4 Symbols and abbreviated terms

For the purpose of this document the following the symbols and abbreviations generally apply. However, some sections may contain further symbols and abbreviations due to their special use.

A	constant in fatigue crack growth relationship
A	surface area
A	material constant (creep crack growth)
A_1	area of rectangle which demarcates flaw
A_2	full load bearing area containing flaw
A_c	crack area
B	section thickness in plane of flaw
B	specimen thickness
B'	effective section thickness ($2a + 2p$)
B'	material constant (cyclic crack growth)
B^*	normalised T-stress
B_{min}	minimum remaining thickness of a corroded spherical shell
B_n	net specimen thickness
B_0	original, measured, pipe or vessel wall thickness, or wall thickness as defined in the original design code
B_{ss}	sub-size Charpy specimen thickness
C	constant in creep crack propagation equation
C	material constant (cyclic crack growth)
C^*	parameter defining creep crack propagation rate
C^*	steady state crack tip parameter
$\overline{C}^*$	mean estimate of C^* during transient early cycles
C_1	constant in the stress corrosion crack growth relationship
C_D	discharge coefficient
$C(t)$	transient crack tip parameter
D	diameter

D'	constant in creep strain equation
D_{SM}	mean shell diameter
D_c	accumulated creep damage
D_c^{surf}	total surface creep damage
ΔD_c	increment of creep damage
E	Young's (elastic) modulus
E'	elastic modulus corrected for constraint conditions $E' = E$ for plane stress. $E' = E/(1 - \nu^2)$ for plane strain
E_{RT}	elastic modulus at room temperature (say 20 °C)
E_{ET}	elastic modulus at the elevated temperature
E_I	electrical energy per unit length of weld
E^I	E for plaine stress, and $E/(1-\nu^2)$ for plaine strain
F_{AR}	reduction factor to allow for loss of load-bearing area due to presence of a flaw in a tubular joint
F_a, F_K, F_Y	reserve factors on flaw size, toughness and yield strength
F^L	reserve factor on load, pressure etc
F^K	reserve factor on characteristic fracture toughness
F^R	reserve factor on yield strength
F^a	reserve factor on flaw size
F_e	generic term for yield limit load
F_{eH}	limit load defined at upper yield strength
F_e^M	yield limit load for mismatched weldments
F_e^B	yield limit load for base material
F_p	limit load defined by proof strength
G	constant in tubular joint stress intensity factor solutions
H	specimen half-length
H	crack-opening area (COA)
H'	constant in tubular joint stress intensity factor solutions
H_c	creep component of crack-opening area (COA)
H_e	elastic component of crack-opening area (COA)
J	a line or surface integral that encloses the crack front from one crack surface to the other, used to charaterize the local stress-strain field around the crack front

J_0 initial value of elastic-plastic crack tip parameter for combined loading

$J_{0.2BL}$ resistance to crack extension expressed in terms of *J* at 0.2 mm crack extension offset to the blunting line

J^s value of *J* for secondary stresses alone

J_c value of *J* at either:

unstable fracture; or onset of arrested brittle crack or pop-in.

This term only applies where Δa_0 < 0.2 mm offset to the blunting line

J_e value of *J* determined using an elastic analysis

J_m value of *J* at first attainment of maximum force plateau

J_{mat} material toughness measured by *J*-methods

$J_{mat}(\Delta a)$ characteristic toughness in units of J for ductile tearing analysis

J_u value of *J* at either:

a) unstable fracture; or

b) onset of arrested brittle crack or pop-in

This term only applies where Δa_0 > 0.2mm offset to the blunting line

ΔJ range of J-integral

K stress intensity factor

K_2 stress intensity factor following unload

$K_{BK,\sigma}$ variable amplitude fatigue strength factor

$K_{BK,\tau}$ variable amplitude fatigue strength factor

K_I applied tensile (mode I) stress intensity factor

K_{Ic} plane strain fracture toughness

K_{Ii} stress intensity factor

K_{Iid} stress intensity factor

K_{Ip} stress intensity factor due to pre-load

$K_I^{bending}$ contributions to K_I of through-wall bending stresses

K_I^p stress intensity factor due to primary stresses $\left[=(Y\sigma)_p\sqrt{(\Pi a)}\right]$

