

# DIN EN 1999-1-3:2024-11 (E)

## Eurocode 9 - Design of aluminium structures - Part 1-3: Structures susceptible to fatigue

---

| <b>Contents</b>  |  | <b>Page</b> |
|--|--|-------------|
| European foreword.....   |  | 7           |
| Introduction .....   |  | 8           |
| <b>1</b> <b>Scope</b> .....  |  | <b>11</b>   |
| <b>1.1</b> <b>Scope of EN 1999-1-3</b> .....                                       |  | <b>11</b>   |
| <b>1.2</b> <b>Assumptions</b> .....  |  | <b>11</b>   |
| <b>2</b> <b>Normative references</b> .....   |  | <b>11</b>   |
| <b>3</b> <b>Terms, definitions and symbols</b> .....                               |  | <b>12</b>   |
| <b>3.1</b> <b>Terms and definitions</b> .....                                      |  | <b>12</b>   |
| <b>3.2</b> <b>Symbols</b> .....  |  | <b>16</b>   |
| <b>4</b> <b>Basis of design</b> .....  |  | <b>18</b>   |
| <b>4.1</b> <b>Basic rules</b> .....  |  | <b>18</b>   |
| <b>4.2</b> <b>Methods of fatigue design</b> .....                                  |  | <b>19</b>   |
| <b>4.2.1</b> <b>Safe life design (SLD)</b> .....                                   |  | <b>19</b>   |
| <b>4.2.2</b> <b>Damage tolerant design (DTD)</b> .....                             |  | <b>19</b>   |
| <b>4.2.3</b> <b>Design assisted by testing</b> .....                               |  | <b>19</b>   |
| <b>4.3</b> <b>Fatigue loading</b> .....  |  | <b>19</b>   |
| <b>4.3.1</b> <b>Sources of fatigue loading</b> .....                               |  | <b>19</b>   |
| <b>4.3.2</b> <b>Derivation of fatigue loading</b> .....                            |  | <b>20</b>   |
| <b>4.3.3</b> <b>Equivalent fatigue loading</b> .....                               |  | <b>20</b>   |
| <b>4.4</b> <b>Partial factors for fatigue loads</b> .....                          |  | <b>21</b>   |
| <b>4.5</b> <b>Execution requirements</b> .....                                     |  | <b>21</b>   |
| <b>4.5.1</b> <b>General</b> .....  |  | <b>21</b>   |
| <b>4.5.2</b> <b>Execution classes</b> .....  |  | <b>21</b>   |
| <b>4.5.3</b> <b>Execution specification</b> .....                                  |  | <b>21</b>   |
| <b>4.5.4</b> <b>Operation manual</b> .....   |  | <b>22</b>   |
| <b>4.5.5</b> <b>Inspection and maintenance manual</b> .....                        |  | <b>22</b>   |
| <b>5</b> <b>Materials, constituent products and connecting devices</b> .....       |  | <b>22</b>   |
| <b>6</b> <b>Durability</b> .....   |  | <b>23</b>   |
| <b>7</b> <b>Structural analysis</b> .....  |  | <b>24</b>   |
| <b>7.1</b> <b>Global analysis</b> .....  |  | <b>24</b>   |
| <b>7.1.1</b> <b>General</b> .....  |  | <b>24</b>   |
| <b>7.1.2</b> <b>Use of beam elements</b> .....                                     |  | <b>25</b>   |
| <b>7.1.3</b> <b>Use of membrane, shell and solid elements</b> .....                |  | <b>25</b>   |
| <b>7.2</b> <b>Types of stresses</b> .....  |  | <b>26</b>   |
| <b>7.2.1</b> <b>General</b> .....  |  | <b>26</b>   |
| <b>7.2.2</b> <b>Nominal stresses</b> .....   |  | <b>26</b>   |
| <b>7.2.3</b> <b>Modified nominal stresses</b> .....                                |  | <b>26</b>   |
| <b>7.2.4</b> <b>Hot spot stresses</b> .....  |  | <b>27</b>   |
| <b>7.3</b> <b>Derivation of stresses</b> .....                                     |  | <b>29</b>   |
| <b>7.3.1</b> <b>Derivation of nominal stresses</b> .....                           |  | <b>29</b>   |
| <b>7.3.2</b> <b>Derivation of modified nominal stresses</b> .....                  |  | <b>29</b>   |
| <b>7.3.3</b> <b>Derivation of hot spot stresses</b> .....                          |  | <b>30</b>   |
| <b>7.3.4</b> <b>Stress orientation</b> .....                                       |  | <b>30</b>   |
| <b>7.4</b> <b>Stress ranges for specific initiation sites</b> .....                |  | <b>30</b>   |
| <b>7.4.1</b> <b>Parent material, welds, and mechanically fastened joints</b> ..... |  | <b>30</b>   |
| <b>7.4.2</b> <b>Fillet and partial penetration butt welds</b> .....                |  | <b>30</b>   |

