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

Annex A [normative]: Basis for calculation of fatigue resistance ... 39

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

Annex B [informative]: Guidance on assessment of crack growth by fracture mechanics ... 47

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 a2 ... 50

Annex C [informative]: Testing for fatigue design ... 60

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

Bibliography 105