# INTERNATIONAL STANDARD

# ISO 14347

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# Fatigue — Design procedure for welded hollow-section joints — Recommendations

*Fatigue — Procédure de dimensionnement à la fatigue des assemblages soudés de profils creux — Recommandations*



Reference number
ISO 14347:2008(E)

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# Foreword

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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.

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ISO 14347 was prepared by the International Institute of Welding, Commission XV, *Design, analysis and fabrication of welded structures*, recognized as an international standardizing body in the field of welding in accordance with Council Resolution 42/1999.

Requests for official interpretations of any aspect of this International Standard should be directed to the ISO Central Secretariat, who will forward them to the IIW Secretariat for an official response.

# Fatigue — Design procedure for welded hollow-section joints — Recommendations

## 1 Scope

### 1.1 General

This International Standard gives recommendations for the design and analysis of unstiffened, welded, nodal joints in braced structures composed of hollow sections of circular or square shape (with or without rectangular chord) under fatigue loading.

This International Standard applies to structures:

a) fulfilling quality requirements for hollow sections (see Annex A);

b) complying with recommended weld details (see Annex B);

c) employing permitted steel grades (see 1.2);

d) having hollow section joints (see 1.3);

e) having either

  1) square or rectangular hollow sections with a thickness between 4 mm and 16 mm, or

  2) circular hollow sections with a thickness between 4 mm and 50 mm;

f) having as stress range the range of "hot-spot" stress;

g) having identical brace (branch) members.

### 1.2 Materials

This International Standard applies to both hot-finished and cold-formed steel structural hollow sections, complying with the applicable national manufacturing specification, that fulfil specified quality requirements (see Annex A).

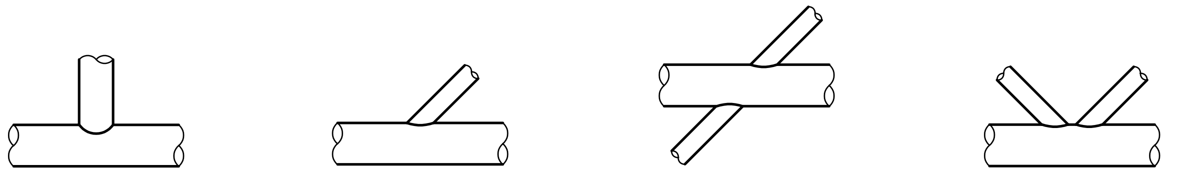
### 1.3 Types of joints

This International Standard applies to joints consisting of circular hollow sections (CHS) or rectangular hollow sections (RHS) as used in uniplanar or multiplanar trusses or girders, such as T-, Y-, X-, K-, XX-, and KK-joints (see Figure 1 and Figure 2).

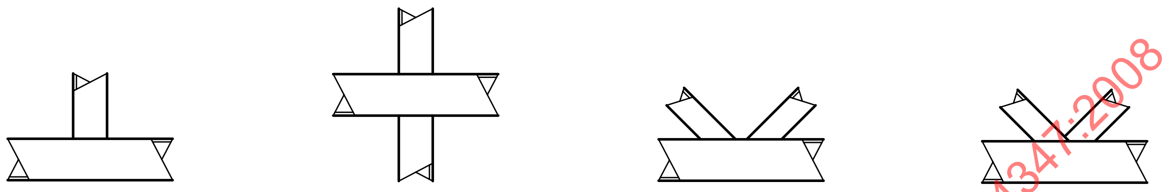
## 2 Normative references

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 630:1995, *Structural steels — Plates, wide flats, bars, sections and profiles*



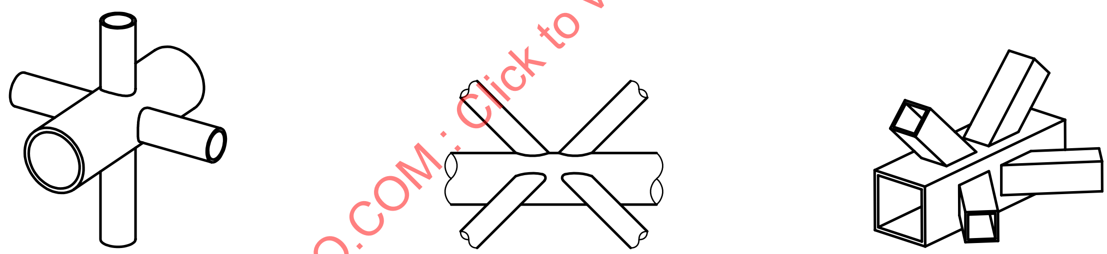
a) CHS T-joints    b) CHS Y-joints    c) CHS X-joints    d) CHS K-joints with gap



e) RHS T-joints    f) RHS X-joints    g) RHS K-joints with gap    h) RHS K-joints with overlap

NOTE RHS are assumed to be square, although this International Standard is likely to be applicable to rectangular chord members, welded to square branch members.

**Figure 1 — Types of uniplanar joints covered by this International Standard**



a) CHS XX-joints    b) CHS KK-joints with gap    c) RHS KK-joints with gap

NOTE RHS are assumed to be square, although this International Standard is likely to be applicable to rectangular chord members, welded to square branch members.

**Figure 2 — Types of multiplanar joints covered by this International Standard**



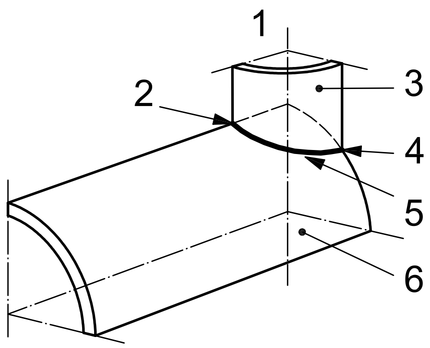
## 3 Terms and definitions

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

**3.1**
**brace**
branch
⟨welded hollow section joints⟩ cut and welded member

See Figure 3.

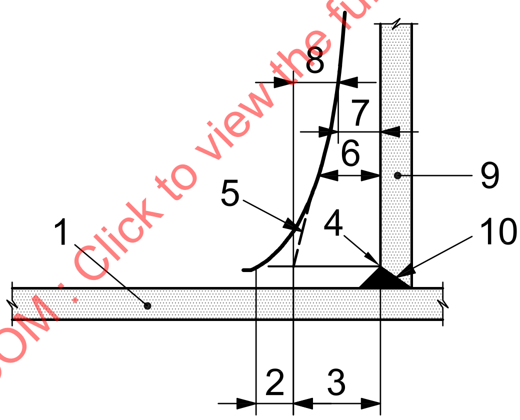



**Key**

1 load applied in the branch
2 crown point
3 branch
4 saddle point
5 weld
6 chord

**a) Joint nomenclature**



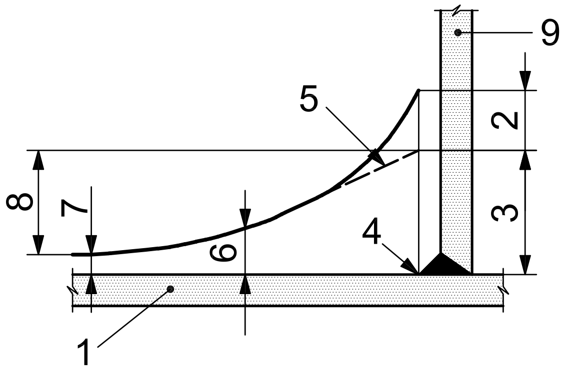



**Key**

1 chord wall
2 stress increase due to weld geometry
3 brace hot-spot stress
4 weld toe
5 extrapolation of geometric stress distribution to weld toe
6 stress in branch
7 nominal stress
8 increase in stress due to overall joint geometry
9 branch wall
10 weld

**b) Stress distribution in branch**

**Figure 3 — Hot-spot stress definition in nodal joints**




**Key**

1 chord wall
2 stress increase due to weld geometry
3 chord hot-spot stress
4 weld toe
5 extrapolation of geometric stress distribution to weld toe
6 stress in chord
7 nominal stress
8 increase in stress due to overall joint geometry
9 branch wall

**c) Stress distribution in chord**

**Figure 3** (*continued*)



**3.2**
**constant amplitude fatigue limit**
⟨welded hollow section joints⟩ stress range for a specific $\Delta S$-$N$ curve when the number of cycles, $N$, is 5 million or greater

**3.3**
**cut-off limit**
stress range for a specific $\Delta S$-$N$ curve when the number of cycles, $N$, is 100 million or greater, used in the assessment of fatigue under variable amplitude loading

**3.4**
**fatigue**
deterioration of a component due to the initiation and growth of cracks under fluctuating loads

**3.5**
**fatigue life**
**endurance**
$N_f$
number of applied cycles to achieve a defined failure criterion

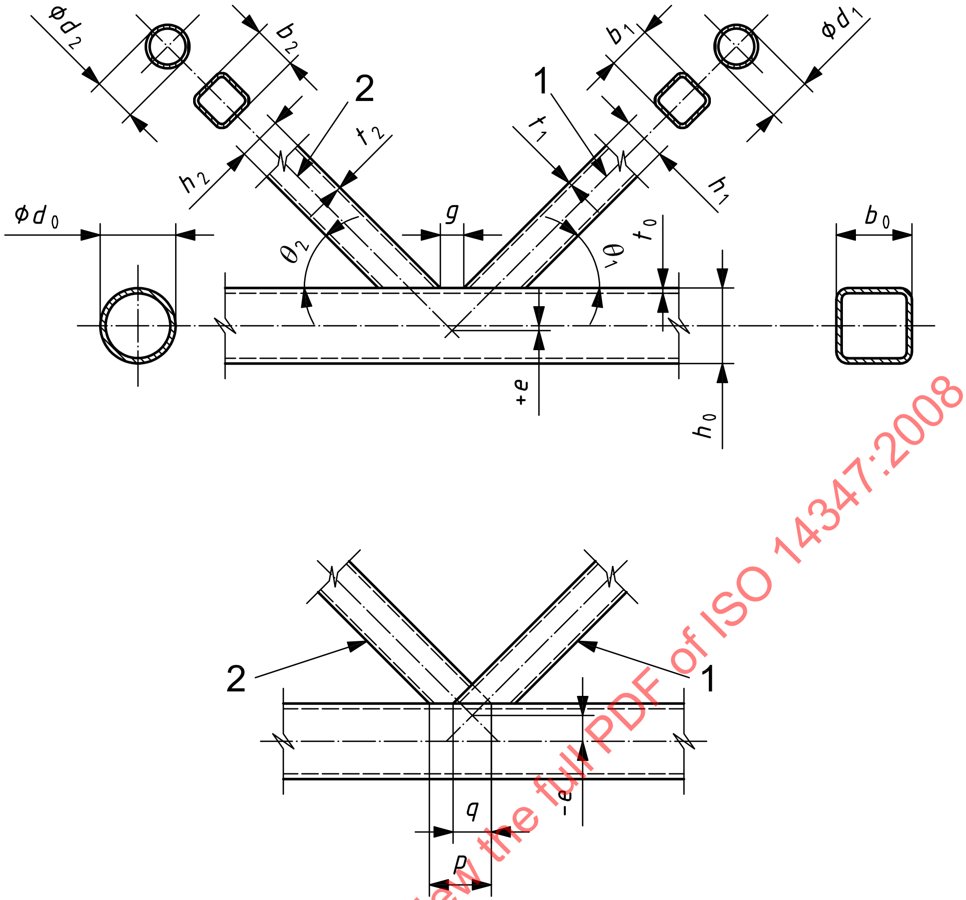
[ISO 1099:2006, 3.14]

NOTE In this International Standard, crack growth through the wall thickness is considered as failure.

**3.6**
**gap length**
$g$
distance measured along the length of the connecting face of the chord between the toes of the adjacent brace members

See Figure 4.




**Key**

1 member (overlapping in the lower diagram)

2 optionally overlapped member

NOTE For variable definitions, see Clause 4.

**Figure 4 — Definition of gap $g$ and overlap $q$**

**3.7**

**hot-spot stress**

⟨welded hollow section joints⟩ point along the weld vicinity where the extrapolated primary stress has its maximum value (i.e. the maximum geometric stress)

NOTE This definition differs from the more general definition of hot-spot stress as the structural stress at the weld toe. The extrapolation is carried out from the region outside the influence of the effect on the stress of geometric discontinuities due to the joint configuration, but close enough to fall inside the zone of the stress gradient caused by the global geometrical effects of the connection. The extrapolation is carried out on the branch or brace (cut and welded member) side and the chord (continuous member) side of each weld (see Figure 3). The hot-spot stress can be determined by considering the stress perpendicular to the weld toe for the chord and the stress parallel to the brace axis for the brace.

**3.8**

**nominal stress**

⟨welded hollow section joints⟩ maximum stress in a cross-section calculated on the actual cross-section by simple elastic theory without taking into account the effect of geometrical discontinuities due to the joint configuration on the stress



**3.9**
**overlap**
$O_v$
ratio of the overlap length, $q$, to the projected connecting length to chord of overlapping brace, $p$

NOTE The overlap is expressed as a percentage.

See Figure 4, where $b_1 = h_1 = h_2$, $t_1 = t_2$, and $\theta_1 = \theta_2$. See Clause 4 for the variable definitions.

**3.10**
**$\Delta S$-$N$ curve**
curve giving the relation between the stress range and the number of cycles to failure

NOTE 1 Conventionally, the range of stress is plotted on the vertical axis and the number of cycles on the horizontal axis using logarithmic scales for both axes.

NOTE 2 The $\Delta S$-$N$ curves given in this International Standard have been derived from a statistical analysis of relevant experimental data and represent lives that are less than the mean life by two standard deviations of lg $N$.

**3.11**
**stress concentration factor**
**SCF**
$K_t$
⟨welded hollow section joints⟩ ratio between the hot-spot stress at the joint and the nominal stress in the member due to a basic member load that causes this hot-spot stress

NOTE In joints with more than one branch, each branch is considered. Generally, stress concentration factors are calculated for the chord and branch.

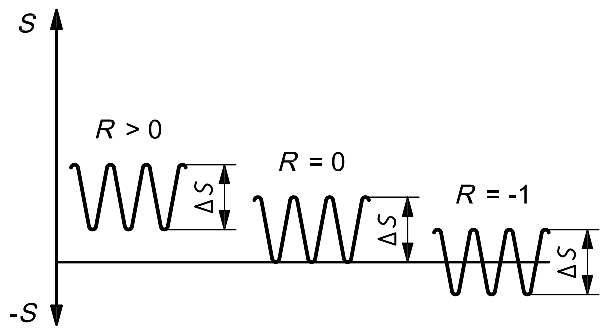
**3.12**
**stress range**
$\Delta S$
arithmetic difference between the maximum and minimum stress

$$\Delta S = S_{max} - S_{min}$$

NOTE 1 Adapted from ISO 1099:2006, 3.10.

NOTE 2 The nominal stress range is based on the nominal stresses while the hot-spot stress range is based on hot-spot stresses.

See Figure 5.




**Key**
$S$ tensile stress
$-S$ compressive stress

**Figure 5 — Stress range, $\Delta S$, and stress ratio, $R$**



**3.13**
**stress ratio**
*R*
algebraic ratio of the minimum and maximum stress of a cycle:

$$R = S_{\text{min}}/S_{\text{max}}$$

[ISO 11782-1:1998, 3.6]

NOTE Tension is taken as positive and compression as negative.

See Figure 5.

