SLOVENSKI STANDARD
SIST EN 13445-3:2014/oprA20:2019

01-maj-2019

Neogrevane tlačne posode - 3. del: Konstruiranje - Dopolnilo A20

Unfired pressure vessels - Part 3: Design

Unbefeuerte DruckbehÃ¤lter - Teil 3: Konstruktion

Récipients sous pression non soumis à la flamme - Partie 3 : Conception

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EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

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EN 13445-3:2014

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May 2019

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English Version

Unfired pressure vessels - Part 3: Design

Récipients sous pression non soumis à la flamme - Partie 3 : Conception

Unbefeuerte DruckbehÃ¤lter - Teil 3: Konstruktion

This draft amendment is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 54.

This draft amendment A20, if approved, will modify the European Standard EN 13445-3:2014. If this draft becomes an amendment, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for inclusion of this amendment into the relevant national standard without any alteration.

This draft amendment was established by CEN in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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European foreword

This document (EN 13445-3:2014/prA20:2019) has been prepared by Technical Committee CEN/TC 54 "Unfired pressure vessels", the secretariat of which is held by BSI.

This document is currently submitted to the CEN Enquiry.

This document has been prepared under a standardization request given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For relationship with EU Directive(s), see informative Annex ZA, which is an integral part of EN 13445-3:2014.

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1 Modification to Clause 18

Replace all of Clause 18 by the following:

18 Detailed assessment of fatigue life

18.1 Purpose

18.1.1 This clause specifies requirements for the detailed fatigue assessment of welded and unwelded components and zones of pressure vessels that are subjected to repeated fluctuations of mechanical and thermal loads.

NOTE 1 In fatigue, welds and welded material behave differently from plain parent (unwelded) material. Therefore, the assessment procedures for welded and parent materials are different.

NOTE 2 The fatigue assessment of welded components and regions is based on fatigue design curves (SN curves) obtained from welded specimens tested under load control, except for applied strains exceeding yield (low cycle fatigue), where test data are obtained under strain control.

NOTE 3 The fatigue assessment of unwelded components and regions and bolts is based on SN curves obtained from plain materials under strain-controlled test data.

18.1.2 The requirements in this clause are only applicable to steels specified in EN 13445-2. This clause assumes that the vessel has been designed in accordance with all other requirements of this standard.

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18.1.3 These requirements can also be applied to steel castings, but in case of welding or weld repairs on steel castings, the requirements for welded regions shall apply.

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18.1.4 This clause includes the effect on fatigue of weld toe improvement where this is carried out.

NOTE In the case of fillet and partial penetration welds, where failure can occur from the weld root, improvement of the weld toe cannot be relied upon to give an increase in fatigue strength of the joint.

18.1.5 Plain material can contain flush ground weld repairs, which may reduce in the fatigue life of the material. Hence, only material which is certain to be free from welding shall be assessed as unwelded.

18.1.6 These requirements are not applicable to testing group 4 pressure vessels. For welded joints in testing group 3 pressure vessels, see the special provisions in 18.10.2.1.

18.1.7 This fatigue assessment method is not intended for design involving elastic follow-up (definition below and see reference [1] in Annex N).

18.1.8 The fatigue assessment shall be made at all locations where there is risk of fatigue crack initiation.

Fatigue assessment shall be made at points of highest stress and stress concentration and at locations subject to high numbers of stress cycles.

18.1.9 Fatigue assessment using this clause may be performed using either a given history of operating loads or specified design loads. Recommended methods are given in Annex NB.

18.1.10 In this clause the equivalent stress range is used for fatigue assessment of all welded and unwelded regions. The determination of cycles and equivalent stress range is given in Annex NB.

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NOTE The maximum principal stress range is no longer used for fatigue design in this Clause.

18.1.11 This clause applies primarily for components operating below the creep temperature range. It may, however, also be applied for components operating in the creep temperature range provided sufficient allowance is made for the effects of creep and high temperatures.