$K_I^{pressure}$ contributions to K_I of pressure-induced membrane stresses

K_I^s stress intensity factor due to secondary stresses $\left[=(Y\sigma)_s\sqrt{(\Pi a)}\right]$

$K_I^{(p+s)}$	stress intensity factor due to primary and secondary stresses
K_{ISCC}	critical stress intensity factor for stress corrosion cracking
K_{II}	mode II linear elastic stress intensity factor
K_{IIC}	critical value of K_{II} at onset of brittle fracture in mode II
K_{IIp}, K_{IIs}	values of K_{II} due to primary and secondary stresses, respectively
K_{III}	mode III linear elastic stress intensity factor
K_{IIIp}, K_{IIIs}	values of K_{III} due to primary and secondary stresses, respectively
K_d	technological size factor
K_{eff}	effective linear elastic stress intensity factor in mixed mode loading
K_f	stress intensity factor at failure
K_g	notional K value after flaw extension Δa_g
K_{mat}	material toughness measured by stress intensity factor
$K_{mat}(\Delta a)$	characteristic toughness in units of K for ductile tearing analysis
K^c_{mat}	creep toughness (TDFAD)
K^c_{mat}	Value of K_{mat} modified by constraint
$K^c_{mat}(\Delta a_j)$	Value of K_{mat} (Δa_j) modified by constraint
K_{max}	maximum stress intensity factor in cycle
K_{min}	minimum stress intensity factor in cycle
K_p^s	effective stress intensity factor used to define K_r^s
K_r	fracture ratio of applied elastic K value to K_{mat}
K_s	factor for the effect of cyclic strain hardening or softening
K_S	surface roughness factor
K^p	stress intensity factor due to primary load
K^s	stress intensity factor due to secondary loading
K_ε^s	effective stress intensity factor defined from elastic-plastic strain field
K_σ^s	effective stress intensity factor defined from elastic-plastic stress field
ΔK	stress intensity factor range
ΔK_I	cyclic range in K_I
ΔK_{eff}	effective stress intensity factor range

ΔK_o threshold stress intensity factor range below which fatigue crack growth (or corrosion fatigue crack growth) does not occur

L attachment length

L_r ratio of applied load to yield or proof load

L_r load ratio P / P_L

L_r^{max} cut-off on TDFAD

L_r^{max} maximum permitted value of L_r

$L_r(L)$ value of L_r when structure is loaded to its limiting load.

M mismatch ratio across weldment given by R_e^W/R_e^B

M bulging correction factor

M_{ai}, M_{ao} applied in and out of plane moments for tubular joints

M_{ci}, M_{co} fully plastic moments for cracked tubular joints calculated for in and out of plane loads

M_m, M_b, M_{km}, M_{kb} stress intensity magnification factors

M_m*, M_b* factors used in calculating M_m and M_b

M_s, M_T stress magnification factor

M_σ mean stress sensitivity

N strain hardening exponent

N fatigue life

N_c number of corrosion flaws in a colony of interacting flaws

ΔN increment in N

P primary stress

P load

P_L limit load

P_a applied axial load on tubular joint

P_b primary bending stress

$P_{b,l}$ primary bending stress due to locally applied bending loads

P_c collapse load for cracked tubular joint

P_e yield limit pressure

P_f fluid pressure

P_f failure pressure of a corroded pipe or vessel

P_f probability of K_{mat} being less than estimated

P_m primary membrane stress

$P_{m,a}$ primary membrane stress due to global axial loads

$P_{m,b}$ primary membrane stress due to global bending moments

$P_{m,p}$ primary membrane stress due to pressure loading

P_{nm} failure pressure of combined adjacent corrosion flaws n to m, formed from a colony of interacting flaws

P_0 failure pressure of plain unflawed pipe or pressure vessel

P_{sw} safe working pressure of the corroded pipe or pressure vessel

$P_{1,2,\ldots,N}$ failure pressures of individual corrosion flaws forming a colony of interacting flaws