**3.14**
**structural stress**
geometric stress
⟨welded hollow section joints⟩ linearly distributed stress across the section thickness that arises from applied loads and the corresponding reaction of the particular structural part, taking account of all geometrical discontinuities but excluding the notch effects of local structural discontinuities (e.g. weld toe)

## 4 Symbols and abbreviated terms

| | |
|---|---|
| $A$ | cross-sectional area of a member |
| $a$ | throat thickness |
| $b_0$ | RHS chord width |
| $b_i$ | width of brace $i$ |
| $C$ | chord-end fixity factor |
| $D$ | cumulative fatigue damage index |
| $d_0$ | CHS chord diameter |
| $d_i$ | diameter of brace $i$ (CHS) |
| $e$ | joint eccentricity |
| $F_{\text{ax}}$ | axial force |
| $F_{\text{ch}}$ | force in chord |
| $F_{\text{cov}}$ | force in carry-over brace |
| $F_i$ | function in determining SCF (see D.1.2, D.2.2) |
| $F_{\text{ref}}$ | force of reference brace |
| $f_{\text{c}}$ | correction factor |
| $f_{\text{m}}$ | magnification factor |
| $f_{\text{mc}}$ | multiplanar correction factor (see Tables 4 and 5) |
| $g$ | gap length |

| | |
|---|---|
| $g'$ | ratio of the gap length to the chord wall thickness, $g/t_0$ |
| $h_0$ | RHS chord depth |
| $h_i$ | depth of brace $i$ |
| $K_t$ | stress concentration factor |
| $K_{t,0,b,ax}$ | reference SCF for brace under basic balanced axial loading |
| $K_{t,0,b_4,cov}$ | carry-over SCF for brace at location 4 (see D.4.2.1.2.2) |
| $K_{t,0,b_4,ref}$ | reference SCF for brace at location 4 (see D.4.2.1.1.2) |
| $K_{t,0,ch,ax}$ | reference SCF for chord under basic balanced axial loading |
| $K_{t,0,ch_2,cov}$ | carry-over SCF for chord at location 2 (see D.4.2.1.2.1) |
| $K_{t,0,ch_2,ref}$ | reference SCF for chord at location 2 (see D.4.2.1.1.1) |
| $K_{t,ax,b}$ | SCF for load condition “axial force in brace” |
| $K_{t,ax,c}$ | SCF for load condition “axial force in chord” |
| $K_{t,ax,cov\text{-}b}$ | SCF for load condition “axial force in carry-over brace” |
| $K_{t,ax,ref\text{-}b}$ | SCF for load condition “axial force in reference brace” |
| $K_{t,b,ax}$ | SCF for brace under basic balanced axial loading |
| $K_{t,b,c}$ | SCF for brace under chord loading |
| $K_{t,b_A,ax}$ | SCF for brace along line A under basic balanced axial loading (see E.1.2.1.2) |
| $K_{t,b_E,ax}$ | SCF for brace along line E under basic balanced axial loading (see E.1.2.1.2) |
| $K_{t,b_A,ipb}$ | SCF for brace along line A under in-plane bending on the brace (see See E.1.2.2.2) |
| $K_{t,b_E,ipb}$ | SCF for brace along line E under in-plane bending on the brace (see See E.1.2.2.2) |
| $K_{t,b_3,cov,ax}$ | SCF for brace at location 3 under axial loading in carry-over brace (see D.4.2.1.2.2) |
| $K_{t,b_4,cov,ax}$ | SCF for brace at location 4 under axial loading in carry-over brace (see D.4.2.1.2.2) |
| $K_{t,b_3,cov,ipb}$ | SCF for brace at location 3 under in-plane bending in carry-over brace (see D.4.2.2.2.2) |
| $K_{t,b_4,cov,ipb}$ | SCF for brace at location 4 under in-plane bending in carry-over brace (see D.4.2.2.2.2) |
| $K_{t,b_3,cov,opb}$ | SCF for brace at location 3 under out-of-plane bending in carry-over brace (see D.4.2.3.2.2) |
| $K_{t,b_4,cov,opb}$ | SCF for brace at location 4 under out-of-plane bending in carry-over brace (see D.4.2.3.2.2) |
| $K_{t,b,cr,ax}$ | SCF for brace crown under axial loading |
| $K_{t,b,cr,ipb}$ | SCF for brace crown under in-plane bending |
| $K_{t,b,cr,opb}$ | SCF for brace crown under out-of-plane bending |
| $K_{t,b_3,ref,ax}$ | SCF for brace at location 3 under axial loading in reference brace (see D.4.2.1.1.2) |



| | |
|---|---|
| $K_{t,b_4,ref,ax}$ | SCF for brace at location 4 under axial loading in reference brace (see D.4.2.1.1.2) |
| $K_{t,b_3,ref,ipb}$ | SCF for brace at location 3 under in-plane bending in reference brace (see D.4.2.2.1.2) |
| $K_{t,b_4,ref,ipb}$ | SCF for brace at location 4 under in-plane bending in reference brace (see D.4.2.2.1.2) |
| $K_{t,b_3,ref,opb}$ | SCF for brace at location 3 under out-of-plane bending in reference brace (see D.4.2.3.1.2) |
| $K_{t,b_4,ref,opb}$ | SCF for brace at location 4 under out-of-plane bending in reference brace (see D.4.2.3.1.2) |
| $K_{t,b,s,ax}$ | SCF for brace saddle under axial loading |
| $K_{t,b,s,opb}$ | SCF for brace saddle under out-of-plane bending |
| $K_{t,b,s,ipb}$ | SCF for brace saddle under in-plane bending |
| $K_{t,ch,ax}$ | SCF for chord under basic balanced axial loading |
| $K_{t,ch,ch}$ | SCF for chord under chord loading |
| $K_{t,ch_B,ax}$ | SCF for chord along line B under axial loading in the brace (see E.1.2.1.1) |
| $K_{t,ch_C,ax}$ | SCF for chord along line C under axial loading in the brace (see E.1.2.1.1) |
| $K_{t,ch_D,ax}$ | SCF for chord along line D under axial loading in the brace (see E.1.2.1.1) |
| $K_{t,ch_B,ipb}$ | SCF for chord along line B under in-plane bending in the brace (see E.1.2.2.1) |
| $K_{t,ch_C,ipb}$ | SCF for chord along line C under in-plane bending in the brace (see E.1.2.2.1) |
| $K_{t,ch_D,ipb}$ | SCF for chord along line D under in-plane bending in the brace (see E.1.2.2.1) |
| $K_{t,ch_1,cov,ax}$ | SCF for chord at location 1 under axial loading in carry-over brace (see D.4.2.1.2.1) |
| $K_{t,ch_2,cov,ax}$ | SCF for chord at location 2 under axial loading in carry-over brace (see D.4.2.1.2.1) |
| $K_{t,ch_1,cov,ipb}$ | SCF for chord at location 1 under in-plane bending in carry-over brace (see D.4.2.2.2.1) |
| $K_{t,ch_2,cov,ipb}$ | SCF for chord at location 2 under in-plane bending in carry-over brace (see D.4.2.2.2.1) |
| $K_{t,ch_1,cov,opb}$ | SCF for chord at location 1 under out-of-plane bending in carry-over brace (see D.4.2.3.2.1) |
| $K_{t,ch_2,cov,opb}$ | SCF for chord at location 2 under out-of-plane bending in carry-over brace (see D.4.2.3.2.1) |
| $K_{t,ch,cr,ax}$ | SCF for chord crown under axial loading |
| $K_{t,ch,cr,ipb}$ | SCF for chord crown under in-plane bending |
| $K_{t,ch,cr,opb}$ | SCF for chord crown under out-of-plane bending |
| $K_{t,ch_1,ref,ax}$ | SCF for chord at location 1 under axial loading in reference brace (see D.4.2.1.1.1) |
| $K_{t,ch_2,ref,ax}$ | SCF for chord at location 2 under axial loading in reference brace (see D.4.2.1.1.1) |
| $K_{t,ch_1,ref,ipb}$ | SCF for chord at location 1 under in-plane bending in reference brace (see D.4.2.2.1.1) |
| $K_{t,ch_2,ref,ipb}$ | SCF for chord at location 2 under in-plane bending in reference brace (see D.4.2.2.1.1) |
| $K_{t,ch_1,ref,opb}$ | SCF for chord at location 1 under out-of-plane bending in reference brace (see D.4.2.3.1.1) |

$K_{t,ch_2,ref,opb}$ SCF for chord at location 2 under out-of-plane bending in reference brace (see D.4.2.3.1.1)

$K_{t,ch,s,ax}$ SCF for chord saddle under axial loading

$K_{t,ch,s,ipb}$ SCF for chord saddle under in-plane bending

$K_{t,ch,s,opb}$ SCF for chord saddle under out-of-plane bending

$K_{t,ipb,b}$ SCF for load condition “in-plane bending in brace”

$K_{t,ipb,ch}$ SCF for load condition “in-plane bending in chord”

$K_{t,ipb,ref-b}$ SCF for load condition “in-plane bending in reference brace”

$K_{t,K}$ SCF for uniplanar K-joints

$K_{t,KK}$ SCF for multiplanar KK-joints

$K_{t,T}$ SCF for uniplanar CHS T-joints subjected to in-plane bending

$K_{t,opb,b}$ SCF for load condition “out-of-plane bending in brace”

$K_{t,opb,cov-b}$ SCF for load condition “out-of-plane bending in carry-over brace”

$K_{t,opb,ref-b}$ SCF for load condition “out-of-plane bending in reference brace”

$K_{t,\theta}$ SCF for acute angle between brace and chord axes

$L$ chord length between simple support or contraflexure points (see Figure D.1)

$M_{ch}$ bending moment in chord member

$M_{cov}$ bending moment in carry-over brace

$M_{ipb}$ in-plane bending moment (see Figure D.2)

$M_{opb}$ out-of-plane bending moment (see Figure D.2)

$M_{ref}$ moment of reference brace

$m$ ratio of the brace axial load in the carry-over plane to that in the reference plane (see Figure 8)

$N$ number of cycles

$N_f$ number of cycles to failure

$n_i$ number of cycles of stress range, $\Delta S_i$

$O_v$ overlap, $(q/p) \times 100$

$R$ stress ratio

$p$ projected connecting length to chord of overlapping brace

$q$ overlap length

SCF stress concentration factor

$S_{max}$ maximum stress



| | |
|---|---|
| $S_{min}$ | minimum stress |
| $T_i$ | terms used to simplify the writing of SCF equations for T-joints (see D.1.2) |
| $t$ | thickness of member subjected to fatigue-cracking test |
| $t_0$ | chord wall thickness |
| $t_i$ | thickness of brace wall $i$ |
| $W_{ipb}$ | elastic section modulus of a member for in-plane bending |
| $W_{opb}$ | elastic section modulus of a member for out-of-plane bending |
| $X_i$ | terms used to simplify the writing of SCF equations for X-joints (see D.2.2) |
| $\alpha$ | relative chord length, $2L/d_0$ or $2\ L/b_0$ |
| $\beta$ | diameter or width ratio, $d_i/d_0$ or $b_i/b_0$ |
| $\gamma$ | chord slenderness, $d_0/2t_0$ or $b_0/2t_0$ |
| $\gamma_{Ff}$ | partial safety factor for fatigue loading |
| $\gamma_{Mf}$ | partial safety factor for fatigue strength |
| $\Delta S$ | stress range |
| $\Delta S_{ax}$ | axial stress range |
| $\Delta S_{ax,b}$ | stress range for load condition “axial force in brace” |
| $\Delta S_{ax,ch}$ | stress range for load condition “axial force in chord” |
| $\Delta S_{ax,cov\text{-}b}$ | stress range for load condition “axial force in carry-over brace” |
| $\Delta S_{ax,ref\text{-}b}$ | stress range for load condition “axial force in reference brace” |
| $\Delta S_{hs}$ | hot-spot stress range |
| $\Delta S_{ipb,b}$ | stress range for load condition “in-plane bending in brace” |
| $\Delta S_{ipb,ch}$ | stress range for load condition “in-plane bending in chord” |
| $\Delta S_{ipb,ref\text{-}b}$ | stress range for load condition “in-plane bending in reference brace” |
| $\Delta S_{opb,b}$ | stress range for load condition “out-of-plane bending in brace” |
| $\Delta S_{opb,cov\text{-}b}$ | stress range for load condition “out-of-plane bending in carry-over brace” |
| $\Delta S_{opb,ref\text{-}b}$ | stress range for load condition “out-of-plane bending in reference brace” |
| $\theta_i$ | acute angles between brace and chord axes (in Y-, X- and K-joints) |
| $\tau$ | wall thickness ratio, $t_i/t_0$ |
| $\phi$ | angle between planes with braces in multiplanar joints (see Figure D.9) |
| $\psi$ | circumferential gap parameter, $\phi - 2 \arcsin \beta$ |

## 5 Cumulative fatigue damage

**5.1** For constant amplitude loading, it is assumed that there is no fatigue damage when the stress range is below the constant amplitude fatigue limit defined in 3.2.

**5.2** For variable amplitude loading, the stress ranges below the cut-off limit defined in 3.3 do not contribute to fatigue damage.

**5.3** When the stress ranges for a constant amplitude loaded structure, or when the maximum stress ranges for a variable amplitude loaded structure, are above the constant amplitude fatigue limit, the cumulative fatigue damage index, $D$, can be assessed using the Palmgren-Miner linear rule, for each potential crack location; i.e.

$$D = \sum \frac{n_i}{N_f}$$

where

$n_i$ is the number of cycles of a particular stress range, $\Delta S_i$;

$N_f$ is the number of cycles to failure for that particular stress range.

**5.4** The allowable cumulative fatigue damage index for structures in a non-aggressive environment is generally taken as 1,0, if the effect of fatigue cracks and the possibility for inspection are taken into account by partial safety factors.

## 6 Partial safety factor

**6.1** The partial safety factor for fatigue loading, $\gamma_{Ff}$, is taken as 1,0.

**6.2** The partial safety factor for fatigue strength, $\gamma_{Mf}$, is given in Table 1.

**Table 1 — Partial safety factor for fatigue strength on hot-spot stress ranges**

| Inspection and access | Fail-safe (redundant) component | Non fail-safe (statically determinate) component |
|---|---|---|
| Periodic inspection and maintenance (Accessible joint detail) | 1,0 | 1,25 |
| Periodic inspection and maintenance (Poor accessibility detail) | 1,15 | 1,35 |



## 7 Fatigue design procedures

### 7.1 Hot-spot stress method

The hot-spot stress (also called geometric stress) method relates the fatigue life of a joint to the hot-spot stress at the weld toe rather than the nominal stress. It takes the uneven stress distribution around the perimeter of the joint into account directly.

### 7.2 Design procedures

**7.2.1** Determine the axial force ranges and bending moment ranges in the chord and braces using a structural analysis as described in 8.1.

**7.2.2** Determine the nominal stress ranges, $\Delta S$, as specified in 8.2.

**7.2.3** Determine the stress concentration factors (SCFs) as specified in 8.3.

**7.2.4** Determine the hot-spot stress ranges, $\Delta S_{hs}$, as specfied in 8.4.

**7.2.5** Determine the permissible number of cycles for a given hot-spot stress range at a specific joint location from a fatigue strength curve given in 8.5.

NOTE A fatigue assessment procedure is given in Annex C.

## 8 Fatigue strength

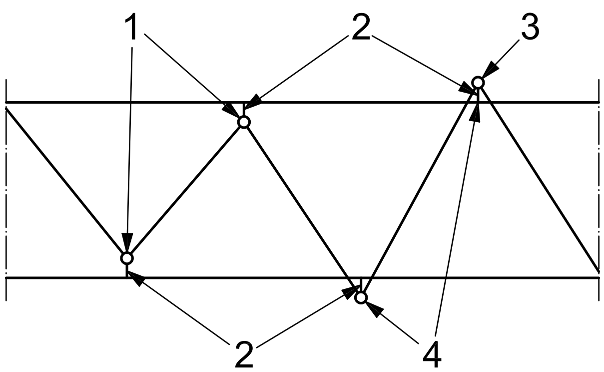
### 8.1 Member forces

**8.1.1 General**. For welded hollow section structures, member forces shall be obtained by analysis of the complete structure, in which noding eccentricity of the member centrelines at the joint (see Figure 6), as well as local joint flexibility, is taken into account. This can be achieved by one of the methods specified in 8.1.2 to 8.1.4.

