FITNESS For SERVICE and RISK BASED INSPECTION

Theoretical, Engineering and Experimental Validation Program

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Introduction

1. European Regulation (PED) and consequences

The essential safety requirements, to Design and Manufacture a European Pressure Equipment, laid down in this Directive [1] are **mandatory**. The obligations following from those essential safety requirements apply only if the corresponding hazard exists for the pressure equipment in question when it is used under conditions which are "reasonably foreseeable" by the manufacturer.

The manufacturer is under an obligation to analyze the hazards and risks in order to identify those which apply to his equipment on account of pressure; he shall then design and construct it taking account of his risk analysis

Pressure Equipment shall be designed for adequate strength associated to pressure loads **and for loadings appropriate to its intended use and other reasonably foreseeable operating conditions**. In particular, different degradation mechanisms shall be taken into account, as: fatigue, ratcheting, creep, creep-fatigue, corrosions, erosion…

Pressure equipment and assemblies below or equal to the limits set out in points (a), (b) and (c) of paragraph 1 and in paragraph 2 respectively shall be designed and manufactured in accordance with the sound engineering practice of a Member State in order to ensure safe use. Pressure equipment and assemblies shall be accompanied by **adequate instructions for use**. (Art. 4.3 of [1])

From PED [1] Annex 1: ESSENTIAL SAFETY REQUIREMENTS

1. *General*
   - *1.1. Pressure equipment shall be designed, manufactured and checked, and if applicable equipped and installed, in such a way as to ensure its safety when put into service in accordance with the manufacturer's instructions, or in reasonably foreseeable conditions.*
   - *1.2. In choosing the most appropriate solutions, the manufacturer shall apply the principles set out below in the following order:*
     - *eliminate or reduce hazards as far as is reasonably practicable;*
     - *apply appropriate protection measures against hazards which cannot be eliminated;*
     - *where appropriate, inform users of residual hazards and indicate whether it is necessary to take appropriate special measures to reduce the risks at the time of installation and/or use*

Consequently:

- some margins have to be justified in front of the **basic pressure equipment failure modes**, as: plastic collapse, plastic instability, local failure without crack, buckling, creep… at the Design Level
- **potential degradation** that can affect the pressure boundary has to be considered at the design stage: no thinning, no loss of material properties (material strength and toughness), no cracks, associated to do different degradation mechanisms, as fatigue, plastic shakedown, corrosions or thermal ageing….
- in some cases of user specification, the **"flaw tolerance"** of the pressure equipment has to be evaluated at design level to assure safe operation life of the equipment
- in operation, **a dedicated surveillance program** has to be developed by the Operator with In-Service Inspection, location, performance and frequency, associated to acceptance criteria; this operation activity is not covered directly by PED, generally through national regulation, nevertheless a part of these degradation analyses can be used in the Design hazards and risk analysis to develop the Instruction Notice.

2. Needs of standards or Harmonized European Rules

- assure "easy to use" Standards, sufficiently explained, justified, at the state of the art technical level
- assure European "competitiveness" with similar international standard to assure relevance of the Standard to assure safe and competitive PE operation
- anticipate "specific or future needs" of European Pressure Equipment industry on the future "Clean Energy" market and other innovative Pressure Equipment application.

- 2 specific topics have to be covered:
  - Fitness For Service (FFS) with analyses rules of major PE degradations
  - Risk Based Inspection (RBI) with proposed surveillance program associated to consequences of degradation (as operation time shutdown or loss of operation…) associated to reliability target.

2. Major Objectives of EPERC TG7

- help all the users of EN Design and Construction Standards on Pressure Equipment: EN 15492-15493 for Boilers, EN 13445 for Vessels and EN 13480 for Piping System to design pressure equipment and **perform Hazard and Risk Analyses** and develop the required **Instruction Notice**
- review format and content of existing international standards for:
  - FFS (ASME BPVC Section XI [6], RSEM/RCCMRx [7], R5-R6 [8], API-ASME [9], FITNET [10], BS7910 [11], JSME [12], KEPIC [13], VERLIFE [14]…)
  - RBI (ASME BPVC Sec XI Code Cases/Division 2 RIM [6], API [9], RIMAP [15], ENIQ [16], TWI [17], JSME [12]…)
- collect all the references that support and justify all the proposal available inside the standards
- identified gaps and needs to remain competitive at the State Of the Art Level and to cover new needs associated to innovation use of Pressure Equipment (pressure, temperature, environment),
- analyze all the uncertainties (methods, criteria and material properties) associated to Failure Modes and Degradation Mechanism considered
- propose improvement or new rules in a dedicated EPERC set of Reports to support a European Standard with R&D validation program and new rules proposal
- a dedicated topic has to be associated to PE reliability evaluation and probability of leak or failure
- propose a set of typical Benchmarks to assure applicability of the new standardized rules
- develop a set of practical examples on typical cases for the more complex rules
- develop a dedicated Road Map for regular reviews of Project and Tasks advancement
- Reports and knowledge dissemination closely connected, including participation to Workshop and Conferences, training courses or Master Class proposals…