Q Normalised hydrostatic stress used as a constraint parameter

Q secondary stress

Q material constant (cyclic crack growth)

Q^p, Q^s Value of Q for σ^p, σ^s stresses, respectively

Q_b secondary bending stress

Q_c length correction factor for corrosion flaws

Q_i length correction factor of an individual flaw forming part of a colony of interacting corrosion flaws

Q_m secondary membrane stress

Q_{mf} mass flow through an equivalent rectangular crack

Q_{nm} length correction factor for a flaw combined from adjacent flaws n to m in a colony of interacting corrosion flaws

Q_β factor to allow for increased strength observed in tubular joints at $\beta > 0.6$

R stress ratio [ratio of minimum (σ_{min}) to maximum (σ_{max}) algebraic value of the absolute stress level ($k_{tm}.P_m + k_{tb}.P_b + Q$)]

R stress intensity factor ratio $(= K_{min} / K_{max})$

R' length in estimate of C^*

R' parameter used in creep crack propagation equation

R_F flow stress

R_F^M mismatch flow stress of weldment

R_K stress intensity factor ratio (2CD)

R_N Notch radius

R_P proof strength

R_Z average roughness of the surface

R_a surface roughness of crack

R_e general term for yield or proof strength

R_{el} lower yield strength

R_i, R_o Internal and external radii, respectively

R_m ultimate tensile strength

R_p cyclic plastic zone size

R_s reserve strength factor = $\frac{P_f}{P_o}$

R_{eH} upper yield strength or limit of proportionality

R_e^W yield or proof strength of weld metal

R_e^B yield or proof strength of base metal

R_m ultimate tensile strength

R_σ stress ratio (2CD)

S stress range or, for variable amplitude loading, the equivalent constant amplitude stress range

S_{nom} nominal membrane stress for Level 1 analysis

S_r ratio of applied load to flow strength load

S_y minimum 0.2% proof stress

T Elastic stress parallel to the crack, used as a constraint parameter

T temperature

T^p, T^s Value of T for σ^p, σ^s stresses, respectively

T_c creep exclusion temperature

T_k temperature term describing the scatter in Charpy versus fracture toughness correlation

T_0 temperature for a median toughness of 100 MPa□m in 25 mm thick speciments

T_{ref} reference temperature

T_1 temperature at pre-load

T_2 temperature at re-load

$T_{27\,J}$	temperature for energies of 27 J measured in a standard 10 mm × 10 mm Charpy V specimen
$T_{40\,J}$	temperature for energies of 40 J measured in a standard 10 mm × 10 mm Charpy V specimen
U_T	total area under load-displacement curve
U_c	creep area under load-displacement curve
U_e	elastic area under load-displacement curve
U_p	Plastic area under load vs load-point displacement record
V	volume
V	parameter treating interactions between primary and secondary stress
W	width (in a- dimension) of fracture toughness specimen
W	plate width in plane of flaw
W_c	crack opening width
X	factor relating δ_I and K_I to account for constraint and work hardening capability variation
X_i	Polinomial coefficients (I=0-6)
X_{nm}	corrosion flaws interaction parameters
Y	stress intensity factor correction
Y_m, Y_b	stress intensity correction factors for membrane and bending stress
Y_{wm}, Y_{wb}	stress intensity correction factors for the weld location for membrane and bending stress
$(Y_\sigma)^p$	primary stress intensity factor correction function
$(Y_\sigma)^s$	secondary stress intensity factor correction function
Z	circumferential angular spacing between projection lines in the analysis of corrosion flaws
Z	elastic follow-up factor
a	half flaw length for through-thickness flaw, flaw height for surface flaw or half height for embedded flaw
a	crack size
a_0	initial crack size
$a_{BK,\sigma}$	degree of utilization
$a_{BK,\tau}$	degree of utilization
a_G	constant
a_M	constant
$a_{R,\sigma}$	constant

