

**TG4 - NONLINEAR DESIGN RULES**

**EPERC TG4 Potential Technical Program**

**General Introduction**

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| <b>4 major degradations:</b>                              | failure modes   | degradation mechanisms   | flaw tolerance   | special cases   |
| <b>4 major steps</b>                                      | basic procedure   | validation:<br>- theoretical<br>- experimental   | complementary R&D program  | - synthesis<br>- benchmarks<br>- best practice<br>- Code Case<br>- Knowledge transfer |
| <b>WP 1: Existing International Codes &amp; Standards</b> | updating of existing review/comparison of International Codes and Rules |  | gaps & needs, including new needs associated to innovative industries  |   |
| <b>WP2: Failure Modes</b>                                 | <b>Plastic Collapse</b>   | - definition / existing validation<br>- methode1: limit load<br>- methode 2: elastic-plastic<br>- criteria   | - recommendation to user<br>- existing tests<br>- complementary R&D program<br>- benchmarks<br>- best practice and Code case<br>- recommendation to user |   |
|   | <b>Plastic Instability</b>  | - definition / existing validation<br>- methode1: limit load<br>- methode 2: elastic-plastic<br>- criteria   | - existing tests<br>- complementary R&D program<br>- benchmarks<br>- best practice and Code case   |   |
|   | <b>Local failure</b>  | - definition / existing validation<br>- analysis rules<br>- criteria   | - recommendation to user<br>- existing tests<br>- complementary R&D program<br>- benchmarks<br>- best practice and Code case                             |   |
|   | <b>Buckling</b>   | - definition / existing validation<br>- analysis rules (bifurcation...)<br>- criteria<br>- interaction with other degradation mechanisms (progressive deformation, creep...) | - recommendation to user<br>- existing tests<br>- complementary R&D program<br>- benchmarks<br>- best practice and Code case                             |   |
| <b>WP3: Degradation Mechanisms</b>                        | <b>Fatigue</b>  | - cyclic plasticity strain amplification<br>- cycle by cycle approach<br>- criteria  | - material constitutive equations and calibration tests<br>- validation tests on small specimenn on real structure<br>- review of existing tests         |   |
|   | <b>Plastic Shakedown</b>  | - simplified elastic perfectly plastic rule<br>- cycle by cycle approach<br>- criteria   | - material constitutive equations and calibration tests<br>- validation tests on small specimens and on real structure<br>- review of existing tests     |   |
|   | <b>Creep consequences</b>   | - cyclic viscoplastic method<br>- criteria   | - material constitutive equations and calibration tests<br>- validation tests on small specimens and on real structure<br>- review of existing tests     |   |
|   | <b>Corrosions</b>   | - review of major mechanisms<br>- key parameters<br>- surface stress level   | - corrosion rate: thinning and crack growth<br>- validation tests on small specimens and on real structure<br>- review of existing tests                 |   |
| <b>WP4: Flaw Tolerance</b>                                | <b>Reference stress method</b>  | - methode presentation<br>- limit load of cracked components   | - recommendation to user<br>- existing tests<br>- complementary R&D program<br>- benchmarks<br>- best practice and Code case                             |   |
|   | <b>Crack growth and crack tip cyclic plasticity</b>                     | - crack tip plasticity<br>- from $\Delta K_{Ic}$ to $\Delta J$   | - existing tests<br>- complementary R&D program<br>- benchmarks<br>- best practice and Code case   |   |
|   | <b>Critical crack size</b>  | - direct J computation<br>- including ductile tearing<br>- cyclic load consideration   | - existing tests<br>- complementary R&D program<br>- benchmarks<br>- best practice and Code case   |   |
|   | <b>Creep consequences</b>   | - C* definition<br>- direct C* computation   | - existing tests<br>- complementary R&D program<br>- benchmarks<br>- best practice and Code case   |   |
|   | <b>Local Approach of Fracture</b>                                       | - review of existing models<br>- associated computation of parameters  | - material parameters and calibration tests<br>- validation tests on small specimens and on real structure<br>- review of existing tests                 |   |

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| WP5: Specific cases | Elastic Follow-up                       | <ul style="list-style-type: none"> <li>- definition</li> <li>- simplified methods</li> <li>- elastic / plastic approaches</li> <li>- criteria: primary/secondary stress</li> </ul> | <ul style="list-style-type: none"> <li>- material parameters</li> <li>- validation tests on real structure : piping systems</li> <li>- review of existing tests</li> </ul>   |
|                     | Bolted Flange and Leak Evaluation       | <ul style="list-style-type: none"> <li>- selection of typical Bolted Flange</li> <li>- seal properties</li> <li>- leak tests</li> <li>- fugitive emission evaluation</li> </ul>    | <ul style="list-style-type: none"> <li>- different seal parameters</li> <li>- review of existing tests</li> <li>- validation tests on real structure : piping systems</li> <li>- complementary R&amp;D program</li> <li>- benchmarks</li> <li>- best practice and Code case</li> </ul> |
|                     | Dynamic Loads: seismic and water hammer | <ul style="list-style-type: none"> <li>- low / high seismic analysis</li> <li>- water hammer analysis</li> </ul>   | <ul style="list-style-type: none"> <li>- validation tests on real structure</li> <li>- complementary R&amp;D program</li> <li>- benchmarks</li> <li>- best practice and Code case</li> </ul>   |
|                     | Cumulative Strain based Criteria        | <ul style="list-style-type: none"> <li>- criteria comparison: on stress / on strain</li> <li>- cyclic cumulation</li> </ul>  | <ul style="list-style-type: none"> <li>- complementary R&amp;D program</li> <li>- benchmarks</li> <li>- best practice and Code case</li> </ul>   |
|                     | Opening Reinforcement Rules             | <ul style="list-style-type: none"> <li>- define some reinforced nozzles</li> <li>- comparison elastic stress classification / limit load approach</li> </ul>                       | <ul style="list-style-type: none"> <li>- complementary R&amp;D program</li> <li>- benchmarks</li> <li>- best practice and Code case</li> </ul>   |
|                     | HDPE Piping                             | <ul style="list-style-type: none"> <li>- definition of a visco-plastic models</li> <li>- criteria</li> </ul>   | <ul style="list-style-type: none"> <li>- complementary R&amp;D program</li> <li>- benchmarks</li> <li>- best practice and Code case</li> </ul>   |

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| WP6: Material Properties | <b>All needed material properties</b> |  | <ul style="list-style-type: none"> <li>- material constitutive equations</li> <li>- local approach mat. properties</li> <li>- <math>da/dN</math> and <math>\Delta K</math> to <math>\Delta J</math></li> <li>- <math>J\Delta a</math> curves</li> <li>- <math>da/dt - C^*</math></li> <li>- thinning rate / corrosion rate</li> <li>- stress-strain curves</li> <li>- thermal ageing consequences</li> <li>- all material data for all the previous WP</li> </ul> |
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| WP7: Benchmarks on practical cases | definition | performances | synthesis |
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| WP8: TG4 Synthesis | All task and WP synthesis | <b>Final Best Practices Report</b> | <b>Code Case proposal to European Standards</b> |
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| WP9: Large Knowledge Transfert | Workshop - Training - International Conferences |
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| WP10: Road Map management | Regularly up-dated with all TG4 actions |
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