacture, heat treatment, weldability, and quality control. Such written specification may be either a published or manufacturer's proprietary document.

All materials for primary load-carrying components, including weld metals, shall be low alloy steels having properties as represented by test coupons conforming to the specifications of 5.1.5. Test coupons shall be cut from a separate or attached block, taken from the same heat and, when applicable, formed similarly and given the same heat treatment as the product material they represent.

5.1.2 Chemical composition

All materials shall conform to the chemical composition provided in the manufacturer's written specification. Conformance with the manufacturer's composition specification shall be demonstrated by mill analysis or test sample verification.

5.1.3 Mechanical properties

All materials shall meet the minimum and maximum mechanical properties specified in the manufacturer's written specification. Materials for primary load-carrying components, including weldments, shall additionally meet the minimum mechanical properties in Table 1.

Tensile testing shall be performed in accordance with ISO 6892 after all heat treatment for mechanical properties and using representative test coupons conforming to the specifications of 5.1.5.

Table 1 — Minimum mechanical properties

Property	Minimum value
Elongation	18 %
Reduction of area	35 %

5.1.4 Impact testing

Materials for components that are in the load path, including weldments, shall meet the following minimum Charpy V-notch impact values:

a) average for three specimens: 41 J @ −20 °C (30 ft-lbf @ −4 °F);

b) minimum single value: 28 J @ −20 °C (21 ft-lbf @ −4 °F).

Charpy impact testing shall be performed in accordance with ISO 148 after all heat treatment for mechanical properties and shall use representative test coupons. Notch impact tests shall be performed with the test specimens oriented longitudinally to the grain orientation of the parent metal.

5.1.5 Test specimens

5.1.5.1 General

Test specimens shall be taken from a qualified test coupon (QTC) in accordance with ISO 10423:2001, 5.7 and 5.7.4.1.

5.1.5.2 Tensile and impact testing

Tensile and impact test specimens shall be removed from the same QTC after the final QTC heat treatment cycle.

Tensile and impact specimens shall be removed from the QTC so that their longitudinal centreline axis is wholly within the centre core 1/4 "*t*" envelope for a solid QTC or within 6 mm (1/4 in) of the mid-thickness of the thickest section of a hollow QTC (see Figure 1).

When a sacrificial production part is used as a QTC, the impact and tensile test specimens shall be removed from the 1/4 "*t*" location of the thickest section in that part.

5.1.5.3 Hardness testing

The following steps apply to hardness testing:

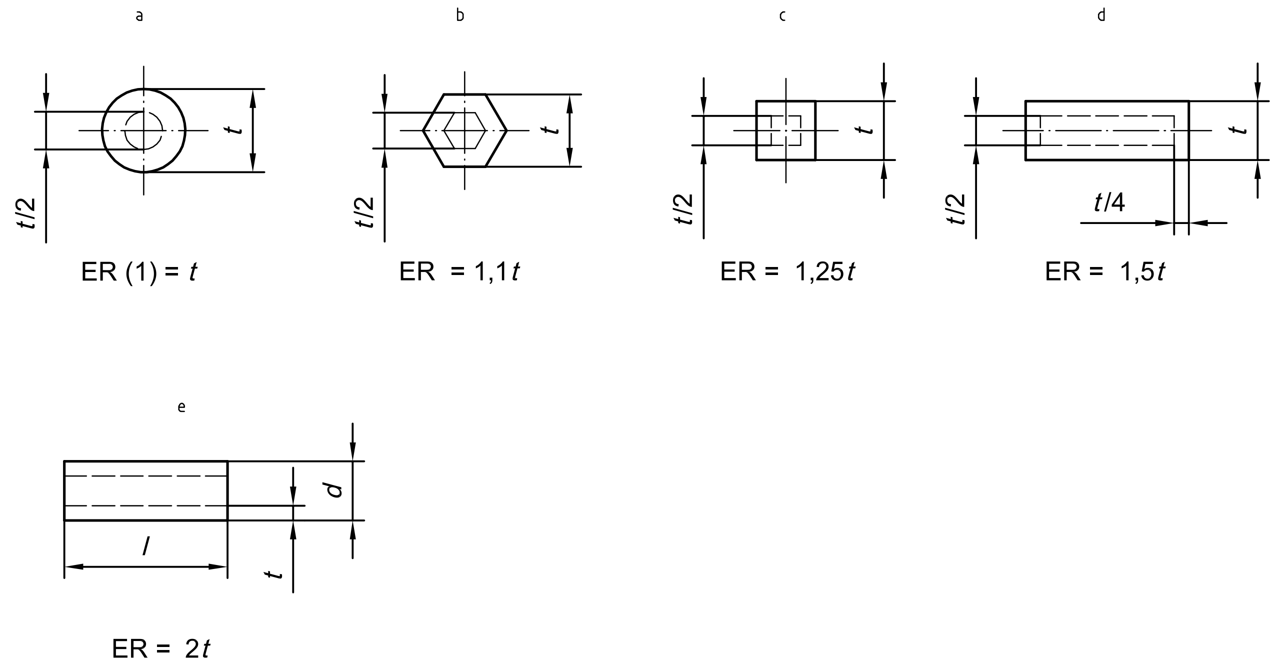
a) a minimum of two Brinell hardness tests shall be performed on the QTC after the final heat treatment cycle;