3. Potential EU Research Support

A dedicated Report has been proposed by CEN-CENELEC:

- "How to Link Standardization with EU research projects" [2] can be found on www.cencenelec.eu/research .
- "Horizon 2020" December 2019 [3] on https://ec.europa.eu/programmes/horizon2020/en/background-material
- "Strategic Plan" December 2019 [4] on https://ec.europa.eu/info/files/strategic-planning-process-and-strategic-plan_en
- "Different CEN cooperation working products": ES, TS, TR, GU, CWA [5] https://www.cen.eu/work/products/cwa/pages/default.aspx

4. EPERC TG7 - Detailed Proposed Working Program

4.1. Project Introduction

The major objective is to consider how leak tightness of bolted can be assured with efficient Design and Installation rules, and how existing standards can help to solve some particular situation, to justify more simple engineering rules, to help in margins understanding associated to major uncertainties on Methods, Data, Parameters and Material properties used in each analysis. Identification of essential variables for each Work Package will be covered.

4.2. Potential Topics

- comparison of International Codes and Standards for Fitness for Service and Risk Based Inspection:
  - FFS (ASME BPVC Section XI, RSEM/RCCMRx, R5-R6, ASME-API, FITNET, BS7910, JSME, KEPIC, VERLIFE…)
  - RBI (ASME BPVC Sec XI Code Cases/Division 2 RIM, API, RIMAP, ENIQ, TWI, JSME…)
- identification of Gaps and Needs, in particular to support innovation (high pressure, high/low temperature, different environment as hydrogen…, new materials…
- concerning the degradation analysis, 3 major directions:
  - crack initiation and propagation to critical size, including Leak Before Break approach,
  - local and general thinning areas
  - loss of material properties, as thermal ageing
- non-metallic materials, as HDPE pipe are associated to particular questions
- in term of innovation consideration of creep damage need more investment, as cracks in creep conditions….
- condition to accept a leak for small duration can be a particular task
- different reference tests on material as toughness measurement, transition temperature, crack growth (fatigue, corrosion, creep…), thinning rate, HTHA will be also review in the Project with transferability aspect from Laboratory to Plant situation
- probabilistic and reliability approaches will be considered for uncertainties and criteria in one hand and for risk based with target reliability of components and systems in the other hand
- collection of material properties for existing and new conditions, improvement of existing rules and contribution to European harmonized rules will be proposed by EPERC TG7

4.3. List of Work Packages and Tasks

4.3.1. Work Package 1: Overview of existing International Standards

- Task 1.1: General Introduction
- Task 1.2: Fitness for Service Codes/ Rules
  - API /ASME FFS-1, Fitness-For-Service - RP 579-1
  - R5-R6- BS7910: assessing flaws in metallic structures
  - RCC-MRx Appendix 16/RSE-M Appendix 5: Flaw Evaluation for Nuclear and Non-nuclear plants
  - ASME XI Division 1: In-service Inspection of Nuclear Power Plants
  - FITNET/ SINTAP: Fitness-for-service Fracture Assessment of Structures Containing Cracks
  - VERLIFE: integrity and lifetime assessment of components and piping in WWER NPPs
  - JSME/JAEA Flaw Evaluation Rules
  - KEPIC Flaw Evaluation Rules
- Task 1.3: Risk Based Inspection
  - ASME XI Division 1: Code Cases on Risk informed
  - ASME XI Division 2: Reliability and Integrity Management
  - API- Risk-Based Inspection - RP 580-3
  - ENIQ: European network for inspection and qualification
  - RIMAP: Risk-Based Inspection and Maintenance for European Industries
  - TWI Risk Based Inspection Methods

4.3.2. Work Package 2: Gaps and Needs evaluation

- Task 2.1: General overview on FFS and RBI available Standards
- Task 2.2: Fracture Mechanic
- Task 2.3: Thinning Rate and consequences
- Task 2.4: Ageing effects on materials and welds
- Task 2.5: Leak Before Break approach
- Task 2.6: Reliability approaches
- Task 2.7: Non Steel / Non Metallic Materials