**8.1.2 Sophisticated three dimensional finite element modelling**, where plate, shell, and solid elements are used at the joints (appropriate for experienced analysts).

**8.1.3 Simplified structural analysis using frame analysis for triangulated trusses or lattice girders**. Axial forces and bending moments in the members can be determined using a structural analysis assuming a continuous chord and pin-ended braces (see Figure 6). This produces axial forces in the braces, and both axial forces and bending moments in the chord. This modelling assumption is particularly appropriate for moving loads along the chord members in structures such as cranes and bridges.

**8.1.4 Rigid frame analysis for two or three dimensional Vierendeel girders**.




**Key**

1 noding condition for most overlap connections
2 extremely stiff members
3 pin
4 noding condition for most gap connections

**Figure 6 — Frame modelling assumptions**

## 8.2 Nominal stress ranges

**8.2.1** The determination of nominal stress ranges depends on the method used to determine member forces.

**8.2.2** For analysis undertaken using the approach in 8.1.2, the nominal range of stresses due to axial, $\Delta S_{ax}$, in-plane bending, $\Delta S_{ipb}$, and out-of-plane bending, $\Delta S_{opb}$, in any member can be determined by Equations (1), (2), and (3), respectively:

$$\Delta S_{ax} = \frac{F_{ax}}{A} \quad (1)$$

$$\Delta S_{ipb} = \frac{M_{ipb}}{W_{ipb}} \quad (2)$$

$$\Delta S_{opb} = \frac{M_{opb}}{W_{opb}} \quad (3)$$

See Clause 4 for the variable definitions.

**8.2.3** For analysis undertaken using the approach in 8.1.3, the nominal stress range in any member can be determined by Equation (2) or Equation (4):

$$\Delta S_{ax} = f_m \frac{F_{ax}}{A} \quad (4)$$

where the magnification factor, $f_m$, is given in Table 2.

**8.2.4** For analysis undertaken using the approach in 8.1.4, the nominal stress range in any member can be determined by Equations (1), (2), and (3).

**Table 2 — Magnification factor, $f_m$, to account for secondary bending moments in K-joints**

| Type of K-joint | Chord member | Brace member |
|---|---|---|
| **CHS gap** | 1,5 | 1,3 |
| **RHS gap** | 1,5 | 1,5 |
| **RHS overlap** | 1,5 | 1,3 |

## 8.3 SCF calculations

**8.3.1** If the analysis has been undertaken using the approach in 8.1.2, the SCFs can be calculated from the analysis or using Clause 9 (for CHS joints) or Clause 10 (for RHS joints).

**8.3.2** If the analysis has been undertaken using the approach in 8.1.3, the SCFs can be calculated using Clause 9 (for CHS joints) or Clause 10 (for RHS joints).

**8.3.3** If the analysis has been undertaken using the approach in 8.1.4, the SCFs can be calculated using Clause 9 (for CHS joints) or Clause 10 (for RHS joints).

## 8.4 Hot-spot stress ranges

**8.4.1** For analysis undertaken using the approach in 8.1.2, the hot-spot stress ranges can be obtained directly from the analysis for each load combination. In all other cases, the following procedures should be used to determine the hot-spot stress ranges.

**8.4.2** The hot-spot stress range at *one location* under *one load case* is the product of the nominal stress range and the corresponding stress concentration factor (SCF).

**8.4.3** Superposition of the hot-spot stress ranges at the *same location* can be used for combined load cases.

**8.4.4** If the position of the maximum hot-spot stress in a member, for the relevant loading condition, cannot be determined, then the maximum SCF values shall be applied to all points around the periphery of the member at a joint.

**8.4.5** Hot-spot stress ranges shall be calculated for both the chord member and brace members.

**8.4.6** Under general loading conditions, the hot-spot stress range at any location, in the chord member, is given by the equations in 8.4.6.1 and 8.4.6.2.

**8.4.6.1 For CHS XX-joints**

$$\Delta S_{\text{hs}} = K_{\text{t,ax,ref-b}}\,\Delta S_{\text{ax,ref-b}} + K_{\text{t,ipb,ref-b}}\,\Delta S_{\text{ipb,ref-b}} + K_{\text{t,opb,ref-b}}\,\Delta S_{\text{opb,ref-b}} + K_{\text{t,ax,ch}}\,\Delta S_{\text{ax,ch}} + K_{\text{t,ax,cov-b}}\,\Delta S_{\text{ax,cov-b}} + K_{\text{t,opb,cov-b}}\,\Delta S_{\text{obp,cov-b}}$$

**8.4.6.2 For all other joints**

$$\Delta S_{\text{hs}} = K_{\text{t,ax,b}}\,\Delta S_{\text{ax,b}} + K_{\text{t,ipb,b}}\,\Delta S_{\text{ipb,b}} + K_{\text{t,opb,b}}\,\Delta S_{\text{opb,b}} + K_{\text{t,ax,ch}}\,\Delta S_{\text{ax,ch}} + K_{\text{t,ipb,ch}}\,\Delta S_{\text{ipb,ch}}$$

For K-joints, $\Delta S_{\text{ax,ch}}$ refers to the additional stress range determined from Figures D.5 b), E.3 b), or E.12 b).

**8.4.7** Under general loading conditions, the hot-spot stress range at any location, in the brace member, is given by the equations in 8.4.7.1 and 8.4.7.2.

**8.4.7.1 For CHS XX-joints**

$$\Delta S_{\text{hs}} = K_{\text{t,ax,ref-b}}\,\Delta S_{\text{ax,ref-b}} + K_{\text{t,ipb,ref-b}}\,\Delta S_{\text{ipb,ref-b}} + K_{\text{t,opb,ref-b}}\,\Delta S_{\text{opb,ref-b}} + K_{\text{t,ax,cov-b}}\,\Delta S_{\text{ax,cov-b}} + K_{\text{t,opb,cov-b}}\,\Delta S_{\text{opb,cov-b}}$$

**8.4.7.2 For all other joints**

$$\Delta S_{\text{hs}} = K_{\text{t,ax,b}}\,\Delta S_{\text{ax,b}} + K_{\text{t,ipb,b}}\,\Delta S_{\text{ipb,b}} + K_{\text{t,opb,b}}\,\Delta S_{\text{opb,b}}$$

## 8.5 Fatigue strength curves

**8.5.1** The fatigue strength curves ($\Delta S_{\text{hs}}$–$N_{\text{f}}$) are shown in Figure 7.

**8.5.2** The equations for the fatigue strength curves ($\Delta S_{\text{hs}}$–$N_{\text{f}}$) are:

for $10^3 < N_{\text{f}} < 5 \times 10^6$

$$\lg \Delta S_{\text{hs}} = \frac{1}{3}(12{,}476 - \lg N_{\text{f}}) + 0{,}06 \lg N_{\text{f}} \lg\left(\frac{16}{t}\right) \tag{5}$$

or

$$\lg N_{\text{f}} = \frac{12{,}476 - 3 \lg \Delta S_{\text{hs}}}{1 - 0{,}18 \lg (16/t)} \tag{6}$$

for $5 \times 10^6 < N_{\text{f}} < 10^8$ (variable amplitude only)

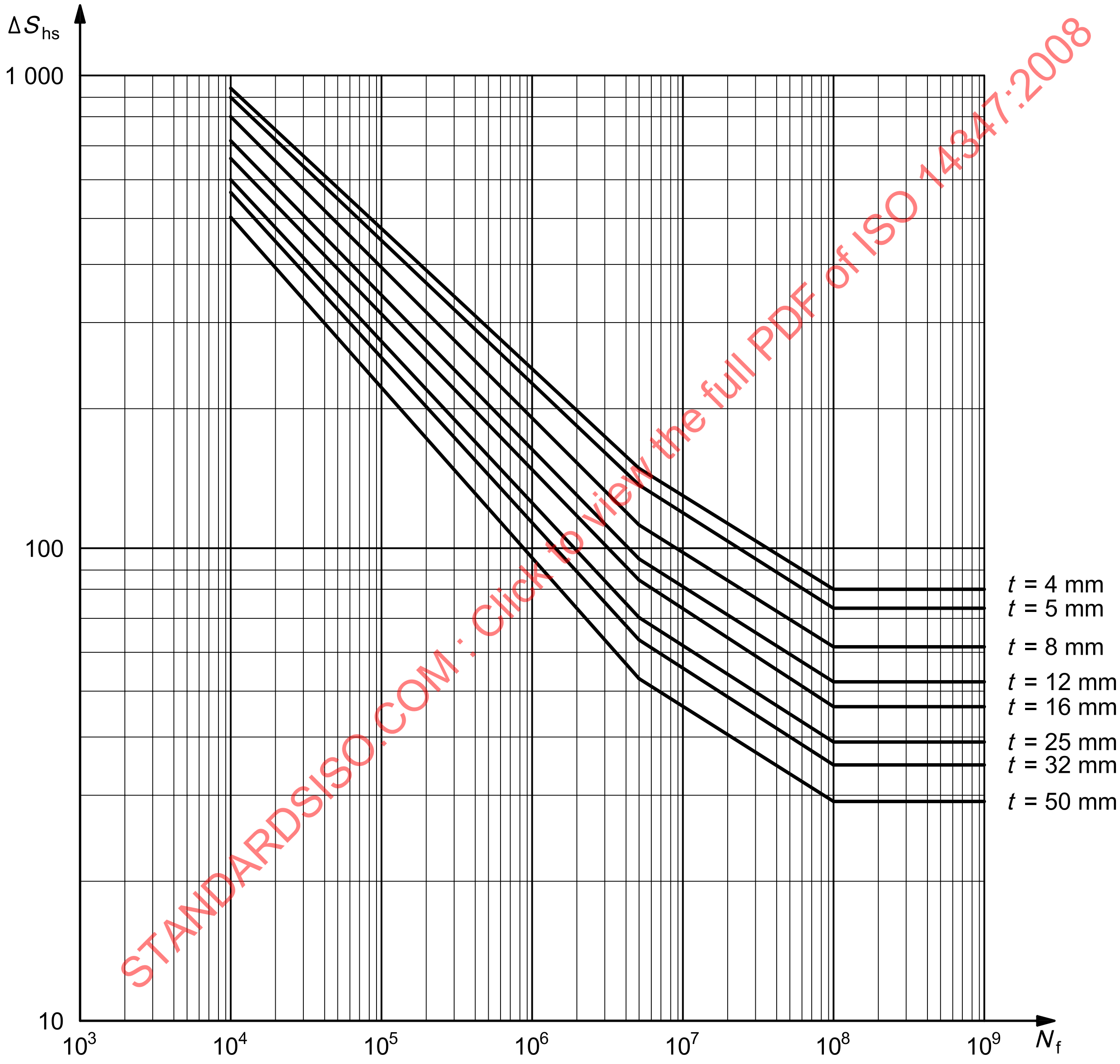
$$\lg \Delta S_{\text{hs}} = \frac{1}{5}(16{,}327 - \lg N_{\text{f}}) + 0{,}402 \lg \left(\frac{16}{t}\right) \tag{7}$$

or

$$\lg N_f = 16,327 - 5 \lg \Delta S_{hs} + 2,01 \lg(\frac{16}{t}) \quad (8)$$

In Equations (5) to (8), $t$ is the thickness of applicable member being checked for fatigue cracking: for CHS joints — 4 mm $\leqslant t \leqslant$ 50 mm; for RHS joints — 4 mm $\leqslant t \leqslant$ 16 mm.

**8.5.3** The constant amplitude fatigue limit and cut-off limit in Figure 7 are listed in Table 3.




**Key**

$\Delta S_{hs}$ hot-spot stress range, MPa

$N_f$ number of cycles to failure

$t$ thickness of applicable member being checked for fatigue cracking:

a) for CHS joints: 4 mm $\leqslant t \leqslant$ 50 mm

b) for RHS joints: 4 mm $\leqslant t \leqslant$ 16 mm

**Figure 7 — Fatigue strength curves**

**Table 3 — Constant amplitude fatigue limit and cut-off limit in Figure 7**

| Section type | Thickness<br>mm | Constant amplitude fatigue limit<br>MPa | Cut-off limit<br>MPa |
|---|---|---|---|
| CHS and RHS | 4 | 147 | 81 |
| | 5 | 134 | 74 |
| | 8 | 111 | 61 |
| | 12 | 95 | 52 |
| | 16 | 84 | 46 |
| CHS | 25 | 71 | 39 |
| | 32 | 64 | 35 |
| | 50 | 53 | 29 |



# 9 SCF calculations for CHS joints

## 9.1 Uniplanar CHS T- and Y-joints

**9.1.1** Hot-spot locations are given in Figure D.1.

**9.1.2** Detailed SCF equations for uniplanar CHS T- and Y-joints are given in D.1.2.1 to D.1.2.4 for the load conditions defined in Figure D.2.

**9.1.3** The factor $C$ corresponds to the chord-end fixity. In the case of fully fixed chord ends, $C$ is taken as 0,5. If the chord ends are pinned, $C$ is taken as 1,0. A typical value for $C$ is 0,7.

**9.1.4** When the relative chord length, $\alpha$, is less than 12, a correction factor is needed to take account of the reduced deformation and stresses in short chords, as shown in D.1.2.

**9.1.5** In the case of a diameter or width ratio $\beta \geqslant 0,95$, use SCFs for $\beta = 0,95$.

**9.1.6** The validity conditions for the graphs and equations are:

diameter or width ratio

$0,2 \leqslant \beta \leqslant 1,0$

chord slenderness

$15 \leqslant 2\gamma \leqslant 64$

wall thickness ratio

$0,2 \leqslant \tau \leqslant 1,0$

relative chord length

$4 \leqslant \alpha \leqslant 40$

acute angle between brace and chord axes

$30° \leqslant \theta \leqslant 90°$

## 9.2 Uniplanar CHS X-joints

**9.2.1** Hot-spot locations are given in Figure D.3.

**9.2.2** Detailed SCF equations for uniplanar CHS X-joints are given in D.2.2 for the load conditions defined in Figure D.4.

**9.2.3** In the case of $\beta \geqslant 0{,}95$, use SCFs for $\beta = 0{,}95$.

**9.2.4** The validity ranges are as specified in 9.1.6.

## 9.3 Uniplanar CHS K-joints with gap

**9.3.1** SCFs for uniplanar CHS K-joints with gap are given for two load conditions.

**9.3.1.1** **Load condition 1**: basic balanced axial load as defined in Figure D.5 a).

**9.3.1.2** **Load condition 2**: chord loading (axial and bending) as defined in Figure D.5 b).

**9.3.2** The SCFs for the chord of uniplanar CHS K-joints with gap under basic balanced axial loading, $K_{\text{t,ch,ax}}$, can be calculated using:

$$K_{\text{t,ch,ax}} = f_{\text{c}} \; K_{\text{t,0,ch,ax}}$$

where $K_{\text{t,0,ch,ax}}$ and the corresponding correction factor, $f_{\text{c}}$, are given in Figure D.6.

**9.3.3** The SCFs for the brace of uniplanar CHS K-joints with gap under basic balanced axial loading, $K_{\text{t,b,ax}}$, can be calculated using:

$$K_{\text{t,b,ax}} = f_{\text{c}} \; K_{\text{t,0,b,ax}}$$

where $K_{\text{t,0,b,ax}}$ and the corresponding correction factor, $f_{\text{c}}$, are given in Figure D.7. Minimum values of $K_{\text{t,b,ax}}$ are 2,64 for $\theta = 30°$; 2,30 for $\theta = 45°$; and 2,12 for $\theta = 60°$.