b) hardness testing shall be performed in accordance with ISO 6506-1;

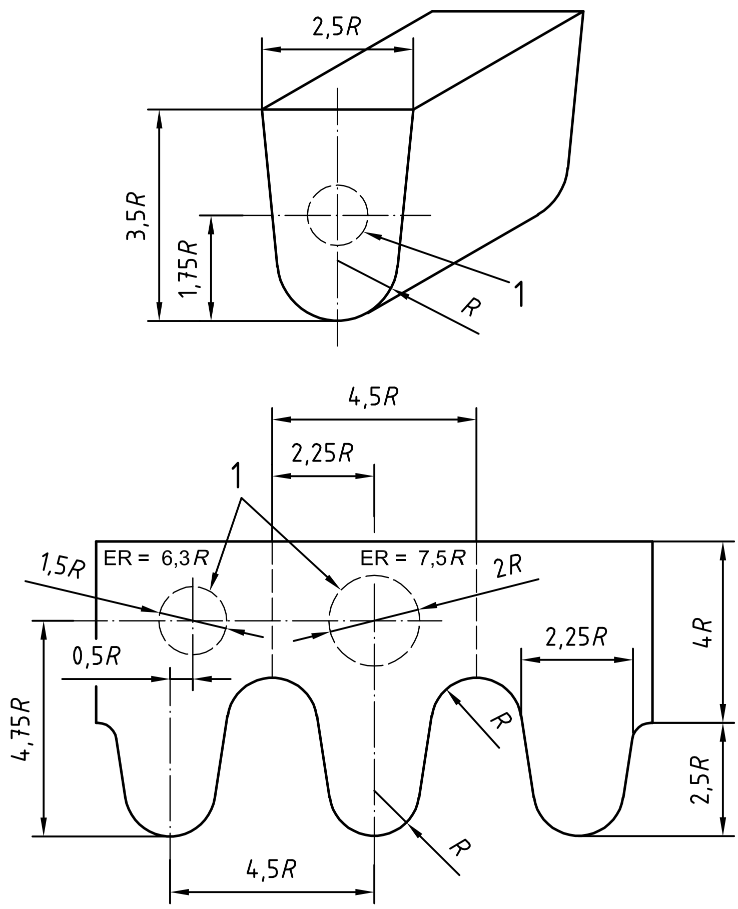
c) the hardness of the QTC shall meet the manufacturer's written specification.

5.2 Welding

Welding procedures and processes shall be in accordance with ISO 10423:2001, 6.3 and 6.3.4.



a) Simple geometric equivalent round sections/shapes having length *l*



b) Keel block configuration (ER = 2,3*R*)

When *l* is less than *t*, consider the section as a plate of *l* thickness.

When *l* is less than *d*, consider the section as a plate of *t* thickness.

NOTE Area inside dashed lines in a) is 1/4*t* envelope for test specimen removal.

Key

1 1/4*t* envelope for test specimen removal

a Round

b Hexagon

c Square

d Rectangle or plate

e Simple hollow shape

Figure 1 — Equivalent round (ER) models

6 Dimensions and weights

6.1 Coupling dimensions

Riser couplings are categorized by mating riser pipe sizes. Riser pipe and the associated couplings are generally sized to be compatible with a specific blowout preventer (BOP) stack size. Compatible BOP bore and riser outer diameter combinations are shown in Table 2. The make-up length, butt weld-to-butt weld, shall be documented.

