

# DIN EN 1999-1-3:2011-11 (E)

## Eurocode 9: Design of aluminium structures - Part 1-3: Structures susceptible to fatigue (includes Amendment A1:2011)

---

### Contents

	Page
1 General .....	10
1.1 Scope .....	10
1.1.1 Scope of EN 1999 .....	10
1.2 Normative references .....	11
1.3 Assumptions .....	11
1.4 Distinction between principles and application rules .....	12
1.5 Terms and definitions .....	12
1.5.1 General .....	12
1.6 Symbols .....	15
1.7 Specification for execution .....	17
1.7.1 Execution specification .....	17
1.7.2 Operation manual .....	17
1.7.3 Inspection and maintenance manual .....	18
2 Basis of design .....	18
2.1 General .....	18
2.1.1 Basic requirements .....	18
2.2 Procedures for fatigue design .....	19
2.2.1 Safe life design (SLD) .....	19
2.2.2 Damage tolerant design (DTD) .....	20
2.2.3 Design assisted by testing .....	20
2.3 Fatigue loading .....	20
2.3.1 Sources of fatigue loading .....	20
2.3.2 Derivation of fatigue loading .....	20
2.3.3 Equivalent fatigue loading .....	21
2.4 Partial factors for fatigue loads .....	21
2.5 Execution requirements .....	22
3 Materials, constituent products and connecting devices .....	22
4 Durability .....	23
5 Structural analysis .....	24
5.1 Global analysis .....	24
5.1.1 General .....	24
5.1.2 Use of beam elements .....	25
5.1.3 Use of membrane, shell and solid elements .....	25
5.2 Types of stresses .....	26
5.2.1 General .....	26
5.2.2 Nominal stresses .....	26
5.2.3 Modified nominal stresses .....	26
5.2.4 Hot spot stresses .....	27
5.3 Derivation of stresses .....	29
5.3.1 Derivation of nominal stresses .....	29
5.3.2 Derivation of modified nominal stresses .....	29
5.3.3 Derivation of hot spot stresses .....	30
5.3.4 Stress orientation .....	30
5.4 Stress ranges for specific initiation sites .....	30
5.4.1 Parent material, welds, and mechanically fastened joints .....	30
5.4.2 Fillet and partial penetration butt welds .....	30
5.5 Adhesive bonds .....	31

5.6	Castings .....	31
5.7	Stress spectra .....	31
5.8	Calculation of equivalent stress range for standardised fatigue load models .....	31
5.8.1	General .....	31
5.8.2	Design value of stress range .....	32
6	Fatigue resistance and detail categories .....	33
6.1	Detail categories .....	33
6.1.1	General .....	33
6.1.2	Factors affecting detail category .....	33
6.1.3	Constructional details .....	33
6.2	Fatigue strength data .....	34
6.2.1	Classified constructional details .....	34
6.2.2	Unclassified details .....	36
6.2.3	Adhesively bonded joints .....	36
6.2.4	Determination of the reference hot spot strength values .....	36
6.3	Effect of mean stress .....	36
6.3.1	General .....	36
6.3.2	Plain material and mechanically fastened joints .....	37
6.3.3	Welded joints .....	37
6.3.4	Adhesive joints .....	37
6.3.5	Low endurance range .....	37
6.3.6	Cycle counting for R-ratio calculations .....	37
6.4	Effect of exposure conditions .....	37
6.5	Improvement techniques .....	38
	<b>Annex A [normative]: Basis for calculation of fatigue resistance .....</b>	<b>39</b>
A.1	General .....	39
A.1.1	Influence of fatigue on design .....	39
A.1.2	Mechanism of failure .....	39
A.1.3	Potential sites for fatigue cracking .....	39
A.1.4	Conditions for fatigue susceptibility .....	40
A.2	Safe life design .....	40
A.2.1	Prerequisites for safe life design .....	40
A.2.2	Cycle counting .....	41
A.2.3	Derivation of stress spectrum .....	41
A.3	Damage tolerant design .....	44
A.3.1	!Prerequisites for damage tolerant design .....	44
A.3.2	Determination of inspection strategy for damage tolerant design .....	44
	<b>Annex B [informative]: Guidance on assessment of crack growth by fracture mechanics .....</b>	<b>47</b>
B.1	Scope .....	47
B.2	Principles .....	47
B.2.1	Flaw dimensions .....	47
B.2.2	Crack growth relationship .....	48
B.3	Crack growth data A and m .....	48
B.4	Geometry function y .....	50
B.5	Integration of crack growth .....	50
B.6	Assessment of maximum crack size a <sub>2</sub> .....	50
	<b>Annex C [informative]: Testing for fatigue design .....</b>	<b>60</b>
C.1	General .....	60
C.2	Derivation of action loading data .....	60
C.2.1	Fixed structures subject to mechanical action .....	60
C.2.2	Fixed structures subject to actions due to exposure conditions .....	61
C.2.3	Moving structures .....	61
C.3	Derivation of stress data .....	61
C.3.1	Component test data .....	61
C.3.2	Structure test data .....	62

C.3.3	Verification of stress history .....	62
C.4	Derivation of endurance data .....	62
C.4.1	Component testing .....	62
C.4.2	Full scale testing .....	63
C.4.3	Acceptance .....	63
C.5	Crack growth data .....	66
C.6	Reporting .....	66
Annex D [informative]: Stress analysis .....		67
D.1	Use of finite elements for fatigue analysis .....	67
D.1.1	Element types .....	67
D.1.2	Further guidance on use of finite elements .....	68
D.2	Stress concentration factors .....	68
D.3	Limitation of fatigue induced by repeated local buckling .....	70
Annex E [informative]: Adhesively bonded joints .....		71
Annex F [informative]: Low cycle fatigue range .....		73
F.1	Introduction .....	73
F.2	Modification to -N curves .....	73
F.3	Test data .....	73
Annex G [informative]: Influence of R-ratio .....		75
G.1	Enhancement of fatigue strength .....	75
G.2	Enhancement cases .....	75
G.2.1	Case 1 .....	75
G.2.2	Case 2 .....	76
G.2.3	Case 3 .....	76
Annex H [informative]: Fatigue strength improvement of welds .....		77
H.1	General .....	77
H.2	Machining or grinding .....	77
H.3	Dressing by TIG or plasma .....	78
H.4	Peening .....	78
Annex I [informative]: Castings .....		79
I.1	General .....	79
I.2	Fatigue strength data .....	79
I.2.1	Plain castings .....	79
I.2.2	Welded material .....	79
I.2.3	Mechanically joined castings .....	79
I.2.4	Adhesively bonded castings .....	80
I.3	Quality requirements .....	80
Annex J [informative]: Detail category tables .....		81
J.1	General .....	81
Annex K [informative]: Hot spot reference detail method .....		97
Annex L [informative]: Guidance on use of design methods, selection of partial factors, limits for damage values, inspection intervals and execution parameters when Annex J is adopted .....		98
L.1	Safe life method .....	98
L.2	Damage tolerant design method .....	98
L.2.1	General .....	98

L.2.2	DTD-I .....	98
L.2.3	DTD-II .....	99
L.3	Start of inspection and inspection intervals .....	100
L.4	Partial factors Mf and the values of Dlim .....	101
L.5	Parameters for execution .....	102
L.5.1	Service category .....	102
L.5.2	Calculation of utilisation grade .....	103
	<b>Bibliography .....</b>	<b>105</b>