|  |   |    |
|--|---|----|
| 7.5  | Adhesive bonds .....  | 31 |
| 7.6  | Castings .....  | 31 |
| 7.7  | Stress spectra .....  | 31 |
| 7.8  | Calculation of equivalent stress range for standardized fatigue load models ..... | 31 |
| 7.8.1  | General .....   | 31 |
| 7.8.2  | Design value of stress range .....  | 32 |
| 8  | Fatigue resistance and detail categories.....                                     | 32 |
| 8.1  | Detail categories .....   | 32 |
| 8.1.1  | General .....   | 32 |
| 8.1.2  | Factors affecting detail category .....   | 32 |
| 8.1.3  | Constructional details.....   | 33 |
| 8.2  | Fatigue strength data .....   | 33 |
| 8.2.1  | Classified constructional details .....   | 33 |
| 8.2.2  | Unclassified details .....  | 36 |
| 8.2.3  | Adhesively bonded joints.....   | 36 |
| 8.2.4  | Determination of the reference hot spot strength values.....                      | 36 |
| 8.3  | Effect of mean stress.....  | 36 |
| 8.3.1  | General .....   | 36 |
| 8.3.2  | Parent material and mechanically fastened joints.....                             | 36 |
| 8.3.3  | Welded joints .....   | 36 |
| 8.3.4  | Adhesive joints .....   | 37 |
| 8.3.5  | Low endurance range.....  | 37 |
| 8.3.6  | Cycle counting for <i>R</i> -ratio calculations .....                             | 37 |
| 8.4  | Effect of exposure conditions .....   | 37 |
| 8.5  | Improvement techniques.....   | 38 |
| Annex A (normative) Basis for calculation of fatigue resistance.....                     |   | 39 |
| A.1  | Use of this annex .....   | 39 |
| A.2  | Scope and field of application .....  | 39 |
| A.3  | General .....   | 39 |
| A.3.1  | Influence of fatigue on design .....  | 39 |
| A.3.2  | Mechanism of failure .....  | 39 |
| A.3.3  | Potential sites for fatigue cracking.....   | 40 |
| A.3.4  | Conditions for fatigue susceptibility.....  | 40 |
| A.4  | Safe life design .....  | 41 |
| A.4.1  | General .....   | 41 |
| A.4.2  | Prerequisites for safe life design .....  | 42 |
| A.4.3  | Design approach .....   | 42 |
| A.4.4  | Cycle counting.....   | 44 |
| A.4.5  | Derivation of stress spectrum.....  | 45 |
| A.5  | Damage tolerant design .....  | 46 |
| A.5.1  | Prerequisites for damage tolerant design.....                                     | 46 |
| A.5.2  | Structural layout and detailing.....  | 47 |
| A.5.3  | Determination of inspection strategy for damage tolerant design .....             | 47 |
| Annex B (informative) Guidance on assessment of crack growth by fracture mechanics ..... |   | 50 |