**9.3.4** The SCFs for the chord of uniplanar CHS K-joints with gap, $K_{\text{t,ch,ch}}$, under chord loading (axial and bending) are given in Figure D.8.

**9.3.5** The SCFs for the brace of uniplanar CHS K-joints with gap under chord loading (axial and bending), $K_{\text{t,b,ch}}$, are negligible and it can be assumed that:

$$K_{\text{t,b,ch}} = 0$$

**9.3.6** The validity conditions for the graphs are:

eccentricity

none

braces

equal

diameter or width ratio

$0{,}3 \leqslant \beta \leqslant 0{,}6$

chord slenderness

$24 \leqslant 2\gamma \leqslant 60$



wall thickness ratio

$0,25 \leqslant \tau \leqslant 1,0$

acute angle between brace and chord axes

$30° \leqslant \theta \leqslant 60°$

## 9.4 Multiplanar CHS XX-joints

**9.4.1** Hot-spot locations are given in Figure D.9.

**9.4.2** SCFs for multiplanar CHS XX-joints are given for the load conditions in 9.4.2.1 to 9.4.2.4 (see Figure D.10).

**9.4.2.1** **Load condition 1**: axial balanced brace loading. The SCFs are given in D.4.2.1

**9.4.2.2** **Load condition 2**: balanced in-plane bending of braces. The SCFs are given in D.4.2.2.

**9.4.2.3** **Load condition 3**: balanced out-of-plane bending of braces. The SCFs are given in D.4.2.3.

**9.4.2.4** **Load condition 4**: axial balanced chord loading. The SCFs are given in D.4.2.4.

**9.4.3** Effects of reference brace ($F_{ref}$, $M_{ref}$) and carry-over brace ($F_{cov}$, $M_{cov}$) shall be combined.

**9.4.4** The validity conditions are:

eccentricity

none

braces

equal

diameter or width ratio

$0,3 \leqslant \beta \leqslant 0,6$

chord slenderness

$15 \leqslant 2\gamma \leqslant 64$

wall thickness ratio

$0,25 \leqslant \tau \leqslant 1,0$

acute angle between brace and chord axes

$\theta = 90°$

angle between planes with braces in multiplanar joints

$\phi = 90°$

circumferential gap parameter

$\psi \geqslant 16,2°$

## 9.5 Multiplanar CHS KK-joints with gap

**9.5.1** The SCFs for multiplanar CHS KK-joints with gap, $K_{t,KK}$, can be calculated from Equation (9):

$$K_{t,KK} = f_{mc} K_{t,K} \quad (9)$$

where

$K_{t,K}$ is the SCF for uniplanar CHS K-joints with gap given in 9.3;

$f_{mc}$ is the multiplanar correction factor accounting for the effects of geometry and loading.

**9.5.2** The values of $f_{mc}$ for an angle between planes with braces in multiplanar joints, $\phi = 180°$, are 1,0 for all values of the ratio of the brace axial load in the carry-over plane to that in the reference plane, $m$ (see Figure 8). The values of $f_{mc}$ for $\phi \leqslant 90°$ are given in Table 4. Interpolation is allowed for values of $m$ between 0 and −1, and for values of $\phi$ between 90° and 180°.

**Table 4 — Multiplanar correction factors, $f_{mc}$, on SCFs for CHS KK-joints with gap ($\phi \leqslant 90°$)**

| Load case | Chord | | | Brace | | |
|---|---|---|---|---|---|---|
| | $m = +1$ | $m = 0$ | $m = -1$ | $m = +1$ | $m = 0$ | $m = -1$ |
| **Axial balanced brace loading** | 1,0 | 1,0 | 1,25 | 1,0 | 1,0 | 1,25 |
| **Chord loading** | 1,0 | 1,0 | 1,0 | 1,0 | 1,0 | 1,0 |

**9.5.3** The validity conditions are:

eccentricity

none

braces

equal

diameter or width ratio

$0,3 \leqslant \beta \leqslant \cos\theta$

chord slenderness

$24 \leqslant 2\gamma \leqslant 48$

wall thickness ratio

$0,25 \leqslant \tau \leqslant 1,0$

acute angle between brace and chord axes

$30° \leqslant \theta \leqslant 60°$

angle between planes with braces in multiplanar joints

$60° \leqslant \phi \leqslant 180°$

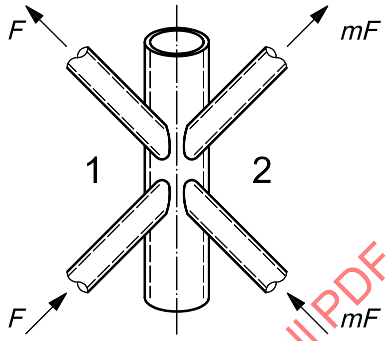
### 9.6 Minimum SCF values

#### 9.6.1 Uniplanar CHS joints

A minimum SCF value of 2,0 is recommended unless otherwise specified such as “negligible” or “no minimum SCF values required.”

#### 9.6.2 Multiplanar CHS joints

When using 9.5.1, the calculated SCF for uniplanar CHS K-joints should be adopted even if it is less than 2,0. A minimum $K_{t,KK}$ value of 2,0 is recommended after applying $f_{mc}$ to $K_{t,K}$.




**Key**

1 reference plane

2 carry-over plane

$F$ load

$m$ ratio of the brace axial load in the carry-over plane to that in the reference plane

| Value of $m$ | Referred to as |
|---|---|
| 1 | symmetrical loading |
| 0 | reference-plane loading |
| −1 | anti-symmetrical loading |

**Figure 8 — Axial balanced loading condition in multiplanar CHS KK-joints**



## 10 SCF calculations for RHS joints

### 10.1 Uniplanar RHS T- and X-joints

**10.1.1** Hot-spot locations (lines A to E) are given in Figure E.1.

**10.1.2** Detailed SCF equations for uniplanar RHS T- and X-joints are given in E.1.2 for the load conditions defined in Figure E.2.

**10.1.3** For fillet-welded connections, multiply SCFs for the brace by 1,4.

**10.1.4** For $\theta = 90°$ RHS T- and X-joints, the validity conditions are:

diameter or width ratio

$$0{,}35 \leqslant \beta \leqslant 1{,}0$$

chord slenderness

$12{,}5 \leqslant 2\gamma \leqslant 25{,}0$

wall thickness ratio

$0{,}25 \leqslant \tau \leqslant 1{,}0$

**10.1.5** For RHS X-joints with 40° $\leqslant \theta \leqslant$ 80°, SCFs can be determined using SCFs for $\theta$ = 90° RHS X-joints with correction factors:

a) for chord locations

$$K_{t,\theta} = 1{,}2\, K_{t,\theta=90^\circ} \sin^2\theta$$

b) for brace locations

$$K_{t,\theta} = 1{,}2\, K_{t,\theta=90^\circ} \sin\theta$$

## 10.2 Uniplanar RHS K-joints with gap

**10.2.1** SCFs for uniplanar RHS K-joints with gap are given for the following load conditions.

**10.2.1.1 Load condition 1**: basic balanced axial load as defined in Figure E.3 a).

**10.2.1.2 Load condition 2**: chord loading (axial and bending) as defined in Figure E.3 b).

**10.2.2** The SCFs for the chord of a uniplanar RHS K-joint with gap under basic balanced axial loading can be calculated from Equation (10):

$$K_{t,ch,ax} = f_c\, K_{t,0,ch,ax} \tag{10}$$

where

$K_{t,0,ch,ax}$ is the reference SCF for chord under basic balanced axial loading (see Figures E.4 to E.7);

$f_c$ is the corresponding correction factor (see Figure E.8).

Interpolation is allowed between the lines for other angles and between the graphs for other ratios of the gap length to the chord wall thickness, $g'$, and $2\gamma$ values.

**10.2.3** The SCFs for the braces of a uniplanar RHS K-joint with gap under basic balanced axial loading can be calculated from Equation (11):

$$K_{t,b,ax} = f_c\, K_{t,0,b,ax} \tag{11}$$

where

$K_{t,0,b,ax}$ is the reference SCF for brace under basic balanced axial loading (see Figure E.9);

$f_c$ is the corresponding correction factor (see Figure E.10).

Interpolation is allowed between the lines for other angles and between the graphs for other $2\gamma$ values.

**10.2.4** The SCFs for the chord of a uniplanar RHS K-joint with gap under chord loading, $K_{t,ch,ch}$, are given in Figure E.11. Interpolation is allowed between the lines for other $g'$ values.

**10.2.5** The SCFs for the braces of a uniplanar RHS K-joint with gap under chord loading, $K_{t,b,ch}$, are negligible, and it can be assumed that:

$$K_{t,b,ch} = 0 \tag{12}$$

**10.2.6** The validity conditions are:

braces

equal

diameter or width ratio

$0,35 \leqslant \beta \leqslant 1,0$

chord slenderness

$10 \leqslant 2\gamma \leqslant 35$

wall thickness ratio

$0,25 \leqslant \tau \leqslant 1,0$

$2\tau \leqslant g'$

acute angle between brace and chord axes

$30° \leqslant \theta \leqslant 60°$

ratio of joint eccentricity to RHS chord depth

$-0,55 \leqslant e/h_0 \leqslant 0,25$



## 10.3 Uniplanar RHS K-joints with overlap

**10.3.1** SCFs for uniplanar RHS K-joints with overlap are given for the load conditions in 10.3.1.1 and 10.3.1.2.

**10.3.1.1** **Load condition 1**: basic balanced axial load as defined in Figure E.12 a).

**10.3.1.2** **Load condition 2**: chord loading (axial and bending) as defined in Figure E.12 b).

**10.3.2** The SCFs for the chord of a uniplanar RHS K-joint with overlap under basic balanced axial loading can be calculated from Equation (10) where

$K_{t,0,ch,ax}$ is the reference SCF for chord under basic balanced axial loading (see Figures E.13 to E.15);

$f_c$ is the corresponding correction factor (see Figure E.16).

Interpolation is allowed between the lines for other angles and between the graphs for other overlap percentages, $O_v$, and $2\gamma$ values.

**10.3.3** The SCFs for the braces of a uniplanar RHS K-joint with overlap under basic balanced axial loading can be calculated from Equation (11) where

$K_{t,0,b,ax}$ is the reference SCF for brace under basic balanced axial loading (see Figures E.17 to E.19);

$f_c$ is the corresponding correction factor (see Figure E.20).

Interpolation is allowed between the lines for other angles and between the graphs for other overlap percentages, $O_v$, and $2\gamma$ values.

**10.3.4** The SCFs for the chord of a uniplanar RHS K-joint with overlap under chord loading, $K_{t,ch,ch}$, are given in Figure E.21.

**10.3.5** The SCFs for the braces of a uniplanar RHS K-joint with overlap under chord loading, $K_{t,b,ch}$, are negligible, and it can be assumed that Equation (12) applies.

**10.3.6** The range of validity is as follows:

braces

equal

diameter or width ratio

$0{,}35 \leqslant \beta \leqslant 1{,}0$

chord slenderness

$10 \leqslant 2\gamma \leqslant 35$

wall thickness ratio

$0{,}25 \leqslant \tau \leqslant 1{,}0$

acute angle between brace and chord axes

$30° \leqslant \theta \leqslant 60°$

percentage overlap

$50 \leqslant O_v \leqslant 100$

ratio of joint eccentricity to RHS chord depth

$-0{,}55 \leqslant e/h_0 \leqslant 0{,}25$

## 10.4 Multiplanar RHS KK-joints with gap

**10.4.1** The SCF for multiplanar RHS KK-joints with gap, $K_{t,KK}$, can be calculated from Equation (9) where

$K_{t,K}$ is the SCF for uniplanar RHS K-joints with gap (see 10.2);

$f_{mc}$ is the multiplanar correction factor accounting for the effects of geometry and loading.

**10.4.2** The values of $f_{mc}$ for $\phi = 180°$ are 1,0 for all ratios of the brace axial load in the carry-over plane to that in the reference plane, $m$. (see Figure 8). The values of $f_{mc}$ for $\phi \leqslant 90°$ are given in Table 5. Interpolation is allowed for $m$ between 0 and –1, and for $\phi$ between 90° and 180°.



**10.4.3** The validity conditions are:

braces

equal

diameter or width ratio

$0{,}25 \leqslant \beta \leqslant 0{,}60$

chord slenderness

$12{,}5 \leqslant 2\gamma \leqslant 25{,}0$

wall thickness ratio

$0{,}5 \leqslant \tau \leqslant 1{,}0$

$2\tau \leqslant g'$

acute angle between brace and chord axes

$30° \leqslant \theta \leqslant 60°$

ratio of joint eccentricity to RHS chord depth

$-0{,}55 \leqslant e/h_0 \leqslant 0{,}25$

angle between planes with braces in multiplanar joints

$60° \leqslant \phi \leqslant 180°$



**Table 5 — Multiplanar correction factors, $f_{mc}$, on SCFs for RHS KK-joints with gap ($\phi \leqslant 90°$)**

| Load case | Chord | | | Brace | | |
|---|---|---|---|---|---|---|
| | Ratio of the brace axial load in the carry-over plane to that in the reference plane | | | | | |
| | $m = +1$ | $m = 0$ | $m = -1$ | $m = +1$ | $m = 0$ | $m = -1$ |
| Axial balanced brace loading | 1,0 | 1,0 | 1,25 | 1,0 | 1,0 | 1,25 |
| Chord loading | 1,0 | 1,0 | 1,0 | 1,0 | 1,0 | 1,0 |

## 10.5 Minimum SCF values

### 10.5.1 Uniplanar RHS joints

A minimum SCF value of 2,0 is recommended unless otherwise specified such as “negligible” or “no minimum SCF values required”.

### 10.5.2 Multiplanar RHS joints

When using 10.4.1, the calculated SCF for uniplanar RHS K-joints should be adopted even if it is less than 2,0. A minimum $K_{t,KK}$ value of 2,0 is recommended after applying $f_{mc}$ to $K_{t,K}$.

# Annex A
(normative)

## Quality requirements for hollow sections

**A.1** The grade and quality of steel chosen shall meet static strength and toughness requirements, taking into account weldability, thickness, environmental conditions, rate of loading, and the consequence of failure.

**A.2** For square and rectangular hollow sections made by cold-forming, the distance between the longitudinal seam and the tangent to the inner radius should be at least twice the wall thickness.

**A.3** Welding is permitted in the zones of cold forming if the minimum conditions of internal corner radius given in Table A.1 are fulfilled.

**Table A.1 — Minimum conditions of internal corner radius**

| **Steel designation to ISO 630:1995, Table 1** | **Minimum yield stress**<br>MPa | **Tensile strength**<br>MPa | $t$<br>mm | $r/t$ |
|---|---|---|---|---|
| Fe 360 at least quality C | 235 | 360 to 460 | $12 < t \leqslant 16$ | $\geqslant$3,0 |
| Fe 430 at least quality C | 275 | 430 to 530 | $8 < t \leqslant 12$ | $\geqslant$2,0 |
| Fe 510 at least quality D | 355 | 490 to 630 | $6 < t \leqslant 8$ | $\geqslant$1,5 |
| | | | $t \leqslant 6$ | $\geqslant$1,0 |

# Annex B
(normative)

# Weld details

**B.1** In welded joints, the connection should be established over the entire perimeter of the hollow section by means of a full penetration weld, a partial penetration weld, a fillet weld, or a combination.

**B.2** Recommendations advocated in this specification are for welds produced to normal structural welding standards, without further weld treatment. It is recognized that better fatigue performance can be achieved by the use of weld-toe improvement techniques.