Table 2 — Compatible BOP bore and riser outer diameter combinations

BOP bore	Riser outer diameter
346 mm (13 5/8 in)	406 mm (16 in) riser
425 mm (16 3/4 in)	473 mm (18 5/8 in) riser
476 mm (18 3/4 in)	508 mm (20 in) or 533 mm (21 in) riser
527 mm (20 3/4 in)	558 mm (22 in) or 609 mm (24 in) riser
539 mm (21 1/4 in)	609 mm (24 in) riser
NOTE A given coupling size may be used with a range of riser pipe outside diameters, wall thicknesses, and material yield strengths.	

6.2 Coupling weight

The coupling weight for each coupling size shall be documented. The weight of a riser coupling shall include the sum of the in-air weights of the structural components of the coupling, the lock mechanisms and the brackets or clamps that support the end extremities of auxiliary and choke and kill lines. The coupling weight includes the in-air weight of any and all parts that contribute to the submerged, in-service weight of the coupling.

7 Quality control

7.1 General

The manufacturer shall retain all records required by this International Standard for a period of ten years after the manufacture of the last unit of that size, model, and service classification.

7.2 Raw material conformance

7.2.1 Traceability

Parts in the primary load path shall be traceable to the individual heat and heat treatment lot.

Identification shall be maintained on materials and parts to facilitate traceability, as required by documented manufacturer's requirements.

Manufacturer's documented traceability requirements shall include provisions for maintenance or replacement of identification marks and identification control records.

7.2.2 Chemical analysis

Chemical analysis shall be performed in accordance with a recognized industry standard.

The chemical composition shall be in accordance with the manufacturer's written specification.

7.3 Manufacturing conformance

7.3.1 General

The manufacturer shall retain drawings and documentation by serial number and part number regarding material properties, heat numbers, riser tube dimensions, minimum through bore, service classifications and date of manufacture, as well as design documentation in accordance with 4.8. In addition, the following steps are required.

7.3.2 Visual examination

The requirements for visual examination are as follows.

a) Each part shall be visually examined.

b) Visual examinations of castings and forgings shall be performed in accordance with the manufacturer's written specification.

c) Acceptance criteria shall be in accordance with the manufacturer's written specifications.

7.3.3 Surface non-destructive examination (NDE)

7.3.3.1 General

All surfaces of each finished part shall be inspected in accordance with 7.3.3.2 to 7.3.3.5.

7.3.3.2 Surface NDE ferromagnetic materials

Well fluid wetted surfaces and all accessible sealing surfaces of each finished part shall be inspected after final heat treatment and after final machining operations by either magnetic particle (MP) or liquid penetrant (LP) methods.

7.3.3.3 Surface NDE non-ferromagnetic materials

All accessible well fluid wetted surfaces of each finished part shall be inspected after final heat treatment and after final machining operations using a liquid penetrant method.

7.3.3.4 Methods

MP inspection shall be in accordance with ASTM E 709. Yoke prods or contact prods are not permitted on well fluid wetted surfaces or sealing surfaces and generally not on sensitive machined parts. The MP dry method is also not allowed on machined parts or on parts where the magnetic powder, when imperfectly removed after control, could lead to corrosion or remain trapped in areas where it might have adverse effects (threads, etc.). In these cases the MP wet method shall be preferred to the MP dry method.

LP examination shall be in accordance with ASTM E 165.

7.3.3.5 MP and LP indications

Inherent indications not associated with a surface rupture (e.g. magnetic permeability variations and non-metallic stringers) are considered non-relevant. If magnetic particle indications are believed to be non-relevant, they shall be examined by LP surface NDE methods or removed and reinspected to prove their non-relevancy.

7.3.3.6 Acceptance criteria for MP and LP

Acceptance criteria for surfaces other than pressure contact sealing surfaces are as follows:

a) no relevant indication with a major dimension equal to or greater than 4,8 mm (3/16 in);

b) no more than ten relevant indications in any continuous 39 cm^2 (6 in^2) area;

c) four or more relevant indications in a line separated by less than 1,6 mm (1/16 in) (edge-to-edge) are unacceptable.

Acceptance criteria for pressure contact (metal-to-metal) sealing surfaces are that there shall be no relevant indications in these surfaces.

7.3.4 Weld NDE

7.3.4.1 General

When examination is required, essential welding variables and equipment shall be monitored. The entire weld, including a minimum of 13 mm (1/2 in) of surrounding base metal, shall be examined in accordance with the methods and acceptance criteria of 7.3.4.

7.3.4.2 Weld prep NDE — Visual

The totality (100 %) of all surfaces prepared for welding shall be visually examined prior to initiating welding. Examinations shall include a minimum of 13 mm (1/2 in) of adjacent base metal on both sides of the weld.

