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System of rules for WWER reactor pressure vessel lifetime assessment

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ABSTRACT

Rules for a standard and accepted assessment of reactor pressure vessel lifetime are of a high importance for all types of reactors. This importance is even more pronounced for VVER type reactors for which no official rules for their assessment and analysis during operation exist. In a Czech Republic, a set of rules and standard procedures for reactor pressure vessels (and other primary circuit components, as well) is prepared under management of Czech State Office for Nuclear Safety.

INTRODUCTION

WWER units type 213/440 MW in operation and WWER units type 320/1000 MW under construction need safety standards improvements together with coordinated international action.
Nuclear power plants in Dukovany (440 MW) and in Temelín (1000 MW) were, or still are built under the agreement between the former Czechoslovakia and USSR in context of on mutual cooperation in building nuclear power plants. Within this agreement, main tendency was to use Soviet design and production standards and rules[1-7], as far as it was possible, as whole NPP design were realized in such a way. Thus, for this case only, Government Decisions from 1978, 1980 and 1985 defined these rules. Early in eighties, extended project of the technical standard documentation of nuclear power plants was organised by and International Economic Association "Interatomenergo" in Moscow. The association was set up to cooperate in the field of nuclear power between individual member states of the Council of Mutual Economical Cooperation (CMEA). After accident in the Chernobyl NPP, a whole project was managed by the "Gosatomenergonadzor" (GAEN) of the Soviet Union. Under control of the GAEN a whole complex of technical standard documentation ended in the 1990, when GAEN finished a whole project at international level, and consequently also in the ČSSR.
The most fundamental problem from the start of the project was a question of legal obligation of these CMEA standards. No satisfactory and acceptable agreement was reached in this area. Last version of legal obligation of a whole complex of technical standards at the level of former member states of the CMEA was given in rules : Elaboration of obligatory standpoint

of ČSSR for determination of possibility of application of technical standards documentation in the legal-agreement relations among the member of the CMEA. From the point of view of the international relations, the procedure could be considered as sufficient, but from the standpoint of Czech nuclear power plants the effectiveness and utilizing of this standards complex is at zero point, no effective steps were organized to bring them into life.
Moreover, neither Soviet standards, nor CMEA ones contained rules for service lifetime assessment of reactor components - only rules for stress analysis and lifetime assessment exist for their design. Thus, assessment of defects, found during in-service inspection has to be based on acceptance levels valid for manufacturing on one side, and on special procedures, prepared by NRI and manufacturers of components, and from case to case accepted by the Czech State Office for Nuclear Safety (SONS).

GENERAL CONSIDERATION

In the paper an elaboration of guidance proposal for residual lifetime evaluation of WWER reactor pressure vessels with austenitic cladding is presented. The evaluation should respect onset material properties, real operation conditions of the units, changes in the material properties obtained from the complementary and re-evaluated surveillance programme, results of in-service inspections and improved calculations of thermal stress fields under real operation regimes.
The proposal should follow the conventional format used for PWR reactors where the specific features of the WWER reactors and their materials are taken into account. Thus, in principle, it is not possible to use any PWR rules or standards in a full version - in all cases it must be taken in account that WWER components were designed and manufactured by different standards and rules which are not fully compatible with PWR ones. Next, somewhat different safety rules, safety factors as well as safety approaches were used for WWER reactors and this fact cannot be neglected. Preparation of these rules has to be based on the former Soviet and CMEA rules and standards [1] - [7] with maximum possible implementation of a PWR approaches without loosing advantages and larger safety factors if they were reached or defined.
The SONS has initiated recently a project "Requirements for Lifetime Evaluation of VVER Main Components". Within this project, a preparation of regulatory requirements for lifetime evaluation of reactor components including all aspects of integrity and degrading processes in these components is being performed. The part concerning with the reactor pressure vessels (RPV) is presented in this paper.
Second activity is concentrated in Czech Association of Mechanical Engineers (ASI) where a set of Codes for Reactor Components Assessment is also in progress. In this case, technical codes are being prepared, suitable for numerical evaluation of individual components.

SONS REGULATORY REQUIREMENTS FOR VVER REACTOR PRESSURE VESSELS

A set of these requirements will cover all problems connected with lifetime evaluation of RPVs during their operation. Their format is prepared in such a way to be consistent with a Code prepared by the ASI. Every part of SONS requirements contains as a minimum, the following chapters :

- definition of the problem,
- requirements to input data and their validation,
- recommended principal procedure or approach for evaluation,
- definition of mandatory values for evaluation (safety factors,
- requirements for procedure/programmes validation and certification,
- format for presentation of results,
- Quality Assurance Programme,
- requirements for data and results storage.

The whole set of requirements for RPVs has been agreed as follows:

1. Requirements and criteria for lifetime evaluation of VVER RPVs - general requirements.
2. Requirements and criteria for lifetime evaluation of VVER RPV internals - general requirements.
3. Approach and principal procedure for evaluation of the RPV resistance against non-ductile failure.
4. Procedure for determination of radiation field in RPV and its internals
   - general requirements,
   - requirements for computational determination,
   - requirements for experimental determination.
5. Procedure and criteria for an evaluation of allowability of defects found during in-service inspections.
6. Procedure and requirements for an evaluation of the effect of pressurized thermal shock on RPV behaviour.
7. Procedure and requirements for mechanical testing of surveillance specimens.
8. Procedure for an application of results from surveillance specimens programme testing to RPV lifetime evaluation.
9. Procedure for a fatigue damage evaluation.
10. Procedure for a corrosion and corrosion-mechanical damage evaluation.
11. Procedure and requirements for instrumented hardness measurement of components in operation.
12. Requirements for repair welding procedures of RPVs and for evaluation of their effect on RPV lifetime.