**B.3** Fillet welds are not generally recommended for wall thicknesses greater than 8 mm. If fillet welds are used, they should satisfy the following conditions:

a)

$$a \geqslant t$$

where

$a$ is the throat thickness of the fillet weld,

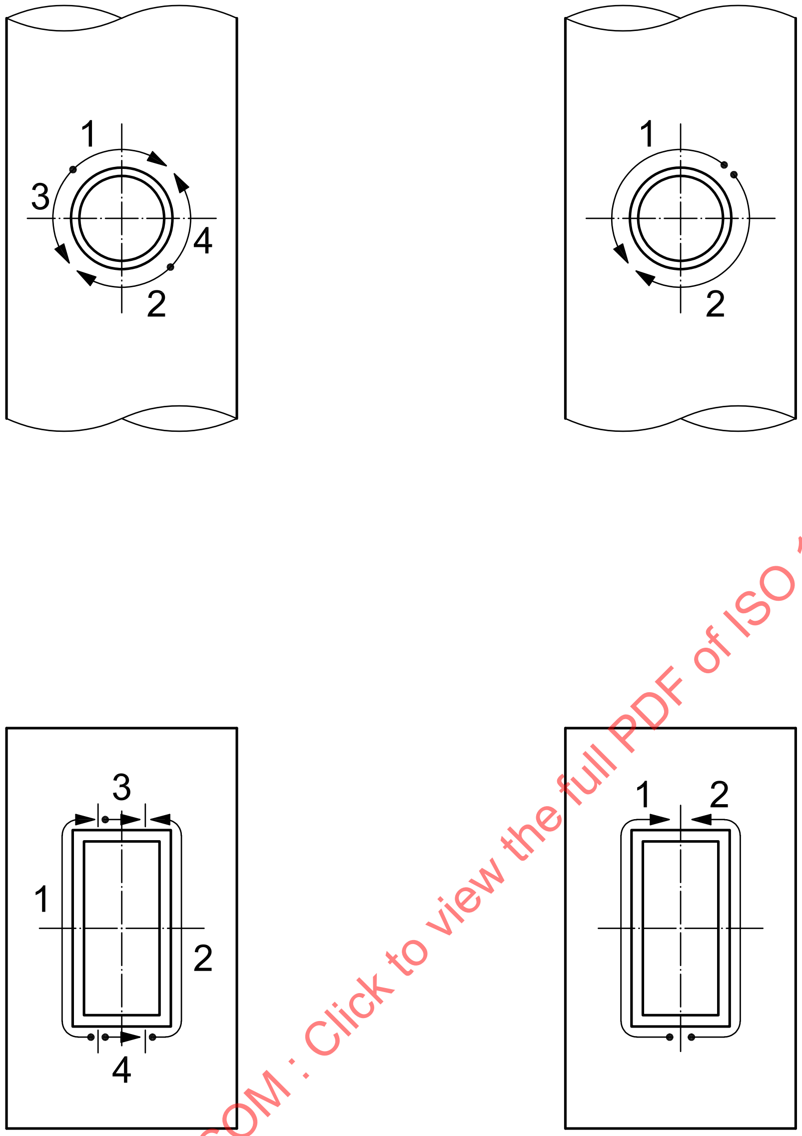
$t$ is the wall thickness of the hollow section to be connected;

b) local dihedral angle at the toe of the brace does not exceed 120°.

**B.4** When fillet welds are not feasible at the saddle regions, partial or full penetration welds should be provided there, while fillet welds may be used at the crown toe and crown heel regions.

**B.5** For connections of brace members with wall thickness larger than 8 mm, partial or full penetration welds are recommended.

**B.6** Weld start/stop positions for non-continuous welds should not be located at points of high stress concentration. Some recommended locations for these weld start/stop positions are shown in Figure B.1.




**Key**

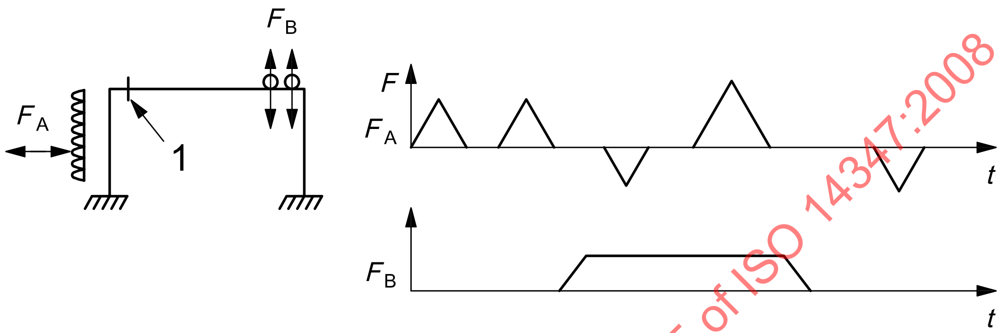
1,2,3,4 recommended weld start/stop positions

**Figure B.1 — Recommended weld start/stop positions**

# Annex C
(informative)

# A fatigue assessment procedure

An illustration of the fatigue assessment procedure is given in Figure C.1.



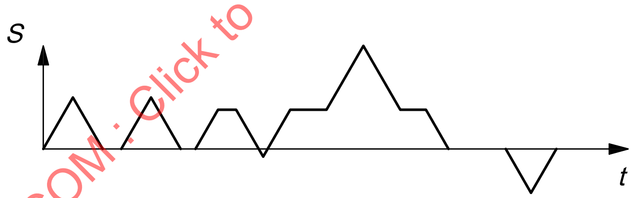

**Key**

$F_i$ loads

$t$ time

1 location of structural detail for design

**a) Loading sequence**

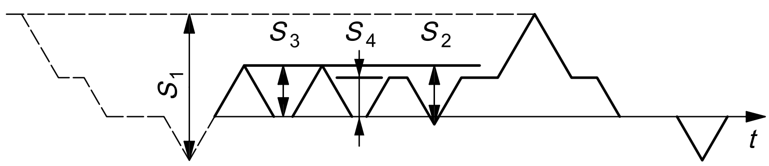



**Key**

$S$ stress

$t$ time

**b) Stress range history at X – X**



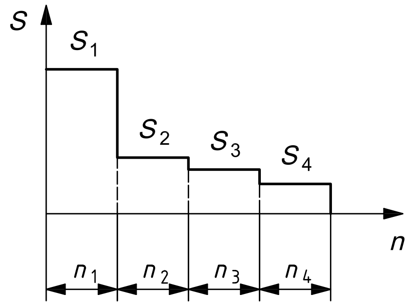

**Key**

$S_i$ stresses

$t$ time (reservoir method)

**c) Cycle counting**

**Figure C.1 — Illustration of fatigue assessment procedure**

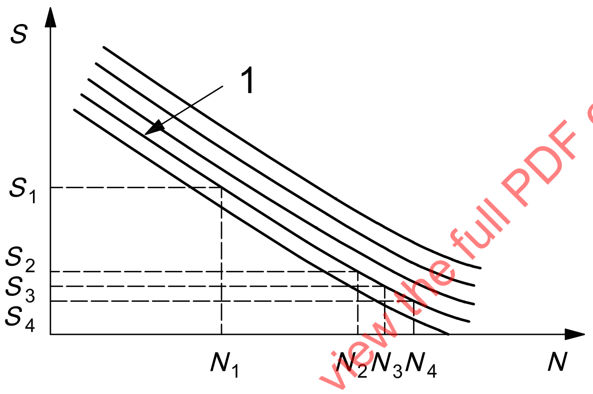



**Key**

$n_i$ number of cycles

$S_i$ stresses

**d) Stress spectrum**




**Key**

$N_i$ number of cycles

$S_i$ stresses

1 $\Delta S$-$N$ line for location of structural detail for design

**e) Cycles to failure**

NOTE Damage summation according to the Palmgren-Miner rule is given by

$$D = \sum \frac{n_i}{N_i} = \frac{n_1}{N_1} + \frac{n_2}{N_2} + \frac{n_3}{N_3} + \frac{n_4}{N_4}$$

**Figure C.1** (*continued*)



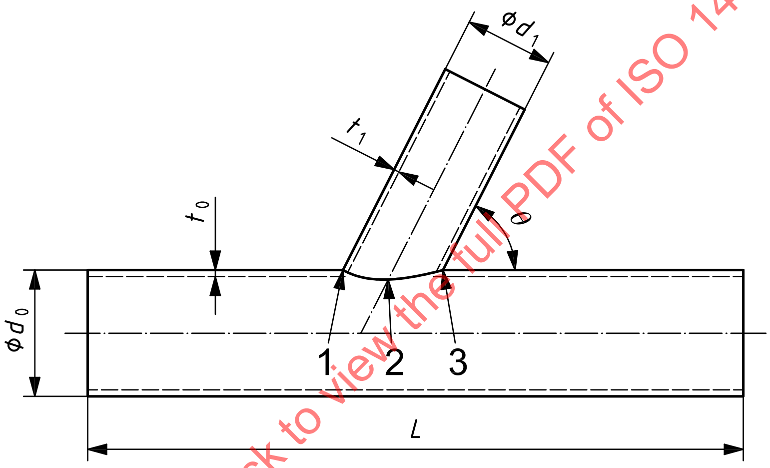
# Annex D
(normative)

# SCF equations and graphs for CHS joints

## D.1 Uniplanar CHS T- and Y-joints

### D.1.1 General

See Figures D.1 and D.2




**Key**

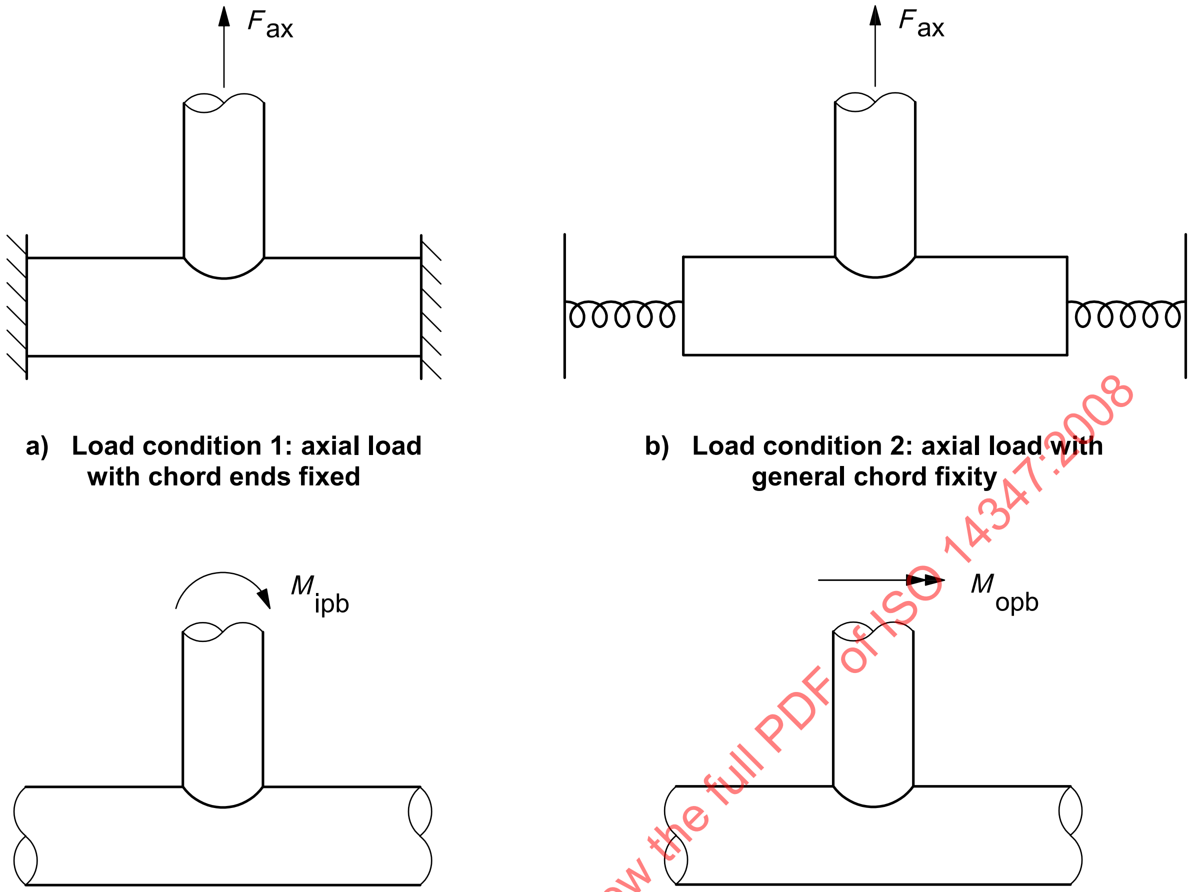
1 crown toe

2 saddle

3 crown heel

NOTE For variable definitions, see Clause 4.

**Figure D.1 — Locations of interest**




a) Load condition 1: axial load with chord ends fixed

b) Load condition 2: axial load with general chord fixity

c) Load condition 3: in-plane bending

d) Load condition 4: out-of-plane bending

NOTE For variable definitions, see Clause 4.

**Figure D.2 — Load conditions**

### D.1.2 SCFs for uniplanar CHS T- and Y-joints

#### D.1.2.1 Load condition 1: Axial load with chord ends fixed

##### D.1.2.1.1 Chord (saddle and crown)

$$K_{\text{t,ch,s,ax}} = T_1 \; F_1$$

$$K_{\text{t,ch,cr,ax}} = T_2$$

##### D.1.2.1.2 Brace (saddle and crown)

$$K_{\text{t,b,s,ax}} = T_3 \; F_1$$

$$K_{\text{t,b,cr,ax}} = T_4$$



**D.1.2.1.3 Source equations**

$$T_1 = \gamma\tau^{1,1}[1,11 - 3(\beta - 0,52)^2]\sin^{1,6}\theta$$

$$T_2 = \gamma^{0,2}\tau[2,65 + 5(\beta - 0,65)^2] + \tau\beta(0,25\alpha - 3)\sin\theta$$

$$T_3 = 1,3 + \gamma\tau^{0,52}\alpha^{0,1}[0,187 - 1,25\beta^{1,1}(\beta - 0,96)]\sin^{(2,7-0,01\alpha)}\theta$$

$$T_4 = 3 + \gamma^{1.2}[0,12e^{-4\beta} + 0,011\beta^2 - 0,045] + \beta\tau(0,1\alpha - 1,2)$$

If $\alpha \geqslant 12$

$$F_1 = 1,0$$

If $\alpha < 12$

$$F_1 = 1 - (0,83\beta - 0,56\beta^2 - 0,02)\gamma^{0,23}e^{-0,21\gamma^{-1,16}\alpha^{2,5}}$$

**D.1.2.2 Load condition 2: axial load with general chord fixity**

**D.1.2.2.1 Chord (saddle and crown)**

$$K_{\text{t,ch,s,ax}} = T_5\ F_2$$

$$K_{\text{t,ch,cr,ax}} = T_6$$

**D.1.2.2.2 Brace (saddle and crown)**

$$K_{\text{t,b,s,ax}} = T_3\ F_2$$

$$K_{\text{t,b,cr,ax}} = T_7$$

**D.1.2.2.3 Source equations**

$$T_5 = \gamma\tau^{1,1}[1,11 - 3(\beta - 0,52)^2]\sin^{1,6}\theta + C_1(0,8\alpha - 6)\tau\beta^2(1 - \beta^2)^{0,5}\sin^2 2\theta$$

$$T_6 = \gamma^{0,2}\tau[2,65 + 5(\beta - 0,65)^2] + \tau\beta(C_2\alpha - 3)\sin\theta$$

$$T_7 = 3 + \gamma^{1,2}(0,12e^{-4\beta} + 0,011\beta^2 - 0,045) + \beta\tau(C_3\alpha - 1,2)$$

$$C_1 = 2(C - 0,5)$$

$$C_2 = \frac{C}{2}$$

$$C_3 = \frac{C}{5}$$

where the instances of $C$ are chord end fixity factors (see 9.1.3).