Weld NDE surface preparation acceptance shall be in accordance with the manufacturer's written specification.

7.3.4.3 Post weld visual examination

All welds shall be examined according to manufacturer's written specification.

All pressure-containing welds shall have complete joint penetration.

Undercut shall not reduce the thickness in the area (considering both sides) to below the minimum thickness.

Surface porosity and exposed slag are not permitted on or within surfaces.

7.3.4.4 Weld NDE — Surface (other than visual)

The totality (100 %) of all welds in the primary load path, pressure-containing welds, repair and weld metal overlay welds, and repaired fabrication welds shall be examined by either magnetic particle or liquid penetrant methods after all welding, post-weld heat treatment and machining operations are completed. Acceptable defect size may be established by industry accepted procedures or using the following size criteria.

Methods, definitions and acceptance criteria for magnetic particle and liquid penetrant examinations shall be the same as those of 7.3.3 except for the following:

a) no relevant linear indications;

b) no rounded indications greater than two-thirds weld thickness;

c) no rounded indications greater than 3 mm (1/8 in) for welds whose depth is 19 mm (3/4 in) or less, or 5 mm (3/16 in) for welds whose depth is greater than 19 mm (3/4 in).

7.3.4.5 Repair welds

At a minimum, all repair welds shall be examined using the same methods and acceptance criteria as used for the base metal (see 7.3.3.6).

Examination shall include 13 mm (1/2 in) of the adjacent base metal on all sides of the weld.

Surfaces of ground-out area for repair welds shall be examined prior to welding to ensure defect removal to the acceptance criteria of fabrication welds, or weld metal in the case of repair to a weld.

7.3.4.6 Weld NDE — Volumetric for fabrication weld

7.3.4.6.1 General

The totality (100 %) of welds in the primary load path shall be examined by either radiography or ultrasonic methods after all welding, post-weld heat treatment and machining operations. All repair welds in which the repair is greater than 25 % of the original wall thickness or 2,54 cm (1 in) — whichever is less — shall be examined by either radiography or ultrasonic methods after all welding and post-weld heat treatment operations. At a minimum, all sides of the weld shall be examined.

7.3.4.6.2 Radiography

Radiographic examinations shall be performed in accordance with procedures specified in ASTM E 94, to a minimum equivalent sensitivity of 2 %. Both X-ray and gamma-ray radiation sources are acceptable within the inherent thickness range limitation of each. Real time imaging and recording/enhancement methods may be used when the manufacturer has documented proof that the methods will result in a minimum equivalent sensitivity of 2 %. Wire-type image quality indicators are acceptable for use in accordance with ASTM E 747.

Acceptance criteria specify that no type of crack, zone of incomplete fusion, or penetration shall be allowed. No elongated slag inclusion shall be allowed which has a length greater than or equal to those given in Table 3.

Table 3 — Maximum length of elongated slag inclusion for radiography (see 7.3.4.6.2)/Reference level length — Maximum amplitude of slag indication for ultrasonic examinations (see 7.3.4.6.3)

Weld thickness t	Inclusion length
$<$ 19,3 mm (0,76 in)	6,4 mm (0,25 in)
19,3 mm to 57,2 mm (0,76 in to 2,25 in)	0,33t
$>$ 57,2 mm (2,25 in)	19,1 mm (0,75 in)

In addition, there may be no group of slag inclusions in a line having an aggregate length greater than the weld thickness (t) in any total weld length 12t, except when the distance between successive inclusions exceeds six times the length of the longest inclusion. No rounded indications in excess of those specified in the ASME *Boiler and Pressure Vessel Code*, Section VIII, Division I, Appendix 1 are permitted.

7.3.4.6.3 Ultrasonic

Ultrasonic examinations shall be performed in accordance with the *ASME Boiler and Pressure Vessel Code*, Section V, Article 5.

No indications whose signal amplitude exceeds the reference level shall be allowed. No linear indications interpreted as cracks, incomplete joint penetration or incomplete fusion shall be allowed. No slag indications shall be allowed with amplitudes exceeding the reference level whose length exceeds the values shown in Table 3.

7.3.4.7 Weld NDE — Hardness testing

All pressure-containing, non-pressure-containing and repair welds shall be hardness tested.

Hardness testing shall be performed in accordance with ISO 6506-1, ISO 6507-1 or ISO 6508-1.

At least one hardness test shall be performed in both the weld and in the adjacent unaffected base metal after all heat treatment and machining operations.