A standard procedure for a preparation of this set of requirements is applied, i.e. three-step revisions and public discussion between SONS, utilities, expert organizations as well as manufacturers is performed

The whole set of these SONS requirements will be finished within this year.

ASI CODE FOR VVER REACTOR COMPONENTS

Preparation of this code was initiated by several facts and reasons:

- necessity for updating of former Soviet/Interatomenergo codes for VVER reactors,
- absence of Codes for NPP under operation,
- necessity for including also Czech/foreign materials besides only Soviet ones.

This Code is planned and realized in five sections, specifically:

Section I - Welding and brazing of components and piping of VVER type NPPs

Section II- Characteristics of materials for components and piping of VVER type NPPs

Section III- Strength assessment of components and piping of VVER type NPPs
Section IV- Evaluation of residual lifetime of components and piping of VVER type NPPs
Section V- Material testing procedures and evaluation

Main problems of first two sections are concentrated in the fact that only Soviet type materials were allowed for use in VVER NPPs according to the former Soviet Codes. In this time, some of these materials are no more produced by domestic factories, and their import is sometimes complicated or even impossible. Thus, change of some materials manufactured according to Soviet standards into Czech or other foreign ones is necessary.
Former Soviet rules [1,2] defined conditions which must be fulfilled if some new material (in this sense a "new" material is also a material with practically identical chemical composition and mechanical properties but manufactured in accordance with other standard or by other technology) could be added into the list of allowable materials. These requirements represent conditions for a "qualification programme" for this new material. Its extent depends on type of material and its use (type of component) but for RPVs materials it represents a very wide experimental programme.
Thus, first two sections (I and II) are now in preparation and are divided into following chapters similar in both sections:

1. Introduction
2. Basic principles, nomenclature and definitions
3. General requirements on a choice of welding/base materials for manufacturing, repair and replacement
4. Conditions for acceptance of new material standards non-mentioned in the list of allowable materials for use
5. Requirements to manufacturers and suppliers of materials
6. Standard/conventional mechanical properties of allowable materials
7. Specific mechanical/physical properties of allowable materials
8. Classification and standards of allowable materials for use in nuclear components
9. Unconventional/non-standard characteristics of materials necessary for strength and lifetime evaluation in accordance with Sections III and IV.

Section III has been finished, approved by the SONS and now is in printing. Structure of this section is similar with the previous ones [1,2] which was used as a basis, but updated in accordance with NTD(Normative Technical Documentation) CMEA. This section was prepared for a design state of calculations, but used methods, in general, are applicable also for evaluation of components during their operation.
Structure of this section is consistent with previous rules, i.e.:

1. Introduction
2. Basic principles, nomenclature and definitions
3. General demands on strength analysis
4. Allowable stresses
5. Basic design dimensions of cylindrical, conical, spherical, elliptical, torospherical and flat parts stressed by internal and external pressure.
6. Basic design dimensions of flanges, thrust rings and coupling parts
7. Basic design dimensions of reinforced opening and coefficients of reduced strength by openings and weld coupling parts
8. Check analysis, stress categories
9. Analysis of static strength

10. Strength analysis at cycling loading
11. Resistance analysis against sudden (unstable) failure
12. Strength analysis at vibrations
13. Analysis of stability
14. Strength analysis at seismic effects

Section IV is only in a preparation stage, i.e. in approval of its structure. The main purpose of this section should be to show standard procedures for lifetime evaluation of components during their operation. The section will be applied for ann principle components of reactor primary circuit, namely: reactor pressure vessel, internals, steam generator, pressurizer, main circulating pump, valves, primary piping. Probable structure of the section can be as follows:

1. Introduction
2. Basic principles, nomenclature and definitions
3. General requirements for examination and inspections
4. Requirements for pressure tests
5. Principle procedure for lifetime evaluation of components and pipings

Appendix A- Procedure for determination of radiation field in RPV and internals
Appendix B- Requirements for surveillance specimens programme and its testing
Appendix C- Procedure for application of results from surveillance specimens testing to RPV material degradation
Appendix D- Assessment of fatigue damage in components and piping
Appendix E- Assessment of corrosion and corrosion-mechanical damage in component and piping
Appendix F- Requirements for a choice and evaluation of pressurized thermal shock regimes
Appendix G- Evaluation of nondestructive examination results
Appendix H- Evaluation of allowability of defects
Appendix I- Requirements for repairs and replacement

Section V will summarize and give either citation of standards (for standard type testing like tensile testing, notch toughness testing and hardness) or full description of standard procedures/test methods for determination of non-standard mechanical properties, like fracture toughness (static, dynamic, arrest), transition temperatures, low-cycle fatigue, cyclic crack growth etc. In the same time, procedures for test raw data evaluation will be given with the aim to construct design/reference curves of individual properties or their degradation rates necessary for lifetime evaluation.

CONCLUSIONS

Paper briefly describes a set of rules and standards which are now under preparation in Czech Republic for evaluation of the behaviour of components and piping of VVER type reactors during operation.

These rules are based on former Soviet rules for VVER reactors in their design state and applied, if possible, some approaches used for evaluation of PWR reactors during operation.

REFERENCES

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