4.3.3. Work Package 3: Non-metallic / Non-Steel materials

- Task 3.1: Particular review on non-steel material
- Task 3.2: Slow Crack Growth in HDPE: base metal and fusion joins
- Task 3.3: Critical crack and scratch in HDPE pipe
- Task 3.4: Non-steel metallic material

4.3.4. Work Package 4: R&D Reports and Test Program

- Task 4.1: General Introduction and R&D Road Map:
  - Complementary identified needs for methods and material property evaluation by standards
  - Collection of major existing tests / data and programs
  - EPERC TG7 Supplementary R&D programs (Reports or/and Tests): material properties, methods, criteria, uncertainties and reliability approach, code cases and standards proposals
- Task 4.2: K, J and C* parameter evaluation: methods and handbooks)
- Task 4.3: Fatigue/ Corrosion/ Creep Crack Growth: reference curves for different materials
- Task 4.4: Hydrogen embrittlement and hot hydrogen attack
- Task 4.5: Thinning rate and flow accelerated corrosion
- Task 4.6: Loss of material properties: thermal ageing
- Task 4.7: Dynamic and Cyclic load effects on toughness
- Task 4.8: Environmental effects: vacuum, air, water, steam, hydrogen, others…
- Task 4.9: Leak Before Break step by step procedure and detailed method validation
- Task 4.10: HDPE piping flaw evaluation
- Task 4.11: Probabilistic Approach and Risk Evaluation

4.3.5. Work Package 5: Benchmarks

- Task 5.1: Benchmarks definition and data collection
- Task 5.2: Benchmark result analyses
- Task 5.3: Synthesis and recommendations

4.3.6. Work Package 6: Recommended Practices

- Task 5.1: Reference Curves for Material properties
- Task 5.2: Evaluation methods through Handbooks, Engineering Methods or Finite Element Analyses
- Task 5.3: Leak Before Break procedure
- Task 5.4: Probabilistic and Risk Informed methods and data
- Task 5.5: Non-steel / non-metallic material

4.3.7. Work Package 7: Practical Cases

- Task 7.1: Case number 1: complete design analysis of selected bolted flange
- Task 7.2: Case number 2: complete design analysis of selected bolted flange

4.3.8. Work Package 8: Project Synthesis and Conclusion

- Knowledge transfer
- Project Synthesis
- Project Conclusion

4.4. Final Reports and Conclusion

Topics to be covered through contribution of different Work Packages:

2. Introduction and Definition
3. Existing Standards Synthesis
4. Gaps and Needs
5. Experimental Program: definition, performance, pre- and post-test analyses
6. Benchmarking
7. Code Case Proposal
8. Recommended Practices
9. Practical Examples
10. Knowledge Transfer
11. Program Synthesis and Conclusion

4.5. Management, Synthesis and Conclusion of the Project

- Chairman and list of members
- Detailed "Roadmap" of R&D program and each tasks
- Periodic updated Planning and Roadmap review
- Report: review by Project members and selected International Key Actors of the domain
- All the documents of each Work Package will be released to: all the sponsors and EPERC TG7 members

5. EC proposal for TS, TR, Guides or CWA

5.1. Proposal preparation

These detailed description of the Work Package have to be filled up with TG7 members (or potential members) to prepare a CEN Committee proposal for a ES (European Standards), TS (Technical Specification), TR (Technical Reports), Gu (Guides) or CWA (CEN Workshop Agreement) (https://www.cen.eu/work/products/guides/Pages/default.aspx)

5.2. Detailed Work Package Developments

To be defined with TG7 members

5.2.1. Work Package 1: Overview of existing International Standards

5.2.2. Work Package 2: Gaps and Needs evaluation

5.2.3. Work Package 3: Non-metallic and Non-steel Materials

5.2.4. Work Package 4: R&D Reports and Test Program

5.2.5. Work Package 5: Benchmarks

5.2.6. Work Package 6: Recommended Practices and Code Cases

5.2.7. Work Package 7: Practical Examples

5.2.8. Work Package 8: Knowledge Transfer, Synthesis, Conclusion

5.3. Deliverables, planning and meetings

To be defined later with TG7 Chairman and Work Package Leaders…

A first SKYPE meeting with volunteers will take place before end of June 2020

5.4. Meetings and Preliminary Budget

5.4.1. TG7 Project Meetings

- To be defined later with Chairman and Work Package Leaders…
- **Max of web-meetings: SKYPE or ZOOM video conference**
    - At WP level
    - At TG7 Project level with TG7 Chairman and WP Leaders
    - 1 EPERC workshop per year

5.4.2. TG7 Budget

- To be defined later with Chairman and Work Package Leaders…

6. References

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