Hardness values shall meet the requirements of the manufacturer's written specification.

8 Testing

8.1 Purpose

In addition to the stress distribution verification test prescribed in 4.4, three types of full-scale design qualification tests shall be performed: a load test to establish the rated load of the coupling design, a make-up test to demonstrate the ability of the coupling to be correctly made up in the field and the repeatability of proper make-up, and an internal pressure test to check pressure integrity and seal effectiveness. These tests shall be performed on a full-scale coupling specimen or specimens to qualify the design of each coupling model.

Optional qualification tests listed in Annex B may also be included. Test couplings used to perform the optional qualification tests shall meet the requirements given in 8.2. A cyclic load or fatigue test may be performed to verify fatigue calculations and to check that no areas of stress concentration were overlooked in the design analysis. Cyclic testing to failure yields a data point that aids in predicting fatigue life. Other optional performance testing may be included to substantiate serviceability. To assure validity of the test results, the testing machine shall be calibrated and so documented. The test coupling for all verification and qualification tests shall be built to standard dimensions and manufacturing tolerances and have standard finishes, coatings and materials. These tests and those given in 4.4 are for design evaluation only; they are not intended for in-service readiness testing.

8.2 Design qualification tests

8.2.1 Load rating test

Axisymmetrical tensile load shall be applied to qualify the coupling design for a rated load in accordance with 4.1.

8.2.2 Make-up test

The manufacturer’s standard make-up tools shall be used to apply preload to the coupling. Strain gauge readings from selected points on the coupling, performed in accordance with 4.4, should corroborate the values used in the analysis performed in accordance with 4.3. Measured preload stresses shall meet or exceed the minimum required preload stresses over at least ten successive make-up sequences.

8.2.3 Internal pressure test

Internal water pressure equal to the coupling rated working pressure shall be applied, with no structural failure or leaks as a result. Test times and sequences shall be described and available to the user on request.

9 Marking

9.1 Stamping

All riser couplings manufactured in accordance with this International Standard shall be marked on an appropriate external surface with the information listed in 9.2. A metal impression stamp shall be used in a low stressed area on both box and pin ends.

9.2 Required information

The following information is required to be indicated:

a) manufacturer’s name or mark and part number;

b) rated load;

c) rated working pressure;

d) nominal diameter;

e) identifying serial number;

f) date of manufacture.

Additional traceable information is specified in Clause 7.

NOTE The rated load or rated working pressure of the coupling may be greater than that of an assembled riser joint.

10 Operation and maintenance manuals

10.1 General

The manufacturer shall provide operation and maintenance manuals, which shall include, as a minimum, the information listed in 10.2 to 10.4.

10.2 Equipment description

A written description, drawings and applicable schematics shall be provided for the riser coupling and interfacing equipment, as follows:

a) the riser coupling box, pin, locks, brackets, etc.;

b) riser handling tool;

c) all make-up and preload tools;

d) riser coupling box and pin protectors.

10.3 Guidelines for coupling usage

The following information should be addressed:

a) use of the handling tool and its interface with the coupling;

b) coupling make-up including, when applicable, detailed procedures for correctly applying coupling preload.

10.4 Maintenance instructions

The following information should be provided:

a) graphic chronological schedule of routine maintenance tasks;

b) sample maintenance forms or check lists as necessary;

c) sample log sheets for recording cumulative use of each riser coupling;

d) storage instructions and replacement schedule for rubber goods and other consumables;

e) specified lubricants, corrosion inhibitors, etc.;

f) procedure and schedule for fatigue crack inspections — manufacturer shall identify highly stressed areas to be inspected.

Annex A
(informative)

Stress analysis

For non-axisymmetric couplings, three-dimensional analysis is necessary to account for variation in stress around the circumference. If the coupling has axial planes of symmetry (planes which include the pipe axis), the three-dimensional analysis can be based on a single sector bounded by two such planes. For example, a coupling having six planes of symmetry would require analysis of a 30° sector (one-twelfth). The axial loading on such a 30° sector can be considered to be that caused by the design tension uniformly distributed around the pipe. Determination of the equivalent load for bending is discussed in 4.5.

The use of finite element analysis permits determination of stresses in complex structures, but accuracy of the analysis is largely dependent on the skill of the analyst. Care and judgement shall be exercised in developing the finite element model. For example, highly stressed regions of the structure require a fine mesh of elements. Therefore, the analyst shall predict where high stresses are likely to occur. Some stresses will be affected by the structural properties of the riser pipe. Therefore, the model shall be continued far enough away from critical areas to ensure that results are free from boundary effects. Finally, the finite element model should be designed so that the finite elements are not distorted beyond their ability to produce accurate results.