a_d	constant
a_f	final flaw size
a_{eff}	effective crack size based on elastic analysis
$a_{eff\sigma}$	effective crack size based on elastic-plastic stress field
$a_{eff\sigma}$	effective crack size based on elastic-plastic strain field
a_g	crack size after growth
a_i	initial flaw size
a_{min}	crack size below which the crack growth rate is assumed to be constant
Δa_i	crack growth corresponding to initiation
$\dot{a}$	crack growth rate
$\dot{a}_c$	rate of crack propagation in height direction due to creep
$\bar{a}$	effective flaw parameter for Level 1 fracture assessment
$\bar{a}_i$	initial value of effective flaw parameter for fatigue analysis
$\bar{a}_{max}$	maximum value of effective flaw parameter for fatigue analysis
$\bar{a}_m$	tolerable flaw parameter for Level 1 fracture assessment
Δa	increment in *a*
Δa_g	limit of tearing flaw extension
Δa_j	intermediate value of tearing flaw extension
Δa_o	notional extension of flaw defining tearing initiation
b	exponent of time in creep strain equations
b_M	constant
b_G	constant
b_0	(W-a_0) in fracture toughness specimen
c	half flaw length for surface or embedded flaws
$2c_b$	surface length of crack at breakthrough
$\dot{c}_c$	crack growth rate in length direction due to creep
Δc	increment in *c*
d	deviation from true circle due to angular misalignment

d_c	depth of corroded region
d_c^{surf}	surface creep damage accumulated in a cycle
d_{eff}	effective diameter
d_i	depth of an individual corrosion flaw
d_m	effective combined depth of interacting corrosion flaws
d_n	effective combined depth of interacting corrosion flaws
d_{nm}	effective depth of combined flaws from n to m
$d_{1,2,etc}$	depth of 1st, 2nd, etc. corrosion flaws
e	axial misalignment (eccentricity or centre line mismatch)
f	frequency of fatigue loading cycle
$f_{W,\sigma}$	fatigue strength factor
$f_{W,\tau}$	fatigue strength factor
f_c	total factor of safety in analysis of corrosion flaw = $f_{c1}.f_{c2}$
f_{c1}	modelling factor in analysis of corrosion flaw
f_{c2}	original design factor in analysis of corrosion flaw
f_f	friction factor for flow through crack
f_{fmax}	effective maximum friction factor for flow through crack
f_{scc}	factor of safety with respect to stress corrosion cracking (f_{scc} >1.0)
f_ϕ, f_w, g	correction terms in stress intensity factor for elliptical flaws
$f(L_r)$	function of L_r defining FAD or CDF
g_{ij}	Normalised elastic stress field ahead of a crack
h	weld leg length
k	factor for the weld zones
k_m	stress magnification factor due to misalignment
k_t	stress concentration factor
k_{tb}	bending stress concentration factor
$k_{t.HS}$	hot spot stress concentration factor in tubular joint
$k_{t.IPB}$, $k_{t.OPB}$	in and out of plane stress concentration factors in tubular joints
k_{tm}	membrane stress concentration factor
l	flaw length (sometimes defined as 2c)

l	distance from axially misaligned joint to load or extremities of region of angular misalignment (shortest distance = l_1)
l	material constant (cyclic crack growth)
l'	generalized crack length (length of surface, buried or through thickness crack) or equivalent length of through thickness crack after recharacterization
l'_L	length of crack which leaks at the minimum detectable rate
$l'_L{}^*$	enhanced length of crack which leaks at the minimum detectable rate
l_c	length of corroded region measured parallel to the axis of a cylindrical vessel or pipe
l'_c	limiting generalized crack length
l_i	length of an individual corrosion flaw forming part of a colony of interacting flaws
l_m	effective combined length of interacting corrosion flaws
l_n	effective combined length of interacting corrosion flaws
l_{nm}	effective longitudinal length of a flaw combined from adjacent flaws n to m in a colony of interacting flaws
l'_r	length of crack at rupture
l_{total}	total longitudinal length of a colony of interacting flaws and the spacing between them
l_w	length of weld
m	parameter defining influence of constraint on fracture toughness
m	exponent in flaw growth law
m'	Beremin modal parameter
m_q	exponent in the calculation of F_{AR}
n	exponent of stress in creep strain equation
n	creep stress exponent
n,m	refer to the n^{th} and m^{th} flaw in a series of corrosion flaws 1…N_c;
$n(scc)$	exponent in the stress corrosion crack growth relationship
n_j	number of cycles in stress spectrum at stress range $\Delta\sigma_j$
n_σ	support factor
n_τ	support factor
p	shortest distance from material surface to embedded flaw
p'	internal pressure