18.1.12 A typical sequence in the design of a vessel for fatigue is shown in Table 18-1.

Table 18–1 — Summary of fatigue assessment process

Task	Comment	Relevant clause(s)
1. Design vessel for static loads	Gives layout, details, sizes	Part 3
2. Define fatigue loading	Based on operating specification, secondary effects identified by manufacturer, etc.	
3. Identify locations of vessel to be assessed	Structural discontinuities, openings, joints (welded, bolted), corners, repairs, etc.	
4. At each location, establish stress range during time period of operation considered	Calculate the components of the stress to be used (nominal, structural, structural hot-spot, notch or weld-throat stress, as appropriate) at the location under consideration	Welded: 18.6, 18.8 and 18.10.4; Unwelded: 18.7 and 18.8 Bolts: 18.7.2.
5. At each location, establish design stress range spectrum	a) Perform cycle counting operation b) Apply plasticity correction factors where relevant c) Unwelded material: derive effective notch stress ranges	18.9 18.8 18.7
6. Note relevant implications and inform relevant manufacturing and inspection personnel	a) Requirements for welds b) Control of or assumptions about misalignment c) Acceptance levels for weld flaws	18.10.1, Tables 18–4 18.10.4 18.10.5
7. Identify fatigue strength data, including allowance for overall correction factor	a) Welded material b) Unwelded material c) Bolted material c) Acceptance levels for weld flaws	18.10, Tables 18–4 18.11 18.12 18.13.5
8. Extract allowable fatigue lives from fatigue design and perform assessment	a) Welded material b) Unwelded material c) Bolts d) Assessment method	18.10, Table 18–7 18.11, Table 18–10 18.12 18.5.5, 18.5.6
Task	Comment	Relevant clause(s)
9. Further action if location fails assessment	a) Re-assess using more refined stress analysis	18.6 (welded), 18.7 (unwelded)

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<table>
<tr><td>Task</td><td>Comment
b) Reduce stresses by increasing thickness*
c) Change detail
d) Apply weld toe dressing (if appropriate)</td><td>Relevant clause(s)

Table 18–4
18.10.2.2</td></tr>
<tr><td colspan="3">*
- for mechanical loading, this is obtained by increasing the wall thickness in the most cases but in some cases (connections of parts with different wall thicknesses) a better distribution of the wall thicknesses can reduce the stresses too.
- for thermal loading, more adjusted modifications are required, e.g. stiffness reduction at appropriate locations of the structure and/or increase of the fatigue strength of the weak parts.</td></tr>
</table>

18.2 Specific definitions

The following terms and definitions apply in this clause.

18 2.1 Critical area

Area where the total cumulative fatigue damage (usage factor) exceeds the value D_{max} = 0,5

18.2.2 Cut-off limit

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Cyclic stress range below which fatigue damage is disregarded

18.2.3 Discontinuity

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Change in shape, thickness or material which affects the stress distribution

18.2.4 Effective notch stress

Stress which governs fatigue behaviour at a notch (reduced total notch stress at unwelded points)

18.2.5 Effective stress concentration factor

Ratio of effective notch stress to structural stress at same point

18.2.6 Elastic follow-up

Phenomenon of large inelastic (plastic) strain accumulation in a weaker region of a component due to elastic strain/stress redistribution of other regions of the component

18.2.7 Endurance limit

Cyclic stress range below which, in the absence of any previous loading, no fatigue damage is assumed to occur under constant amplitude loading

18.2.8 Equivalent stress range

Scalar stress range which represents the multi-axial stress ranges

NOTE 1 The Tresca criterion and von Mises criterion are permitted in this clause.

NOTE 2 The formulae for calculation of equivalent stress range based on the Tresca and von Mises criteria are given in Annex NB. These formulae depend on whether the principal stress directions remain constant or not during the cycle.

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18.2.9 Fatigue

Progressive and localised structural damage to the material of a component due to fluctuation of stress

18.2.10 Fatigue design curves

Curves given in this clause of $\Delta\sigma_R$ against N for welded and unwelded material, and of $\Delta\sigma_R / R_m$ against N for bolts

18.2.11 Gross structural discontinuity

Structural discontinuity which affects the stress or strain distribution across the entire wall thickness

18.2.12 Hot spot

Point in a structure where a fatigue crack may initiate due to the combined effect of structural stress fluctuation and the presence of a weld, notch or other stress concentrating feature

18.2.13 Load cycle

Change of load giving rise to a change in stress with time returning to the initial value and initial direction (i.e. increasing or decreasing) and passing each level once in increasing direction and once in decreasing direction

NOTE When there is a sequence of load giving rise to variable amplitudes of stress, a load cycle may comprise different parts of the stress spectrum. For identification of cycles and cycle counting methods refer to Annex NB.

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18.2.14 Local structural discontinuity

Discontinuity which affects the stress or strain distribution locally, across a fraction of the wall thickness

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18.2.15 Nominal stress

Stress which would exist in the absence of a structural discontinuity

NOTE 1 Nominal stress is a reference stress (membrane + bending) which is calculated using elementary thin shell theory of structures. It excludes the effect of structural discontinuities (e.g. welds, openings, branch connections, nozzles, significant attachments and thickness changes). See Figure 18.2-1.

NOTE 2 The use of nominal stress is permitted for some specific weld details for which determination of the structural stress would be unnecessarily complex. It is also applied to bolts.