If $\alpha \geqslant 12$

$$F_2 = 1{,}0$$

If $\alpha < 12$

$$F_2 = 1 - (1{,}43\beta - 0{,}97\beta^2 - 0{,}03)\gamma^{0{,}04} e^{-0{,}71\gamma^{-1{,}38}\alpha^{2{,}5}}$$

#### D.1.2.3 Load condition 3: in-plane bending

##### D.1.2.3.1 Chord (saddle and crown)

$$K_{\text{t,ch,s,ipb}} = 0$$

$$K_{\text{t,ch,cr,ipb}} = T_8$$

##### D.1.2.3.2 Brace (saddle and crown)

$$K_{\text{t,b,s,ipb}} = 0$$

$$K_{\text{t,b,cr,ipb}} = T_9$$

##### D.1.2.3.3 Source equations

$$T_8 = 1{,}45\beta\tau^{0{,}85}\gamma^{(1-0{,}68\beta)} \sin^{0{,}7}\theta$$

$$T_9 = 1 + 0{,}65\beta\tau^{0{,}4}\gamma^{(1{,}09-0{,}77\beta)} \sin^{(0{,}06\gamma-1{,}16)}\theta$$

#### D.1.2.4 Load condition 4: out-of-plane bending

##### D.1.2.4.1 Chord (saddle and crown)

$$K_{\text{t,ch,s,opb}} = T_{10}\ F_3$$

$$K_{\text{t,ch,cr,opb}} = 0$$

##### D.1.2.4.2 Brace (saddle and crown)

$$K_{\text{t,b,s,opb}} = T_{11}\ F_3$$

$$K_{\text{t,b,cr,opb}} = 0$$

##### D.1.2.4.3 Source equations

$$T_{10} = \gamma\tau\beta(1{,}7 - 1{,}05\beta^3)\sin^{1{,}6}\theta$$

$$T_{11} = \gamma^{0{,}95}\tau^{0{,}46}\beta(1{,}7 - 1{,}05\beta^3)(0{,}99 - 0{,}47\beta + 0{,}08\beta^4)\sin^{1{,}6}\theta$$

If $\alpha \geqslant 12$

$$F_3 = 1{,}0$$

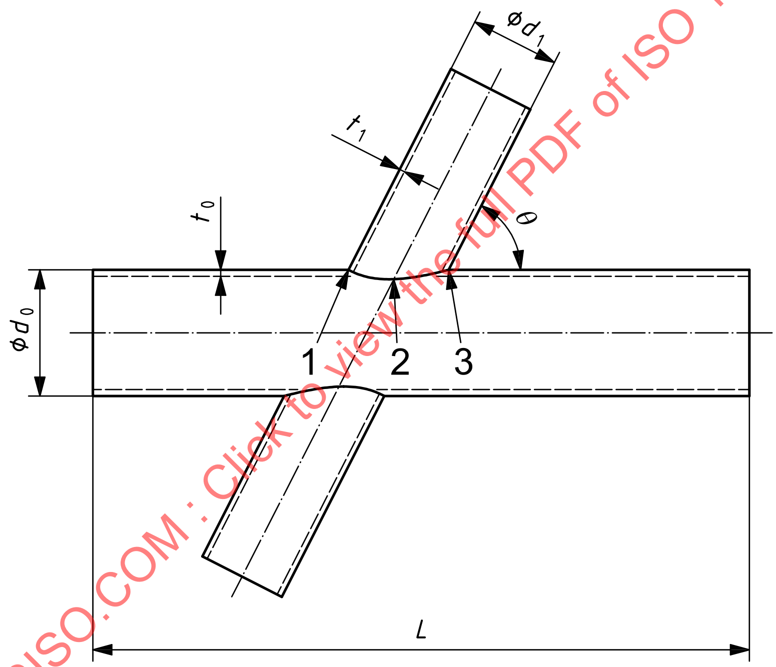
If $\alpha < 12$

$$F_3 = 1 - 0{,}55\beta^{1{,}8}\gamma^{0{,}16}e^{-0{,}49\gamma^{-0{,}89}\alpha^{1{,}8}}$$

## D.2 Uniplanar CHS X-joints

### D.2.1 General

See Figures D.3 and D.4.




**Key**

1 crown toe

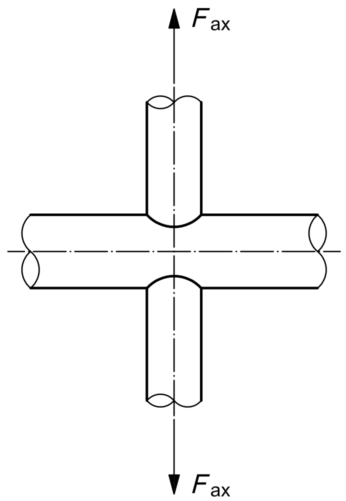
2 saddle

3 crown heel

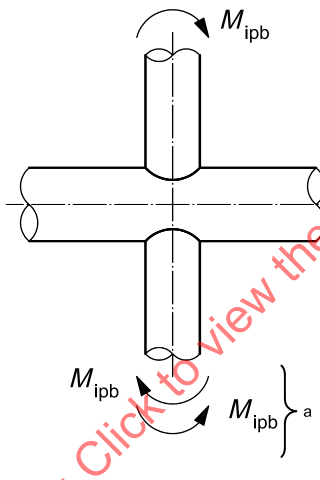
NOTE For variable definitions, see Clause 4.

$$\beta = \frac{d_1}{d_0} \quad \gamma = \frac{d_0}{2t_0} \quad \tau = \frac{t_1}{t_0} \quad \alpha = \frac{2L}{d_0}$$

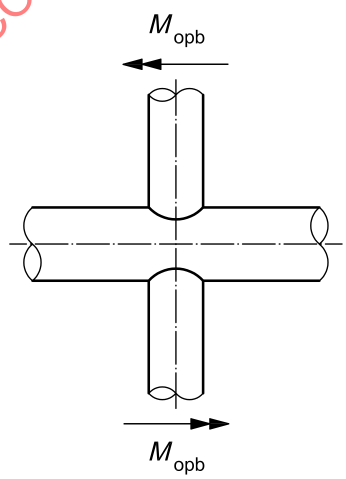
**Figure D.3 — Locations of interest**




a) **Load condition 1: balanced axial load with chord end pinned**




b) **Load condition 2: in-plane bending**




c) **Load condition 3: out-of-plane bending**

[a] Alternatives.

NOTE For variable definitions, see Clause 4.

**Figure D.4 — Load conditions**

### D.2.2 SCFs for uniplanar CHS X-joints

#### D.2.2.1 Load condition 1: balanced axial load with chord ends pinned

##### D.2.2.1.1 Chord (saddle and crown)

$$K_{\text{t,ch,s,ax}} = X_1 F_2$$

$$K_{\text{t,ch,cr,ax}} = X_2$$

##### D.2.2.1.2 Brace (saddle and crown)

$$K_{\text{t,b,s,ax}} = X_3 F_2$$

$$K_{\text{t,b,cr,ax}} = X_4$$

##### D.2.2.1.3 Source equations

$$X_1 = 3{,}87\gamma\tau\beta(1{,}10 - \beta^{1{,}8})\sin^{1{,}7}\theta$$

$$X_2 = \gamma^{0{,}2}\tau[2{,}65 + 5(\beta - 0{,}65)^2] - 3\tau\beta\sin\theta$$

$$X_3 = 1 + 1{,}9\gamma\tau^{0{,}5}\beta^{0{,}9}(1{,}09 - \beta^{1{,}7})\sin^{2{,}5}\theta$$

$$X_4 = 3 + \gamma^{1{,}2}(0{,}12e^{-4\beta} + 0{,}011\beta^2 - 0{,}045)$$

If $\alpha \geqslant 12$

$$F_2 = 1{,}0$$

If $\alpha < 12$

$$F_2 = 1 - (1{,}43\beta - 0{,}97\beta^2 - 0{,}03)\gamma^{0{,}04} e^{-0{,}71\gamma^{-1{,}38}\alpha^{2{,}5}}$$

#### D.2.2.2 Load condition 2: in-plane bending

SCFs are the same as those for uniplanar T-joints subjected to in-plane bending, as given in D.1.2.3.

#### D.2.2.3 Load condition 3: out-of-plane bending

##### D.2.2.3.1 Chord (saddle and crown)

$$K_{\text{t,ch,s,opb}} = X_5 F_3$$

$$K_{\text{t,ch,cr,opb}} = 0$$

##### D.2.2.3.2 Brace (saddle and crown)

$$K_{\text{t,b,s,opb}} = X_6 F_3$$

$$K_{\text{t,b,cr,opb}} = 0$$

#### D.2.2.3.3 Source equations

$$X_5 = \gamma\tau\beta(1{,}56 - 1{,}34\beta^4)\sin^{1{,}6}\theta$$

$$X_6 = \gamma^{0{,}95}\tau^{0{,}46}\beta(1{,}56 - 1{,}34\beta^4)(0{,}99 - 0{,}47\beta + 0{,}08\beta^4)\sin^{1{,}6}\theta$$

If $\alpha \geqslant 12$

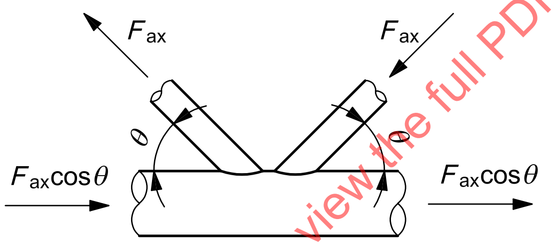
$$F_3 = 1{,}0$$

If $\alpha < 12$

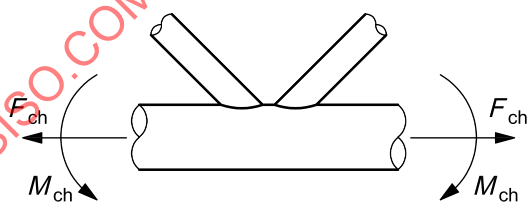
$$F_3 = 1 - 0{,}55\beta^{1{,}8}\gamma^{0{,}16}e^{-0{,}49\gamma^{-0{,}89}\alpha^{1{,}8}}$$

## D.3 Uniplanar CHS K-joints with gap

See Figures D.5 to D.8.



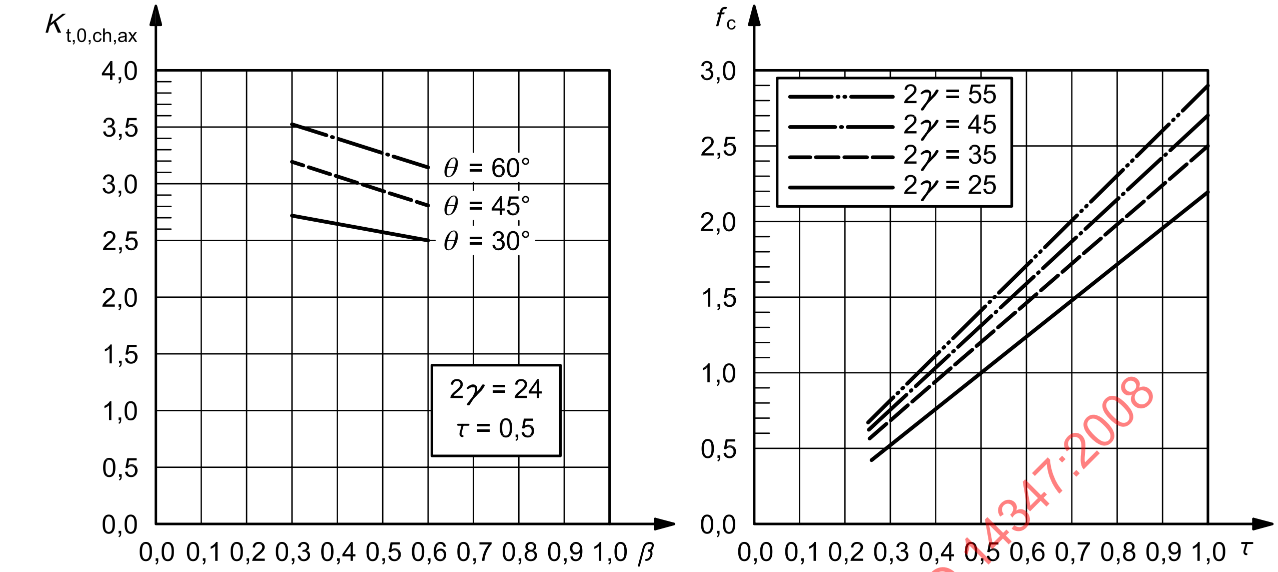

a) Load condition 1: basic balanced axial loading




b) Load condition 2: chord loading (axial and bending)

NOTE For variable definitions, see Clause 4.

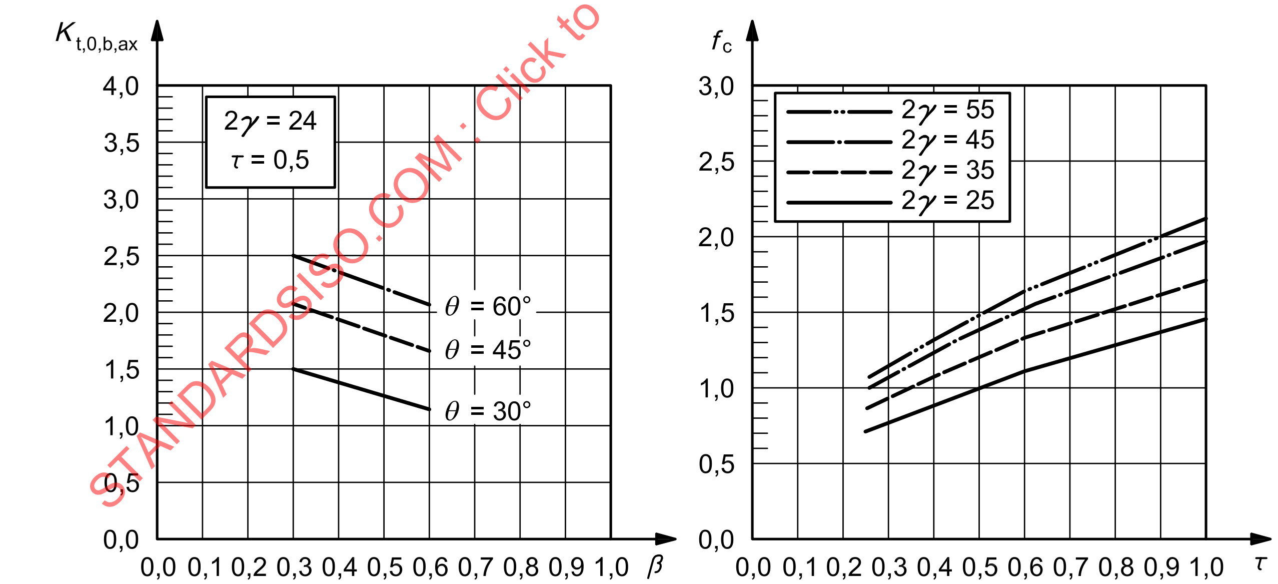
**Figure D.5 — Load conditions for uniplanar CHS K-joints**




**Key**

| | |
|---|---|
| $f_c$ | correction factor |
| $K_{t,0,ch,ax}$ | reference SCF for chord under basic balanced axial loading |
| $\beta$ | diameter or width ratio |
| $\gamma$ | chord slenderness |
| $\theta$ | acute angle between brace and chord axes |
| $\tau$ | wall thickness ratio |