|   |   |           |
|---|---|-----------|
| <b>B.1</b>  | <b>Use of this informative annex</b> .....                                  | <b>50</b> |
| <b>B.2</b>  | <b>Scope and field of application</b> .....                                 | <b>50</b> |
| <b>B.3</b>  | <b>Principles</b> .....   | <b>50</b> |
| <b>B.3.1</b>  | <b>Flaw dimensions</b> .....  | <b>50</b> |
| <b>B.3.2</b>  | <b>Crack growth relationship</b> .....                                      | <b>51</b> |
| <b>B.4</b>  | <b>Crack growth data <math>A</math> and <math>m</math></b> .....            | <b>52</b> |
| <b>B.5</b>  | <b>Geometry function <math>y</math></b> .....                               | <b>53</b> |
| <b>B.6</b>  | <b>Integration of crack growth</b> .....                                    | <b>53</b> |
| <b>B.7</b>  | <b>Assessment of maximum crack size <math>a_2</math></b> .....              | <b>54</b> |
| <b>Annex C (informative) Testing for fatigue design</b> ..... |   | <b>61</b> |
| <b>C.1</b>  | <b>Use of this informative annex</b> .....                                  | <b>61</b> |
| <b>C.2</b>  | <b>Scope and field of application</b> .....                                 | <b>61</b> |
| <b>C.3</b>  | <b>Derivation of action loading data</b> .....                              | <b>61</b> |
| <b>C.3.1</b>  | <b>Fixed structures subject to mechanical action</b> .....                  | <b>61</b> |
| <b>C.3.2</b>  | <b>Fixed structures subject to actions due to exposure conditions</b> ..... | <b>62</b> |
| <b>C.3.3</b>  | <b>Moving structures</b> .....  | <b>62</b> |
| <b>C.4</b>  | <b>Derivation of stress data</b> .....                                      | <b>62</b> |
| <b>C.4.1</b>  | <b>Component test data</b> .....  | <b>62</b> |
| <b>C.4.2</b>  | <b>Structure test data</b> .....  | <b>63</b> |
| <b>C.4.3</b>  | <b>Verification of stress history</b> .....                                 | <b>63</b> |
| <b>C.5</b>  | <b>Derivation of endurance data</b> .....                                   | <b>63</b> |
| <b>C.5.1</b>  | <b>Component testing</b> .....  | <b>63</b> |
| <b>C.5.2</b>  | <b>Full scale testing</b> .....   | <b>64</b> |
| <b>C.5.3</b>  | <b>Acceptance</b> .....   | <b>64</b> |
| <b>C.6</b>  | <b>Crack growth data</b> .....  | <b>67</b> |
| <b>C.7</b>  | <b>Reporting</b> .....  | <b>67</b> |
| <b>Annex D (informative) Stress analysis</b> .....            |   | <b>69</b> |
| <b>D.1</b>  | <b>Use of this informative annex</b> .....                                  | <b>69</b> |
| <b>D.2</b>  | <b>Scope and field of application</b> .....                                 | <b>69</b> |
| <b>D.3</b>  | <b>Use of finite elements for fatigue analysis</b> .....                    | <b>69</b> |
| <b>D.3.1</b>  | <b>Element types</b> .....  | <b>69</b> |
| <b>D.3.2</b>  | <b>Further guidance on use of finite elements</b> .....                     | <b>70</b> |
| <b>D.4</b>  | <b>Stress concentration factors</b> .....                                   | <b>70</b> |
| <b>D.5</b>  | <b>Limitation of fatigue induced by repeated local buckling</b> .....       | <b>72</b> |
| <b>Annex E (informative) Adhesively bonded joints</b> .....   |   | <b>73</b> |
| <b>E.1</b>  | <b>Use of this informative annex</b> .....                                  | <b>73</b> |