Analysis of the effects of preload and the possibility of separation may require special treatment in the finite element analysis. All components that affect the stiffness of the coupling shall be considered in the model. If separation can occur, then provision for it shall be included in the analysis, if possible. If not possible, then an iterative method involving several solutions shall be required.

Maximum stresses almost always occur at surfaces. The finite element model should be designed so that in critical regions, stresses are calculated on the surface as well as near it.

Annex B
(informative)

Optional qualification tests

B.1 Cyclic load test

To simulate in-service load fluctuations, tension plus cyclic bending loads may be applied (as well as internal pressure) to represent a chosen loading condition. Extended testing can be conducted to compare with fatigue life predictions.

B.2 Spider load reaction test

The ability of the coupling to carry the most severe loads applied when a long string of riser supporting a BOP stack is hung off on the spider may be checked. The loads experienced when landing on and hanging from the spider while running and pulling riser may be simulated. When simulating the spider hang-off loads, only the box or pin end (whichever hangs in the spider) should be loaded.

B.3 Handling tool reaction test

The ability of the coupling box or pin (as appropriate) to carry the most severe loads applied when a long string of riser supporting a BOP stack is suspended from the handling tool may be checked. The application of dynamic and static loading on the coupling box or pin interface with the handling tool may be simulated.

B.4 Choke and kill support test

The ability of the C&K stabs to hold pressure and the C&K support brackets to react to loads induced by line pressure may be checked. C&K line test pressure may be applied to C&K stabs installed on the coupling and supported by standard brackets.

Annex C
(normative)

Design for static loading

C.1 Static loading design requirements

The design of a riser coupling for static loading requires that it support the preload and the design load while keeping the maximum cross-sectional stresses within the allowable limits specified in C.4. Local peak stresses are not considered for static loading.

C.2 Stress types and categories

The following defines the types and categories of stress (σ) that are pertinent to riser couplings. A thorough understanding of these stresses is necessary for the proper design of riser couplings.

The following are the stress types that shall be considered.

a) *Membrane stress* in a section is the average stress induced by a force normal to the section. It is calculated using the classical equation for normal stress ($\sigma = F/A$). If a membrane stress is averaged over an entire cross-section, it is a *general membrane stress*, an example of which is the average axial stress in a pipe loaded in tension. If a membrane stress is averaged only over a localized portion of a cross-section, it is a *local membrane stress*, an example of which is the axial stress averaged over the area adjacent to the window of a dog coupling. Determining the area used for averaging a local stress requires judgement. Using a very small area results in the peak stress, not the local membrane stress. On the other hand, averaging over too large an area results in the general membrane stress, not the local membrane stress.

b) A *bending stress* is a stress induced by a bending moment. It varies linearly with the distance from the centroid of the section and is calculated using the classical mechanics equation for bending stress ($\sigma = Mc/I$).

c) A *pure shear stress* in a section is the average stress induced by a force transverse to the section. It is averaged over the total area of the section and is calculated using the classical shear stress equation ($\sigma = F/A$). An example of a pure shear stress is the average shear stress in the threads of a threaded coupling.

d) A *bearing stress* is the normal stress on the contact surfaces of mating surfaces. It is averaged over the total contact area and is calculated using the classical equation for normal stress ($\sigma = F/A$). An example of a bearing stress is the contact stress between the dogs and the loading shoulder of a dog coupling.

e) All stresses can be categorized as *primary*, *secondary* or *peak*.

   1) A *primary stress* is one induced by the external loads or preload and necessary to satisfy the laws of static equilibrium.

      EXAMPLE Membrane stress in a rod loaded by an axial force, bending stress in a simple beam.

   2) A *peak stress* is a highly localized stress that exists at a discontinuity in the load path.

      EXAMPLE High localized stress at the root of a thread in a bolt.

   3) A *secondary stress* is any stress in the structure which is not a primary or peak stress.

C.3 Riser coupling stresses

There are six stresses that shall be evaluated for each riser coupling:

a) σ_{pm} = general primary membrane stress;

b) σ_{lm} = local membrane stress;

c) σ_{pb} = primary bending stress;

d) σ_{se} = secondary stress;

e) σ_{sh} = pure shear stress;

f) σ_{br} = bearing stress.