$p(F)$	probability of failure
q	exponent in creep crack propagation equation
q_o	fraction of total load range for which crack is judged to be open
r	distance from crack tip
r	mean shell radius or radius of round bar or bolt
r_{O}	external shell radius
r_{h}	radius of hole
r_{i}	internal shell radius
r_{m}	mean shell radius
r_p	size of the cyclic plastic zone
$r^p{}_{crack}$	cyclic plastic zone size at the crack tip
s	distance between embedded flaws or longitudinal spacing between adjacent corrosion flaws
s_i	longitudinal spacing between adjacent flaws forming part of a colony of interacting corrosion flaws
s_m	distance between interacting corrosions flaws
s_n	distance between interacting corrosions flaws
t	specimen thickness
t	thickness of structural section
t	time (days, weeks, months or years as appropriate)
t_0	service life to date
t_R	creep rupture life
$t_{R(ref)}$	time to creep rupture at reference stress
t_a	time accumulated from initial start-up of plant
t_{cd}	time to failure of plant by bulk creep rupture, measured from initial start-up
t_{cyc}	time to reach steady cyclic state
t_d	required life of plant, measured from initial start-up
t_{ff}	time to failure by unstable fracture, measured from initial start-up
t_g	time required for the crack to propagate by an amount Δa_g
t_h	hold time at high temperature
t_{i}	crack incubation time, prior to commencement of creep crack growth

t_i	initiation time
t_{ix}	incubation period corresponding to crack growth x
t_m	maximum allowable time at temperature
t_r	rupture time
t_{red}	redistribution time
t_s	desired future service life
t_w	weld throat thickness
$t(2c_\mathrm{b})$	time to breakthrough of a part wall flaw
$t(T)$	time to achieve specific creep strain at proof stress at temperature T
$t(l'_\mathrm{c})$	time to grow crack to limiting length
$t_\mathrm{r}(\sigma)$	time to rupture at the appropriate temperature and at a stress, σ
Δt	time span
Δt_d	time to detect a leak
w	specimen width
x	a/W
y	1-a/W
y	height of peaking due to angular misalignment
z	measure of position through the thickness
z_0	through thickness depth of tensile residual stress zone
z_r	through thickness depth of repair
Δ_T	total displacement
Δ_c	creep displacement
Δ_e	elastic displacement
Δ_p	plastic displacement
Σ	ratio of flow strengths at re-load and pre-load conditions
Φ	complete elliptic integral of the second kind
ϕ_s	factor used in the collapse analysis of spheres
ϕ	circumferential angular spacing between adjacent corrosion flaws
Ω	degree of bending in tubular joints

Ω_{Tot}, Ω_{Ax}, Ω_{IPB}, Ω_{OPB} total, axial, in plane and out of plane degrees of bending in tubular joints

α parameter defining influence of constraint on fracture toughness

α angular change at misaligned joint

α coefficient of thermal expansion

α'' function of *a*, *c*, *B* and *W* used in calculation of collapse stresses

$\alpha(\lambda')$ bulging factor

β normalised constraint parameter

β ratio of brace diameter to chord diameter in a tubular joint

β,γ material constants (creep crack initiation)

β_Q normalized constraint parameter on Q

β_T normalized constraint parameter on T

β' plasticity correction factor, $\beta'=1$for plane stress, $\beta'=1$ for plane strain

β'' factor determining state of stress

β_{sx} factor used in collapse analysis of cylinders

β_{sy} factor used in collapse analysis of cylinders

β_r reliability

γ ratio of chord radius to chord wall thickness in a tubular joint

γ' estimate of K_r^s for through-wall self-balancing stress

γ_σ, γ_a, γ_K, γ_δ, γ_Y partial coefficients on stress, flaw size, fracture toughness in terms of K, fracture toughness in terms of CTOD and yield strength, for safety factor treatment

γ_c safety factor for use with creep data

δ crack tip opening displacement (CTOD)

$\delta_{0.2BL}$ resistance to crack extension expressed in terms of CTOD at 0.2mm crack extension offset to the blunting line

δ_I applied CTOD

δ_c CTOD at either:

a) unstable fracture; or

b) onset of arrested brittle crack or pop-in.