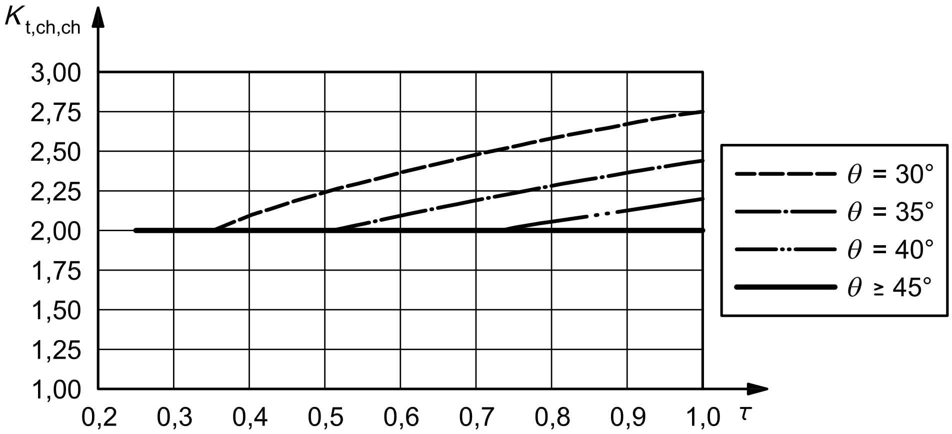
**Figure D.6 — Values of $K_{t,0,ch,ax}$ and corresponding correction factor, $f_c$, for the chord (load condition 1: basic balanced axial loading)**




**Key**

| | |
|---|---|
| $f_c$ | correction factor |
| $K_{t,0,b,ax}$ | reference SCF for brace under basic balanced axial loading |
| $\beta$ | diameter or width ratio |
| $\gamma$ | chord slenderness |
| $\theta$ | acute angle between brace and chord axes |
| $\tau$ | wall thickness ratio |

**Figure D.7 — Values of $K_{t,0,b,ax}$ and corresponding correction factor, $f_c$, for the brace (load condition 1: basic balanced axial loading)**




**Key**

$K_{t,ch,ch}$ SCF for chord under chord loading

$\theta$ acute angle between brace and chord axes

$\tau$ wall thickness ratio

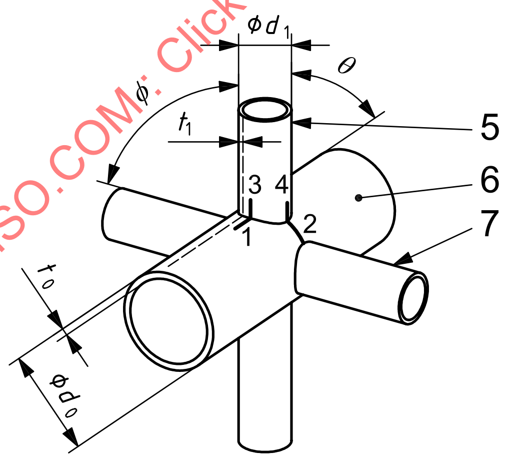
**Figure D.8 — Values of $K_{t,ch,ch}$ for the chord (load condition 2: chord loading)**



## D.4 Multiplanar CHS XX-joints

### D.4.1 General

See Figures D.9 and D.10.




**Key**

1,2,3,4 locations

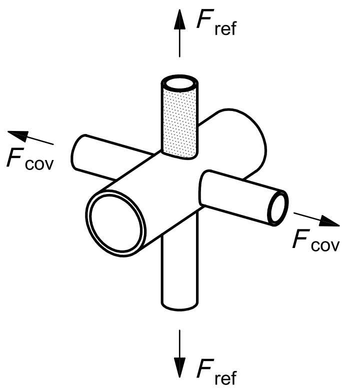
5 reference brace

6 chord

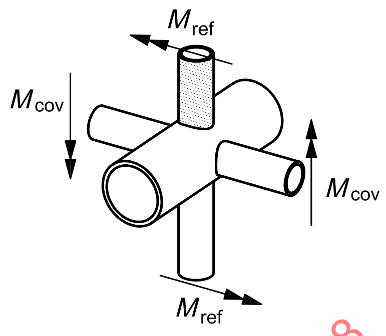
7 carry-over brace

NOTE For variable definitions, see Clause 4.

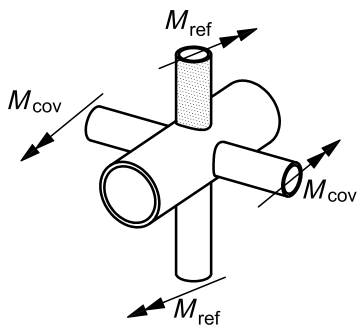
**Figure D.9 — Hot-spot locations**



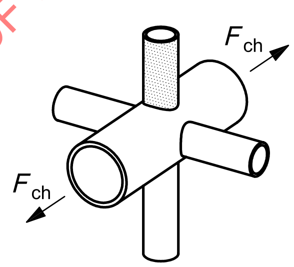

**a) Load condition 1: axial balanced brace loading**




**b) Load condition 2: balanced in-plane bending on braces**




**c) Load condition 3: balanced out-of-plane bending on braces**




**d) Load condition 4: axial balanced chord loading**

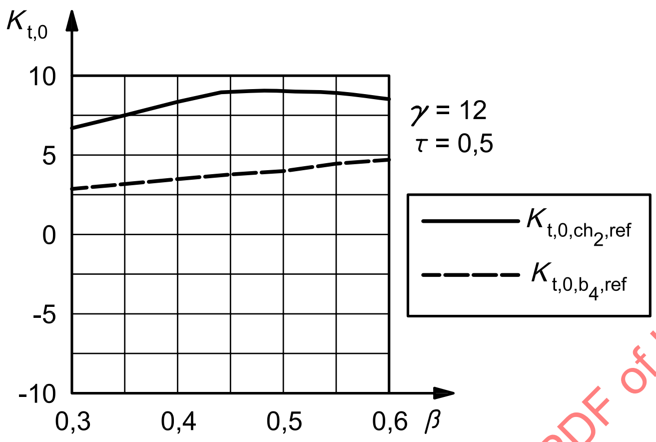
**Figure D.10 — Load conditions for multiplanar CHS XX-joints**

## D.4.2 SCFs for multiplanar CHS XX-joints

### D.4.2.1 Load condition 1: axial balanced brace loading

#### D.4.2.1.1 Axial load in reference braces, $F_{ref}$

See Figure D.11.




**Key**

$K_{t,0}$ reference SCF
$K_{t,0,ch_2,ref}$ reference SCF for chord at location 2
$K_{t,0,b_4,ref}$ reference SCF for brace at location 4
$\beta$ diameter or width ratio
$\gamma$ chord slenderness
$\tau$ wall thickness ratio

**Figure D.11 — Axial load in reference braces, $F_{ref}$**

##### D.4.2.1.1.1 Chord (locations 1 and 2)

$$K_{t,ch_1,ref,ax} = 5\left(\frac{\gamma}{12}\right)^{0,4}(1-\beta)$$

$$K_{t,ch_2,ref,ax} = \left(\frac{\gamma}{12}\right)^{1,1}\left(\frac{\tau}{0,5}\right)^{1,15} K_{t,0,ch_2,ref}$$

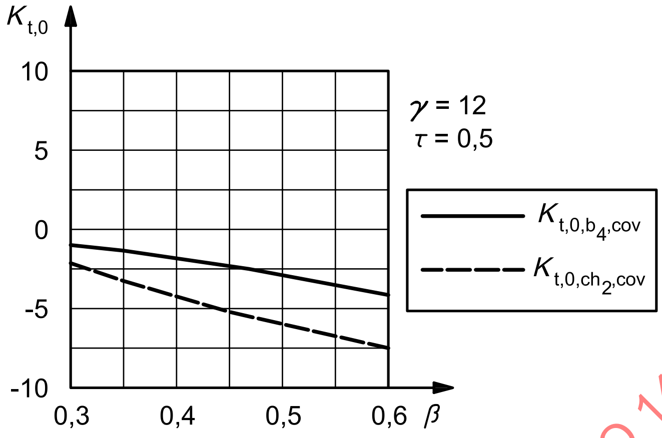
##### D.4.2.1.1.2 Brace (locations 3 and 4)

$$K_{t,b_3,ref,ax} = 2,0$$

$$K_{t,b_4,ref,ax} = \left(\frac{\gamma}{12}\right)^{0,5}\left(\frac{\tau}{0,5}\right)^{0,75} K_{t,0,b_4,ref}$$

#### D.4.2.1.2 Axial load in carry-over braces, $F_{cov}$

See Figure D.12.




**Key**

$K_{t,0}$ reference SCF
$K_{t,0,ch_2,cov}$ carry-over SCF for chord at location 2
$K_{t,0,b_4,cov}$ carry-over SCF for brace at location 4
$\beta$ diameter or width ratio
$\gamma$ chord slenderness
$\tau$ wall thickness ratio

**Figure D.12 — Axial load in carry-over braces, $F_{cov}$**



##### D.4.2.1.2.1 Chord (locations 1 and 2)

$$K_{t,ch_1,cov,ax} = 0$$

$$K_{t,ch_2,cov,ax} = \left(\frac{\gamma}{12}\right)^{1,1} \left(\frac{\tau}{0,5}\right)^{1,15} K_{t,0,ch_2,cov}$$

No minimum value for $K_{t,ch_2,cov,ax}$ is required.

##### D.4.2.1.2.2 Brace (locations 3 and 4)

$$K_{t,b_3,cov,ax} = 0$$

$$K_{t,b_4,cov,ax} = \left(\frac{\gamma}{12}\right)^{0,5} \left(\frac{\tau}{0,5}\right)^{0,75} K_{t,0,b_4,cov}$$

No minimum value for $K_{t,b_4,cov,ax}$ is required.

### D.4.2.2 Load condition 2: balanced in-plane bending in braces

#### D.4.2.2.1 In-plane bending in reference braces, $M_{ref}$

##### D.4.2.2.1.1 Chord (locations 1 and 2)

$$K_{t,ch_1,ref,ipb} = \left(\frac{\gamma}{12}\right)^{0,6} \left(\frac{\tau}{0,5}\right)^{0,8} K_{t,T}$$

where $K_{t,T}$ is the SCF for uniplanar CHS T-joints subjected to in-plane bending ($K_{t,ch,cr,ipb}$ as given in D.1.2.3).

$$K_{t,ch_2,ref,ipb} = 0$$

##### D.4.2.2.1.2 Brace (locations 3 and 4)

$$K_{t,b_3,ref,ipb} = 2,0$$

$$K_{t,b_4,ref,ipb} = 0$$

#### D.4.2.2.2 In-plane bending in carry-over braces, $M_{cov}$

##### D.4.2.2.2.1 Chord (locations 1 and 2)

$$K_{t,ch_1,cov,ipb} = K_{t,ch_2,cov,ipb} = 0$$

##### D.4.2.2.2.2 Brace (locations 3 and 4)

$$K_{t,b_3,cov,ipb} = K_{t,b_4,cov,ipb} = 0$$

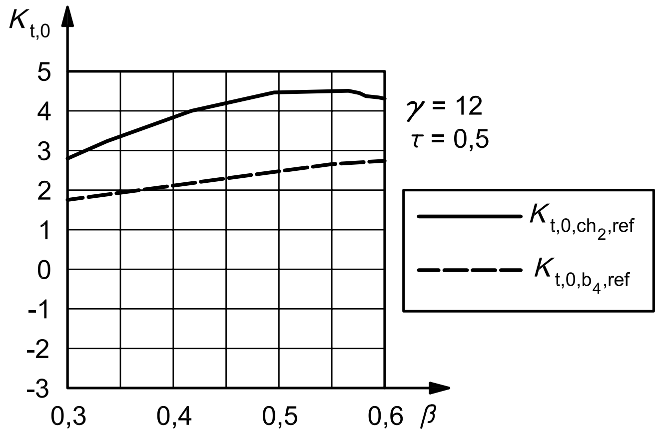
### D.4.2.3 Load condition 3: balanced out-of-plane bending of braces

#### D.4.2.3.1 Out-of-plane bending in reference braces, $M_{ref}$

See Figure D.13.






**Key**

$K_{t,0}$ reference SCF

$K_{t,0,ch_2,ref}$ reference SCF for chord at location 2

$K_{t,0,b_4,ref}$ reference SCF for brace at location 4

$\beta$ diameter or width ratio

$\gamma$ chord slenderness

$\tau$ wall thickness ratio

**Figure D.13 — Out-of-plane bending in reference braces, $M_{ref}$**

#### D.4.2.3.1.1 Chord (locations 1 and 2)

$$K_{t,ch_1,ref,opb} = 0$$

$$K_{t,ch_2,ref,opb} = \left(\frac{\gamma}{12}\right)^{1,25} \left(\frac{\tau}{0,5}\right)^{1,05} K_{t,0,ch_2,ref}$$

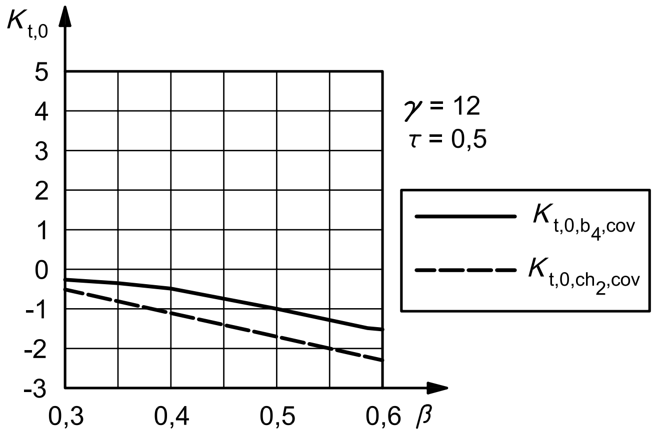
#### D.4.2.3.1.2 Brace (locations 3 and 4)

$$K_{t,b_3,ref,opb} = 2,0$$

$$K_{t,b_4,ref,opb} = \left(\frac{\gamma}{12}\right)^{0,5} \left(\frac{\tau}{0,5}\right)^{0,75} K_{t,0,b_4,ref}$$

#### D.4.2.3.2 Out-of-plane bending in carry-over braces, $M_{cov}$

See Figure D.14.




**Key**

$K_{t,0}$ reference SCF
$K_{t,0,b_4,cov}$ SCF for carry-over brace at location 4
$K_{t,0,ch_2,ref}$ SCF for carry-over chord at location 2
$\beta$ diameter or width ratio
$\gamma$ chord slenderness
$\tau$ wall thickness ratio

**Figure D.14 — Out-of-plane bending in carry-over braces, $M_{cov}$**



### D.4.2.3.2.1 Chord (locations 1 and 2)

$$K_{t,ch_1,cov,opb} = 0$$

$$K_{t,ch_2,cov,opb} = \left(\frac{\gamma}{12}\right)^{1,25}\left(\frac{\tau}{0,5}\right)^{1,05} K_{t,0,ch_2,cov}$$

No minimum value for $K_{t,ch_2,cov,opb}$ is required.

### D.4.2.3.2.2 Brace (locations 3 and 4)

$$K_{t,b_3,cov,opb} = 0$$

$$K_{t,b_4,cov,opb} = \left(\frac{\gamma}{12}\right)^{0,5}\left(\frac{\tau}{0,5}\right)^{0,75} K_{t,0,b_4,cov}$$

No minimum value for $K_{t,b_4,cov,opb}$ is required.

### D.4.2.4 Load condition 4: axial balanced chord loading

### D.4.2.4.1 Chord (locations 1 and 2)

$$K_{t,ch_1,c} = 2,0$$

$$K_{t,ch_2,c} = 0$$

### D.4.2.4.2 Brace (locations 3 and 4)

$$K_{t,b_3,c} = 0$$

$$K_{t,b_4,c} = 0$$

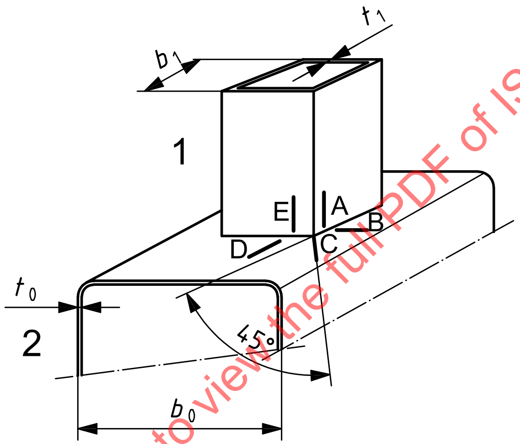
# Annex E
(normative)

# SCF equations and graphs for RHS joints

## E.1 Uniplanar RHS T and X-joints

### E.1.1 General

See Figures E.1 and E.2.