Some of these stresses, such as general primary membrane stresses, can be accurately calculated using hand calculations, but most cannot because of the complex geometry and loading of riser couplings. For this reason, it is required that the stresses in each coupling be calculated with a finite element analysis method in accordance with 4.3.

The load cases for which a coupling shall be analysed depend on whether or not the coupling is preloaded and whether the preload stresses are considered as primary or secondary.

If a coupling is not preloaded, only one load case shall be analysed: design axial tension (coupling design load).

If a coupling is preloaded, the coupling shall be analysed for three load cases:

— design preload;

— design preload plus design axial tension;

— design axial tension only.

Classifying stresses induced by preload as primary or secondary depends on coupling function and not on overstressing the coupling. If preload stresses are classified as secondary, they are allowed to be twice the yield strength. This can result in large permanent deformations, but not in structural failure.

Some coupling designs can tolerate large permanent deformations without jeopardizing their ability to safely function, while other coupling designs will not function after large permanent deformations. Sealing is an example of a functional requirement often affected by large permanent deformation.

If preload stresses are considered as secondary, the designer shall demonstrate that the permanent deformations induced by preload will not cause the coupling to lose any necessary functional capability.

Normally, riser couplings exhibit a linear or bilinear relationship between load and stress. For these couplings, stresses at loads other than the analysis loads can be calculated using the rules of linear interpolation or extrapolation. For those couplings with a non-linear relationship between load and stress, linear interpolations or extrapolations cannot be used. These couplings shall be analysed for several values of load, and plots of load versus stress shall be developed. The coupling rated load shall be determined from these curves.

C.4 Allowable stresses

C.4.1 General

Allowable stresses are given for individual stress categories and for combinations of stress categories, and are functions of the material yield strength (σ_y). The following are the allowable stresses that shall be satisfied in riser couplings for all coupling components except bolts:

$$\sigma_{pm} \leqslant 0,667\sigma_y$$

$$\sigma_{lm} + \sigma_{pb} \leqslant \sigma_y$$

$$\sigma_{lm} + \sigma_{pb} + \sigma_{se} \leqslant 2\sigma_y$$

$$\sigma_{sh} \leqslant 0,4\sigma_y$$

$$\sigma_{br} \leqslant \sigma_y$$

For bolts in the primary load path, the manufacturer shall establish the allowable stress levels for membrane stresses and bending stresses in the bolts.

Bolt stresses, pure shear stresses and bearing stresses are compared directly with their respective allowables. No manipulation of the finite element data is required.

The other stresses shall be linearized, separated into membrane and bending components, categorized, and converted to von Mises effective stresses before they can be compared to the allowable stresses. This procedure is given in detail in C.4.2.

C.4.2 Procedure

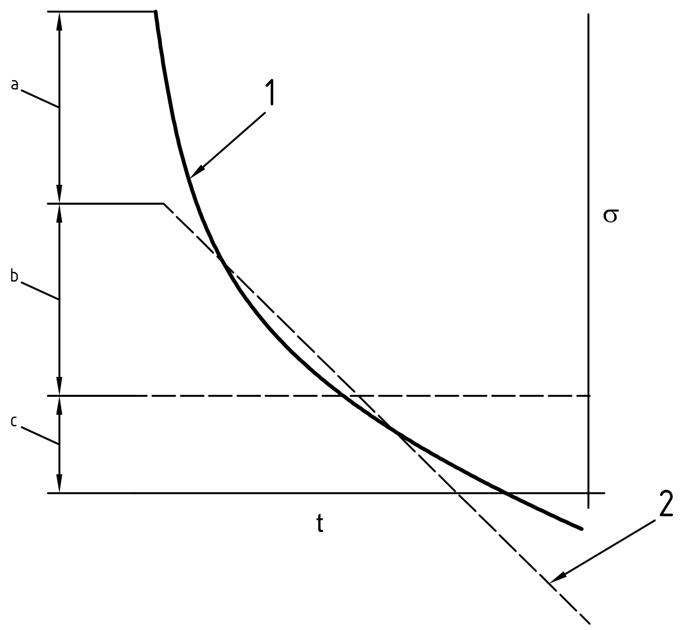
In general, there are six components of stress across any section: three normal components and three shear stress components.

Linearize each of the significant stress components and separate them into membrane and bending components.