This term only applies where Δa_0 < 0.2mm offset to the blunting line

δ_e elastically calculated value of CTOD

δ_g CTOD at limit of permitted tearing

δ_i critical crack tip opening displacement (creep crack initiation)

δ_{ij} Kronecker's delta

δ_{ix} crack opening displacement corresponding to initiation of creep crack growth of extent x

δ_m CTOD at first attainment of maximum force plateau

δ_{mat} material toughness measured by CTOD method

$\delta_{mat}(\Delta a)$ characteristic toughness in units of δ for ductile tearing analysis

δ_r fracture ratio using CTOD parameters

δ_u CTOD at either:

a) unstable fracture; or

b) onset of arrested brittle crack or pop-in.

This term only applies where Δa_0 > 0.2mm offset to the blunting line

ε strain

ε_{Y} yield strain, i.e. strain at σ_Y

ε_{c} accumulated creep strain

$\dot{\bar{\varepsilon}}_c$ equivalent creep strain rate

$\dot{\varepsilon}_c$ creep strain rate

$\dot{\varepsilon}_{c,ref}$ creep strain rate at stress σ_{ref}

$\dot{\varepsilon}^p_{c,ref}$ creep strain rate at stress σ^p_{ref}

ε_e elastic strain at the reference stress (σ_{ref}/E)

ε_f strain to failure of material, as measured in uniaxial creep test

$\bar{\varepsilon}_f$ creep ductility

ε_{ij} elastic-plastic mechanical strains; *ij* = *x*, *y*, *z*

$\varepsilon_{\max}$ maximum tensile strain

ε_p plastic strain

$\varepsilon_{\mathrm{ref}}$ reference strain

ε_{ref}^{e}	elastic strain at stress σ_{ref}
ε_{ref}^{e+p}	elastic plus plastic strain at stress σ_{ref}
$\varepsilon_{ref}^{e+p+c}$	elastic plus plastic plus creep strain at stress σ_{ref}
ε_{ref}^{0}	elastic plus plastic strain at stress σ_{ref}^{0}
$\dot{\varepsilon}_{0}$	creep strain rate at stress σ_{0}
$\Delta\varepsilon$	lower yield or Luder's strain
$\Delta\varepsilon_{c}$	increment of creep strain
$\Delta\overline{\varepsilon}_{t}$	total surface strain range (cyclic crack growth)
ζ	dimensionless geometrical parameter used in collapse analysis of flawed cylinders
η	homogeneous experimental calibration factor
η_{p}	factor used to define J from U_{p}
θ	parametric angle to identify position along an elliptic flaw front
θ	polar co-ordinate at crack tip
κ	constant depending on boundary conditions
λ	$(1+E\Delta\varepsilon / R_{eH})$
λ, λ_{1}, λ_{2}, etc.	constants used in calculating stress intensity factors
λ_{r}	ratio to give the structural cut-off
λ_{s}	factor used in collapse analysis of cylinders
λ''	scaling factor on stress intensity factor, used to define γ'
μ	constant in calculating the failure pressure of a corroded sphere
μ	stress exponent in power law plasticity
ν	Poisson's ratio
ξ	constant in calculating the failure pressure of a corroded sphere
ρ	allowance for plasticity interaction effects from combination of primary and secondary loadings
ρ	plasticity correction factor
ρ_{1}	ạ parameter used in determining ρ
ρ_{I}	parameter replacing ρ in Procedure I