NOTE 3 The nominal stress is the stress commonly used to express the results of fatigue tests performed on laboratory specimens under simple unidirectional axial or bending loading. Hence, fatigue curves derived from such data include the effect of any notches or other structural discontinuities (e.g. welds) in the test specimen.

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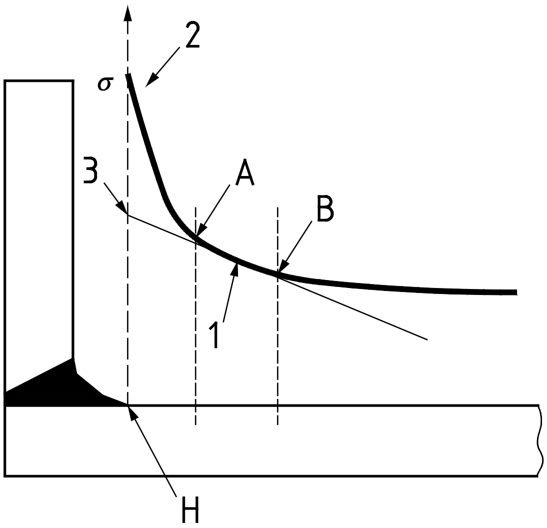

Key

A, B reference points

H hot spot

1 structural stress

2 notch stress

3 surface extrapolated structural hot spot stress

NOTE For calculation of structural stress, see Annex NA.

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Figure 18.2-1 — Illustration of how a stress varies towards a structural discontinuity and notch created at the weld toe

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18.2.16 Notch

Discontinuous change in surface profile that produces stress concentration and a potential fatigue crack initiation site (e.g. weld toe, crevice)

18.2.17 Notch stress

Total stress located at the root of a notch, including the non-linear part of the stress distribution

NOTE See Figure 18.2-1 for the case where the component is welded, but notch stresses may similarly be found at local discontinuities in unwelded components.

Notch stresses are usually calculated using numerical analysis. The stresses given by such calculations being theoretical stresses, they should be converted into effective stresses. This is done by multiplying them by the factor K_f / K_t. This multiplication may be omitted, leading to conservative results. Alternatively, the nominal or structural stress is used in conjunction with the effective stress concentration factor K_f.

18.2.18 Seam weld

Longitudinal or circumferential full penetrated weld joint

18.2.19 Stress on the weld throat

Average stress across the throat thickness in a double-sided fillet weld

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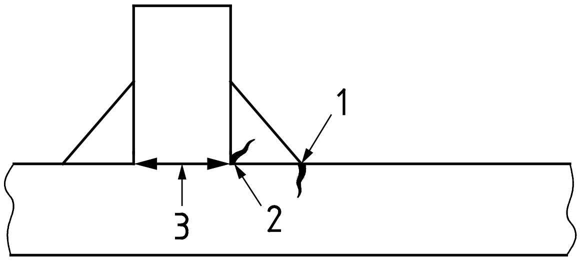
NOTE 1 In the general case of a non-uniformly loaded weld, it is calculated as the maximum load per unit length of weld divided by the weld throat thickness and it is assumed that none of the load is carried by bearing between the components joined.

If there is significant bending across the weld throat, the maximum value of the linearized stress should be used.

NOTE 2 The stress on the weld throat is used exclusively for assessment of fatigue failure by cracking through weld metal in fillet or partial penetration welds (see Figure 18.2-2).



Key

1 weld toe crack

2 weld throat crack

3 unfused land

Figure 18.2-2 — Two dominant fatigue crack locations in a double-sided fillet weld

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18.2.20 Stress range (Δσ)

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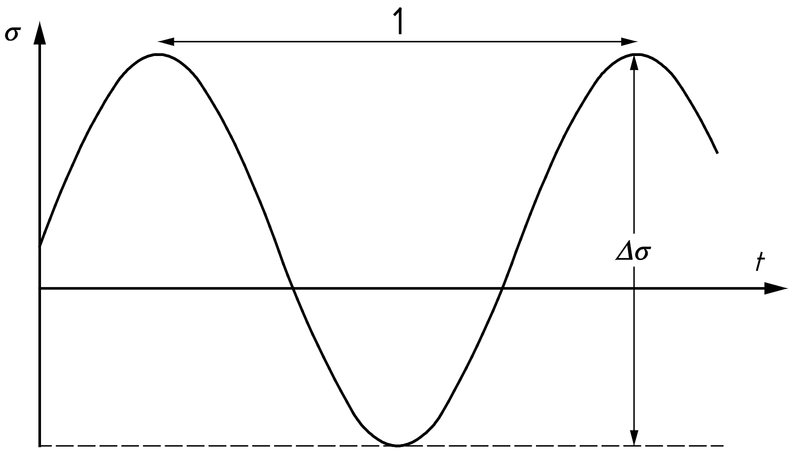
Value from maximum to minimum in the cycle (see Figure 18.2-3) of a nominal stress, a principal stress, a structural stress or a stress component, depending on the rule that is applied



Key

1 one cycle; Δσ Stress range

Figure 18.2-3 — Stress range

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18.2.21 Structural stress

Stress determined at each point taking into account the actual geometry of the structure with the exception of the local structural discontinuities generating stress peaks.