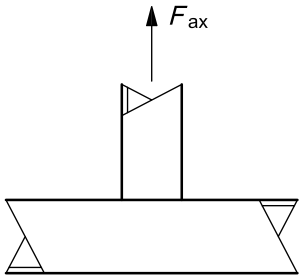



**Key**

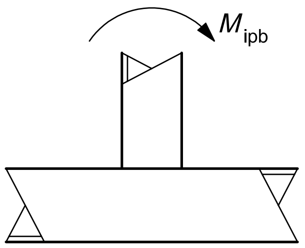
1 brace
2 chord
A,B,C,D,E hot spot lines

NOTE For variable definitions, see Clause 4.

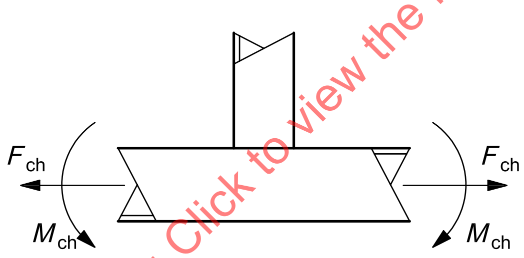
**Figure E.1 — Hot-spot locations**




a) Load condition 1: axial force on the brace




b) Load condition 2: in-plane bending on the brace




c) Load condition 3: chord loading (axial and bending)

NOTE For variable definitions, see Clause 4.

**Figure E.2 — Load conditions for uniplanar RHS T- and X-joints**



## E.1.2 SCFs for uniplanar RHS T- and X-joints

### E.1.2.1 Load condition 1: axial force on the brace

#### E.1.2.1.1 Chord (lines B, C, and D)

$$K_{\text{t,ch}_\text{B}\text{,ax}} = (0{,}143 - 0{,}204\beta + 0{,}064\beta^2)(2\gamma)^{(1{,}377+1{,}715\beta-1{,}103\beta^2)}\tau^{0{,}75}$$

$$K_{\text{t,ch}_\text{C}\text{,ax}} = \left[0{,}077 - 0{,}129\beta + 0{,}061\beta^2 - 0{,}0003(2\gamma)\right](2\gamma)^{(1{,}565+1{,}874\beta-1{,}028\beta^2)}\tau^{0{,}75}$$

$$K_{\text{t,ch}_\text{D}\text{,ax}} = (0{,}208 - 0{,}387\beta + 0{,}209\beta^2)(2\gamma)^{(0{,}925+2{,}389\beta-1{,}881\beta^2)}\tau^{0{,}75}$$

For X-joints with $\beta = 1{,}0$:

$K_{t,ch_C,ax}$ is multiplied by a factor of 0,65;

$K_{t,ch_D,ax}$ is multiplied by a factor of 0,50.

#### E.1.2.1.2 Brace (lines A and E)

$$K_{t,b_A,ax} = K_{t,b_E,ax} = (0{,}013 + 0{,}693\beta - 0{,}278\beta^2)(2\gamma)^{(0{,}790+1{,}898\beta-2{,}109\beta^2)}$$

for joints with fillet welds:

$K_{t,b_A,ax}$ is multiplied by a factor of 1,40;

$K_{t,b_E,ax}$ is multiplied by a factor of 1,40.

### E.1.2.2 Load condition 2: in-plane bending on the brace

#### E.1.2.2.1 Chord (lines B, C, and D)

$$K_{t,ch_B,ipb} = (-0{,}011 + 0{,}085\beta - 0{,}073\beta^2)(2\gamma)^{(1{,}722+1{,}151\beta-0{,}697\beta^2)}\tau^{0{,}75}$$

$$K_{t,ch_C,ipb} = \left[0{,}952 - 3{,}062\beta + 2{,}382\beta^2 + 0{,}0228(2\gamma)\right](2\gamma)^{(-0{,}690+5{,}817\beta-4{,}685\beta^2)}\tau^{0{,}75}$$

$$K_{t,ch_D,ipb} = (-0{,}054 + 0{,}332\beta - 0{,}258\beta^2)(2\gamma)^{(2{,}084-1{,}062\beta+0{,}527\beta^2)}\tau^{0{,}75}$$

#### E.1.2.2.2 Brace (lines A and E)

$$K_{t,b_A,ipb} = K_{t,b_E,ipb} = (0{,}390 - 1{,}054\beta + 1{,}115\beta^2)(2\gamma)^{(-0{,}154+4{,}555\beta-3{,}809\beta^2)}$$

for joints with fillet welds:

$K_{t,b_A,ipb}$ is multiplied by a factor of 1,40;

$K_{t,b_E,ipb}$ is multiplied by a factor of 1,40.

### E.1.2.3 Load condition 3: chord loading

#### E.1.2.3.1 Chord (lines B, C, and D)

$$K_{t,ch_B,c} = 0$$

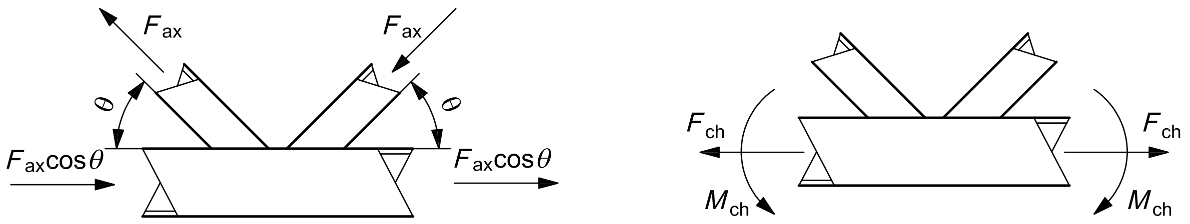
$$K_{t,ch_C,c} = 0{,}725(2\gamma)^{0{,}248\beta}\tau^{0{,}19}$$

$$K_{t,ch_D,c} = 1{,}373(2\gamma)^{0{,}205\beta}\tau^{0{,}24}$$

#### E.1.2.3.2 Brace (lines A and E)

$$K_{t,b_A,c} = K_{t,b_E,c} = 0$$

## E.2 Uniplanar RHS K-joints with gap

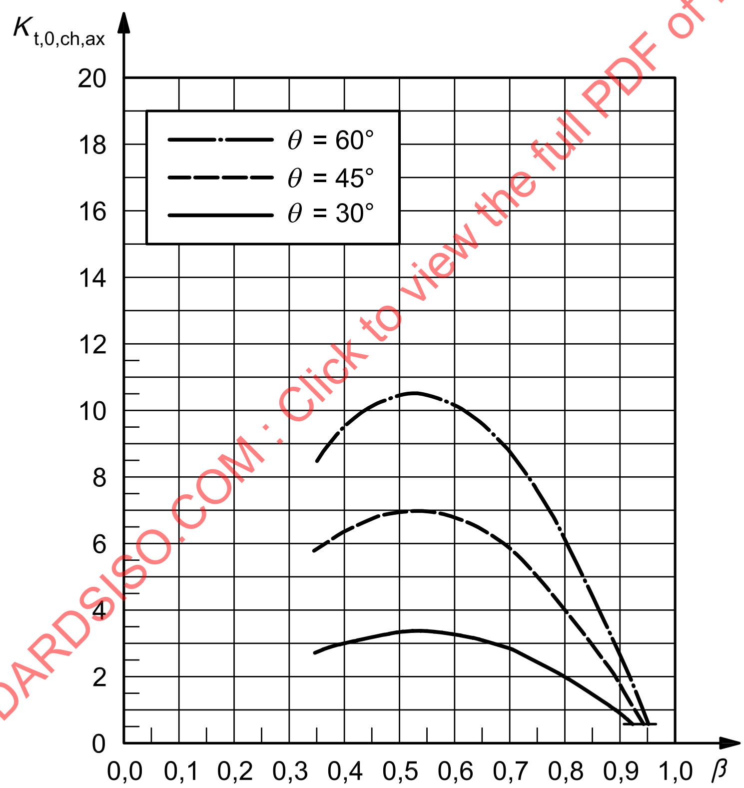



**a) Load condition 1: basic balanced axial loading**

**b) Load condition 2: chord loading (axial and bending)**

**Figure E.3 — Load conditions for uniplanar RHS K-joints with gap**





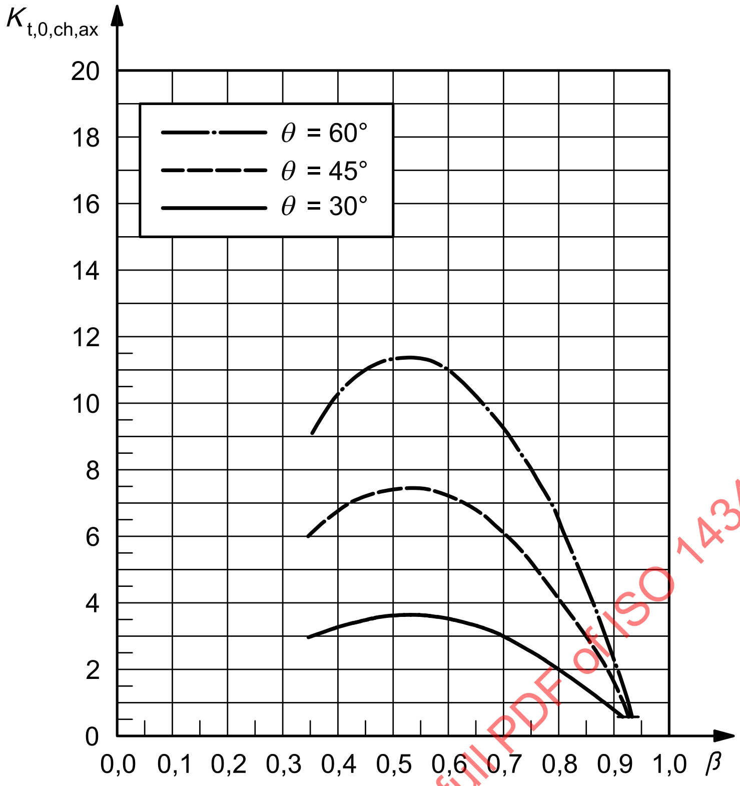

**Key**

$K_{t,0,ch,ax}$ reference SCF for chord under basic balanced axial loading

$\beta$ diameter or width ratio

$\theta$ acute angle between brace and chord axes

**Figure E.4 — The reference value, $K_{t,0,ch,ax}$, for the chord of RHS K-joints with gap ($g'$ = 1,0; load condition 1: basic balanced axial loading)**




**Key**

$K_{t,0,ch,ax}$ reference SCF for chord under basic balanced axial loading

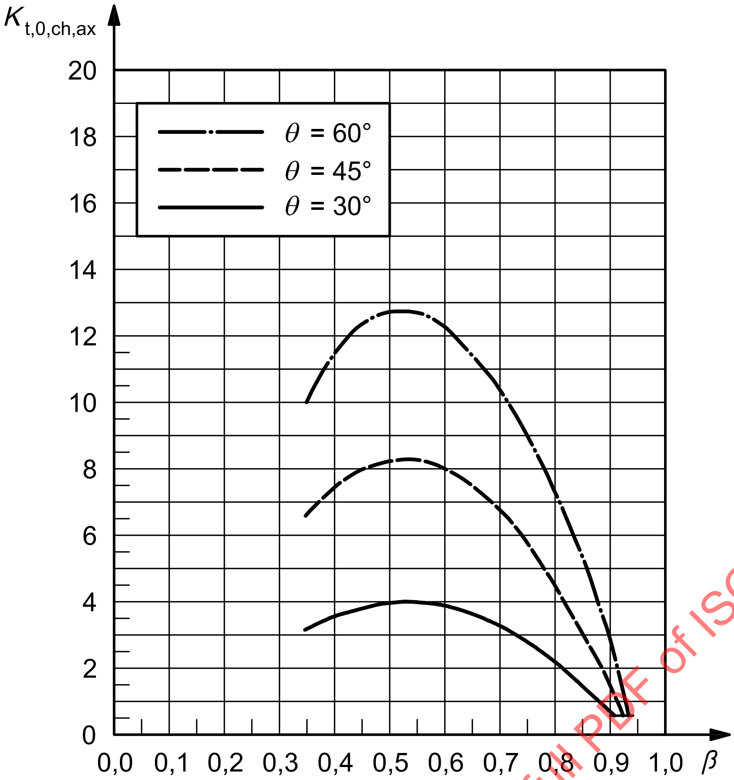
$\beta$ diameter or width ratio

$\theta$ acute angle between brace and chord axes

**Figure E.5 — The reference value, $K_{t,0,ch,ax}$, for the chord of RHS K-joints with gap ($g' = 2,0$; load condition 1: basic balanced axial loading)**





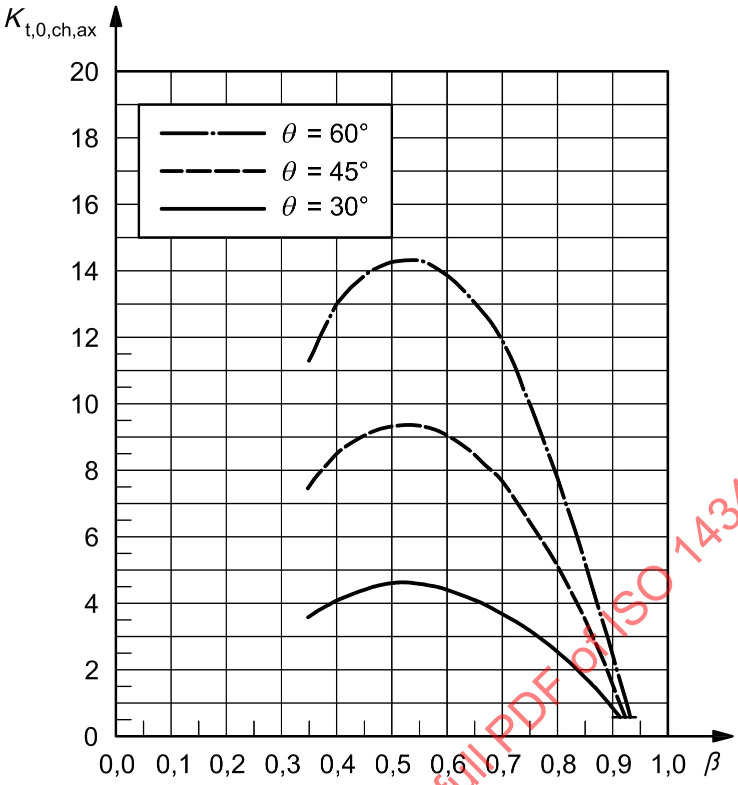

**Key**

$K_{t,0,ch,ax}$ reference SCF for chord under basic balanced axial loading

$\beta$ diameter or width ratio

$\theta$ acute angle between brace and chord axes

**Figure E.6 —The reference value, $K_{t,0,ch,ax}$, for the chord of RHS K-joints with gap ($g' = 4,0$; load condition 1: basic balanced axial loading)**




**Key**

$K_{t,0,ch,ax}$ reference SCF for chord under basic balanced axial loading

$\beta$ diameter or width ratio

$\theta$ acute angle between brace and chord axes

**Figure E.7 — The reference value, $K_{t,0,ch,ax}$, for the chord of RHS K-joints with gap ($g' = 8,0$; load condition 1: basic balanced axial loading)**