ρ_f fluid density

σ general term for stress

$\overline{\sigma}$ short-term flow stress

σ^{ij} stress field

σ_0 initial stress

$\sigma_{0.2}$ 0.2 % proof strength

$\sigma^c{}_{0.2}$ 0.2% creep strength

$\sigma^c{}_{1.0}$ 1.0% creep strength

σ_R residual stress

σ_R creep rupture strength

$\sigma_R{}^L$ longitudinal residual stress

$\sigma_R{}^{L,B}$ longitudinal residual stress at bore

$\sigma_R{}^T$ transverse residual stress

$\sigma_R{}^{T,B}$ transverse residual stress at the bore

$\sigma_R{}^{T,O}$ transverse residual stress on the outer surface

σ_Y lower yield strength or 0.2 % proof strength

σ'_Y yield strength of the material in the vicinity of the flaw

σ_{Y1} yield strength at pre-load conditions

σ_{Y2} yield strength at re-load conditions

σ_a applied stress

σ_b linearized bending stress

σ_{bc} hot spot bending stress for a cracked tubular joint

σ_d stress at a small distance ahead of the crack tip

σ_f flow strength

σ_f' flow strength of the material in the vicinity of the flaw

σ_m linearized membrane stress

σ_{max} maximum tensile stress for Level 1 analyses

σ_{max} peak equivalent welding residual stress

$\sigma_{n,b}$	bending component of collapse stress
$\sigma_{n,m}$	membrane component of collapse stress
$\sigma_{n\,pl}$	nominal stress
σ^p	stress arising from loads which contribute to plastic collapse
σ^P	primary stress
σ^r_{max}	surface value of self-balancing residual stress for through-wall crack
σ_r	reference value of stress at value of strain, ε, on stress strain curve
σ_{ref}	reference stress used for creep and plastic collapse considerations
$\dot{\sigma}_{ref}$	reference stress rate
σ^0_{ref}	initial value of the total reference stress
$\sigma^{cyc=1}_{ref}$	reference stress for first cycle
σ^p_{ref}	reference stress for primary loading
$\sigma_{ref,b}$	reference stress for pure bending
$\sigma^p_{ref,hom}$	homogeneous cracked body reference stress
$\sigma_{ref,m}$	reference stress for pure membrane loading
σ^s	stress arising from loads which do not contribute to plastic collapse
σ^S	secondary stress
σ_s	bending stress due to misalignment
σ^{sss}_{ij}	small-scale yielding stress field for T=0
σ_u	ultimate tensile strength
σ_y	yield stress
σ_{yy}	stress distribution normal to crack plane
$\tilde{\sigma}_{yy}$	pseudo-stress distribution normal to crack plane
σ_w	applied stress on weld throat
σ_w	fatigue limit of the material
$\Delta\sigma$	applied stress range
$\Delta\sigma_{Ax}$	axial stress range in tubular joint

$\Delta\sigma_{IPB}$, $\Delta\sigma_{OPB}$ in and out of plane bending stress ranges in tubular joint

$\Delta\sigma_{Hs.Ax}$ axial, in and out of plane hot spot stress ranges in tubular joint

$\Delta\sigma_{Hs.IPB}$,?

$\Delta\sigma_{Hs.OPB}$

$\Delta\sigma_{Hs.Tot}$ total hot spot stress range in tubular joint

$\Delta\sigma_{b}$ bending component of stress range

$\Delta\sigma_{m}$ membrane component of stress range

$\Delta\sigma_{nom}$ nominal stress range in tubular joint

$\Delta\sigma_{n.Ax}$, nominal axial, in and out of plane stress ranges in tubular joint

$\Delta\sigma_{n.IPB}$,

$\Delta\sigma_{n.OPB}$

$\Delta\sigma'_{b}$ bending stress range excluding the effects of misalignment

$\Delta\sigma_{j}$ stress range in variable amplitude fatigue spectrum which is applied n_j times

τ ratio of brace wall thickness to chord wall thickness in tubular joints

τ' factor used in collapse analysis of cylinders

τ_w fatigue limit of the material

φ parameter used in defining ρ

χ factor used in collapse analysis of bolts

χ normalised stress gradient

ψ parameter used in defining ρ

$\frac{da}{dN}$ flaw growth rate with cycles

$\left(\frac{da}{dN}\right)_f$ rate of crack propagation per cycle in height direction due to fatigue

$\left(\frac{da}{dN}\right)_c$ rate of crack propagation per cycle in height direction due to creep

$\frac{da}{dt}$ flaw growth rate with time