|   |  |            |
|---|--|------------|
| E.2   | Scope and field of application .....         | 73         |
| <b>Annex F (informative) Low cycle fatigue range .....</b>                          |  | <b>76</b>  |
| F.1   | Use of this informative annex.....           | 76         |
| F.2   | Scope and field of application .....         | 76         |
| F.3   | Modification to fatigue strength curves..... | 76         |
| F.4   | Test data.....                               | 77         |
| <b>Annex G (informative) Influence of applied stress ratio <math>R</math> .....</b> |  | <b>78</b>  |
| G.1   | Use of this informative annex.....           | 78         |
| G.2   | Scope and field of application .....         | 78         |
| G.3   | Enhancement of fatigue strength.....         | 78         |
| G.4   | Enhancement cases.....                       | 78         |
| G.4.1   | Case 1 .....                                 | 78         |
| G.4.2   | Case 2 .....                                 | 79         |
| G.4.3   | Case 3 .....                                 | 80         |
| <b>Annex H (informative) Fatigue strength improvement of welds.....</b>             |  | <b>81</b>  |
| H.1   | Use of this informative annex.....           | 81         |
| H.2   | Scope and field of application .....         | 81         |
| H.3   | Machining or grinding.....                   | 82         |
| H.4   | Dressing by TIG or plasma.....               | 83         |
| H.5   | Peening.....                                 | 83         |
| <b>Annex I (informative) Castings .....</b>   |  | <b>84</b>  |
| I.1   | Use of this informative annex.....           | 84         |
| I.2   | Scope and field of application .....         | 84         |
| I.3   | Fatigue strength data .....                  | 84         |
| I.3.1   | Cast material.....                           | 84         |
| I.3.2   | Welded material.....                         | 84         |
| I.3.3   | Mechanically joined castings.....            | 85         |
| I.3.4   | Adhesively bonded castings.....              | 85         |
| I.4   | Quality requirements.....                    | 85         |
| <b>Annex J (informative) Detail category tables.....</b>                            |  | <b>87</b>  |
| J.1   | Use of this informative annex.....           | 87         |
| J.2   | Scope and field of application .....         | 87         |
| <b>Annex K (informative) Hot spot reference detail method .....</b>                 |  | <b>116</b> |
| K.1   | Use of this informative annex.....           | 116        |
| K.2   | Scope and field of application .....         | 116        |
| K.3   | Hot spot reference detail method.....        | 116        |

|   |            |
|---|------------|
| <b>Annex L (informative) Guidance on use of design methods, selection of partial factors, limits for damage values, inspection intervals and execution parameters if Annex J is adopted .....</b> | <b>117</b> |
| <b>L.1 Use of this informative annex .....</b>  | <b>117</b> |
| <b>L.2 Scope and field of application.....</b>  | <b>117</b> |
| <b>L.3 Safe life design approach.....</b>   | <b>117</b> |
| <b>L.3.1 General.....</b>   | <b>117</b> |
| <b>L.3.2 SLD-I.....</b>   | <b>117</b> |
| <b>L.3.3 SLD-II .....</b>   | <b>118</b> |
| <b>L.4 Damage tolerant design approach.....</b>   | <b>118</b> |
| <b>L.4.1 General.....</b>   | <b>118</b> |
| <b>L.4.2 DTD-I.....</b>   | <b>118</b> |
| <b>L.4.3 DTD-II.....</b>  | <b>119</b> |
| <b>L.5 Start of inspection and inspection intervals .....</b>   | <b>119</b> |
| <b>L.6 Partial factors <math>\gamma_{Mf}</math> and the values of <math>D_{Lim}</math>.....</b>   | <b>120</b> |
| <b>L.7 Parameters for execution.....</b>  | <b>122</b> |
| <b>L.7.1 Service category.....</b>  | <b>122</b> |
| <b>L.7.2 Calculation of utilization grade.....</b>  | <b>123</b> |
| <b>Bibliography.....</b>  | <b>125</b> |