In many cases, the structural stress may be considered to be the same as the linearized stress.

The cases where this is not acceptable are those where the following stresses are involved:

— thermal stresses due to a temperature gradient through the wall thickness, stresses whose distribution may be highly non-linear in particular during transients,

— stresses due to mechanical loadings, in very thick walls (e.g. pressure stresses in a thickwalled cylinder, where the stress distribution is not uniform through the thickness).

NOTE 1 Structural stress includes the effects of gross structural discontinuities (e.g. branch connections, cone/cylinder intersections, vessel/end junctions, thickness change, deviations from design shape, presence of an attachment). It excludes the notch effects of local structural discontinuities (e.g. weld toe). See Figure 18.2-1.

NOTE 2 For the purpose of fatigue assessment, the structural stress is evaluated at the potential crack initiation site.

NOTE 3 Structural stresses may be determined by one of the following methods: numerical analysis (e.g. finite element shell analysis (FEA)), use of thin shell theory, or the application of stress concentration factors to nominal stresses obtained analytically. Guidance on the use of numerical analysis is given in Annex NA.

18.2.22 Structural hot spot stress

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Structural stress extrapolated to the location of the hot spot at a weld toe or other weld detail according to 18.6

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18.2.23 Theoretical elastic stress concentration factor

Ratio of notch stress, calculated on purely elastic basis, to structural (nominal) stress at same point

18.2.24 Partial usage factor

Fatigue damage produced by cycles of a given amplitude

18.2.25 Cumulative usage factor (cumulative fatigue damage index)

Aggregate of partial usage factors for cycles of different amplitudes according to 18.13

18.2.26 Weld throat thickness

Minimum thickness in the weld cross-section

18.3 Specific symbols and abbreviations

The following symbols and abbreviations apply in addition to those in Clause 4.

C, C_1 and C_2	are the constants in equation of fatigue design curves for welded components;
D_f	is the cumulative fatigue damage index;
E	is the modulus of elasticity at maximum operating temperature;
F_e , F_s	are intermediate calculation coefficients;

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f_b	is the overall correction factor applied to bolts;
f_c	is the compressive stress correction factor;
f_e	is the thickness correction factor in unwelded components;
f_{ew}	is the thickness correction factor in welded components and bolts;
f_m	is the mean stress correction factor for unwelded material;
f_{m*}	is the mean stress correction factor for fully stress relieved welded material;
f_s	is the surface finish correction factor;
f_{T*}	is the temperature correction factor;
f_u	is the overall correction factor applied to unwelded components;
f_w	is the overall correction factor applied to welded components;
g	is the depth of groove produced by weld toe grinding;
K_f	is the effective stress concentration factor given in equation (18.7.1-3);
K_m	is the stress magnification factor due to deviations from design shape;
K_t	is the theoretical elastic stress concentration factor;
k_e	is the plasticity correction factor for stress due to mechanical loading;
k_ν	is the plasticity correction factor for stress due to thermal loading;
M	is the mean stress sensitivity factor;
m, m_1 and m_2	are exponents in equations of fatigue design curves for welded components;
N_i	is the allowable number of cycles obtained from the fatigue design curves (suffix i refers to allowable number of cycles of the ith stress range);
n_i	is the number of applied stress cycles (suffix *i* refers to number of cycles of the i^{th} stress range);
R	is the mean radius of vessel at point considered;
R_{min}	is the minimum inside radius of cylindrical vessel, including corrosion allowance;
R_{max}	is the maximum inside radius of cylindrical vessel, including corrosion allowance;
R_Z	is the peak to valley height;
r	is the radius of groove produced by weld toe grinding;
S_{ij}	is the difference between either principal stresses (σ_i and σ_j) or structural principal stresses ($\sigma_{struc,i}$ and $\sigma_{struc,j}$) as appropriate;
T_{max}	is the maximum operating temperature;
T_{min}	is the minimum operating temperature;
T^*	is the assumed mean cycle temperature;

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