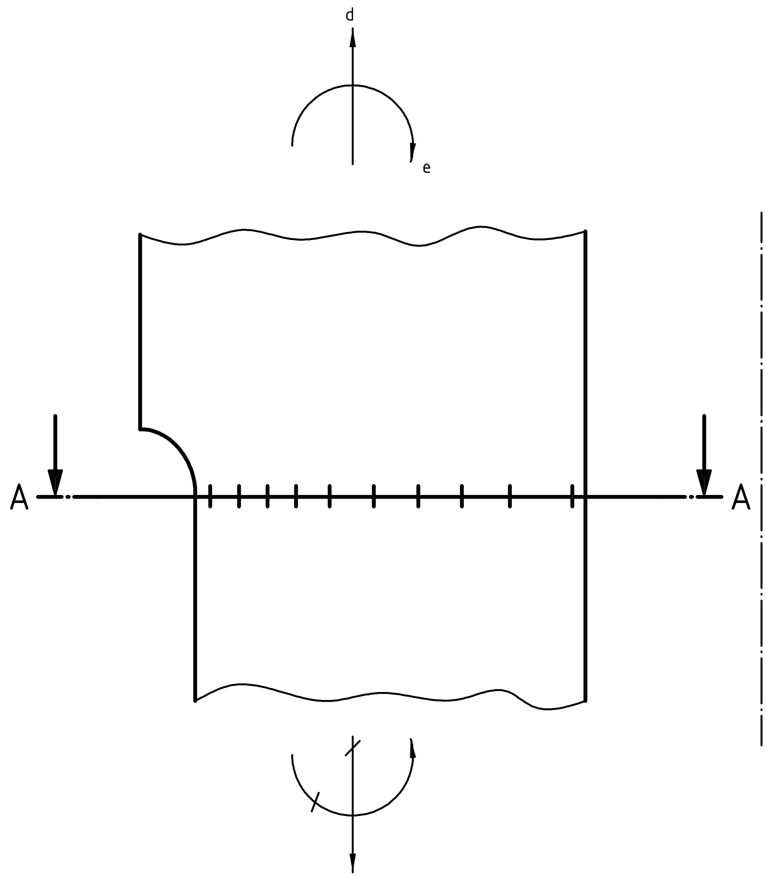
This is graphically shown in Figure C.1, which shows the axial stress across the wall of a riser coupling at a section where the wall thickness changes. The load on the coupling is axial tension. The solid line shows the stress distribution reported by the finite element model, while the dashed line represents the linearized stress distribution. The membrane stress component is the average value of the linearized stress distribution, and the bending stress component is the difference between the largest and the average values of the linearized stress distribution.

Next, categorize the membrane and bending stress components into one of the following stress categories: general primary membrane stress, local membrane stress, primary bending stress or secondary stress.

For the example in Figure C.1, the membrane stress is the axial stress induced by the axial force. Since this stress is necessary for equilibrating the axial force, it is a general primary membrane stress. The bending stress is induced by the local bending moment caused by the discontinuity in the wall thickness. This stress is necessary only to ensure the coupling has continuity of deformations at the discontinuity; thus, it is a secondary stress.



a) For axisymmetric cross-section



b) Stress distribution across A-A

Key

1 Total stress distribution
2 Equivalent linear distribution
a Local peak stress
b Local bending stress
c Net section stress
d Tensile load
e Local bending moment

Figure C.1 — Stress distribution across section A-A

Repeat this procedure for all of the six stress components that are significant; then calculate the von Mises effective stress using the following equation:

$$\sigma_e = \frac{1}{\sqrt{2}}\left[\left(\sigma_x - \sigma_y\right)^2 + \left(\sigma_y - \sigma_z\right)^2 + \left(\sigma_z - \sigma_x\right)^2 + 6T_{xy}^2\right]^{1/2} \quad \text{(C.1)}$$

where

σ_e is the von Mises effective stress;

σ_x, σ_y, σ_z are the three normal stress components;

T_{xy} (T_{yz}, T_{zx}) is the shear stress component.

Note that all stresses are not included when calculating every von Mises effective stress. For example, when the general primary membrane stress is being checked only general primary membrane stresses are included in Equation C.1; secondary stresses, bending stress and local primary membrane stresses are not included.

The maximum shear stress theory of failure can be used in lieu of the von Mises theory of failure. Using the maximum shear stress theory of failure requires that twice the maximum shear stress, defined as the stress intensity, be compared with the allowable stresses instead of the von Mises effective stress. This approach is equal to or slightly conservative when compared to the von Mises approach, but is much easier to use.

Bibliography

[1] API Specification 16R, *Specification for Marine Drilling Riser Couplings*

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