Joint Cooperative Research on Technology Familiarization through Comparison and Analysis of Codes for Czech New NPP Construction

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1. Introduction

The six nuclear power plants operating in the Czech Republic are VVER-type reactors from Russia technology. The Czech nuclear industry is very familiar with VVER technology. However, the new nuclear power plant to be introduced will be selected as a Pressurized Water Reactor (PWR) from Korea, the United States, or France in the end of 2023. Thus, the Czech nuclear industry and academia need to be technically familiarized with the Western reactor type, PWRs in detail.

Based on the above backgrounds, the international consortium R&D project with Czech Technical University (CTU) in 2022 was awarded to support a new nuclear power plant (NPP) construction in the Czech Republic. The cooperative R&D project was focusing on two main subjects will be investigated, as follows:

1. Technology Familiarization through Comparison and Analysis of Codes & Standards, MMIS using Digital I&C Technology and Key Technologies in Reactor Physics.
2. Development of the Czech Accident Tolerant Fuel Model

This paper is only focused on technology familiarization through the comparison and analysis of Codes & Standards to support the localization and national involvement plan for new Czech nuclear power plant.

2. Technology Familiarization through Comparison and Analysis of Codes & Standards

The regulatory authority, State Office of Nuclear Safety (SÚJB) issued a positive opinion on the applicability of the Normative Technical Documentation of the Association of Mechanical Engineers of the Czech Republic (NTD ASI) as Code for operating VVER NPPs. Based on the assessment of all NTD ASI sections, the SÚJB recommended the use of NTD ASI sections I to VI to classify the safety classes components and calculate the stress analysis of equipment of NPPs of the VVER. The NRD-ASI has the following objectives.

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- Evaluation of the strength of apparatus, pipelines and their supports, which were designed, manufactured, inspected, assembled and put into operation according to original or new projects for the area of strength certificates of equipment and pipelines of NPPs,
- Determination of the conditions under which new materials and new additional materials for welding can be included in the list of materials applicable
- Determination of the conditions under which new materials and new additional materials for welding can be included in the list of materials applicable for the production and repair of VVER-type equipment and pipelines,
- Evaluation of the remaining service life of VVER-type equipment and pipelines within the framework of pre-operational security messages.

To meet the objectives, the NTD-ASI consisted six sections as follows:

I. Welding of equipment and pipelines of nuclear power plants of the VVER type
II. Characteristics of materials for equipment and pipelines of nuclear power plants of the VVER type
III. Evaluation of the strength of equipment and pipelines of nuclear power plants of the VVER type
IV. Evaluation of the residual life of equipment and pipelines of nuclear power plants of the VVER type
V. Material tests
VI. Air handling systems of nuclear power plants of the VVER type

NTD-ASI of I to VI should be applied for the special cases of equipment and pipelines of NNPs of the VVER type only.

3. Preliminary Results of Comparison of Codes & Standards

To analyze the results of previous studies, KINGS team is analyzing the Multinational Development Evaluation Programme (MDEP) results, comparison between KEPIC (MKB) and ASME Code Section III in area of

Material, Design, Maintenance, Installation, Testing/ Inspecting and Operation. Currently KINGS is to develop the comparison mapping table between CZR NTD ASI Section III and KEPIC/ASME Section III. In Czech side, UJP and CTU are involving to analysis the comparison between NTD-ASI and ASME Section III to understand the requirements of safety grade components**.**

The NTD-ASI Section III is probably the significant differences from ASME code in structure and technical contents. A one-way comparison was made, i.e. ASME code requirements were compared with the requirements of ASI section III. A reverse line-by-line comparison was not carried out, since this would require full knowledge of all regulatory documents (SÚJB documents in the first place), which KINGS team in the code comparison project do not have the proper knowledge and competence. The following differences are analyzed as preliminary research results:

- NTD ASI section III adopted the philosophy of ASME, i.e. stress categorization, assessment of fatigue strength and strength against sudden brittle fracture.
- NTD-ASI does not contain a clear definition of the boundaries between the components of the different groups, like chapters NN-1130 (NB 1130 Boundaries of Jurisdiction Applicable to this Subsection) of the ASME code.
- The design rules for NTD-ASI section III are practically independent of the safety group, in particular, the strength calculation rules for all safety groups are the same (i.e. class 1, 2 and 3). The rules for manufacturing and operation (including testing and control) depended on the safety group according to NTD-ASI section III.
- NTD-ASI section III does not contain requirements for the marking system and certificate holders similar to those included in the ASME code.
- Being 30 years younger than ASME Code Section III, NTD ASI could more easily accommodate new science and terms, especially the use of finite element method (FEM), hysteresis loop, rain flow method, material memory, into the text.
- NTD ASI Section III, in addition to approximate fatigue strength curves (see Manson 1966), contains relationships for fatigue strength curves measured under cyclic loading. For approximate fatigue strength curves, it is sufficient to do only a tensile test.
- NTD ASI Section III presents the analytical expression of fatigue strength curves, ASME Code only in graphic form and in tables, applicable to a group of similar steels.
- For the ASME Code fatigue strength curves, it is not clear at what cycle range they were measured in the low-cycle fatigue (LCF) region under hard loading and at what cy range in the high-cycle fatigue (HCF) region under soft loading. It can be assumed that they were not only extended from the LCF area to the HCF area.
- NTD ASI Section III uses the rain flow method to determine the peaks of hysteresis loops. ASME Code Section III describes the determination of the stress cycle. NTD ASI Section III more precisely defines the stress cycle as a hysteresis loop. The stress range and the strain range are given by the peaks of the hysteresis loop.
- When changing the direction of the principal stresses under complex loading, where all simultaneously acting loads are not dependent on a single time parameter, the ASME Code Section III approach was taken as a model for NTD ASI Section III. However, NTD ASI Section III, after finding the most unfavorable moment with the largest principal stresses and their directions, has inserted one more phase into the procedure.
- ASME Code Section III defines reversible and non-reversible pipe loading in fatigue testing, which is not in the NTD ASI Section.
- ASME Code Section III defines in more detail the stress assessment and limitations in several component details. NTD ASI expresses this more generally. However, this should not be critical to assess the strength and durability of the components, but will be examined in more detail.

For example, two cases are described for similar or different requirements.

1) All welds shall be examined 100% by radiography in accordance with the method and acceptance. Both Code requested the radiography inspection of welding.

	ASME	NTD ASI
Inspection of Welding	NB-2560 Examination and repair of tubular products and fittings welded with filler metal. The plate shall be examined in accordance with NB-2530 prior to forming, or alternatively, *the finished product shall be examined by the ultrasonic method in ac accordance with NB 2562.*	*Complete ultrasonic and radiographic inspection of welded joints shall be provided for pipes with longitudinal and spiral welds independently.*

2) For forming tolerances, both Code introduced the different formula for Ovality clearance.

NB-4220 FORMING TOLERANCES

NB-4221 Tolerance for Vessel Shells

Cylindrical, conical, or spherical shells of a completed vessel, except formed heads covered by NB-4222, shall meet the requirements of the following subparagraphs at all cross sections.

NB-4221.1 Maximum Difference in Cross-Sectional Diameters. The difference in in. (mm) between the maximum and minimum diameters at any cross section shall not exceed the smaller of

(SI Units)

$$\frac{D}{200} + 1\,250 \text{ and } \frac{D}{100}$$

where D is the nominal inside diameter, in. (mm), at the cross section under consideration.

In NTD ASI, the mentioned requirements are valid if technical documentation on the product does not establish smaller values of deviation of the outlet diameter and ovality value, Ovality is determined by the following formula :

$$\boldsymbol{Ovality = 2 \times \frac{D_{max} - D_{min}}{D_{max} + D_{min}} \times 100 < 1\%}$$

$$D_{max} - D_{min} < 20 \text{ mm}$$

The different formula to check the ovality were suggested from two Codes.

4. Technical and Economic Impacts

Through vitalizing technological cooperation by sharing the codes and standards comparison analysis, the partnerships with domestic institutions and manufacturing companies of both countries will be increased to support localization and national involvement for new NPPs construction of Czech Republic. The high localization rate will be more positive messages to new Czech NPP project.

5. Conclusions

As a result of the comparison, it can be concluded that both compared documents are based on similar technical ideas and normative approaches. Their implementation differs in technical features that have historical roots. For example, ASME code distinguishes 3 safety classes (1, 2 and 3) and NTD-ASI divided three groups (BT1, BT2 and BT3), but one code was applied for all three classes.

The scope of the ASME code is wider than the documents of the NTD ASI Section III, which apply only to the elements of the "nuclear island", which are pressure boundaries. In particular, the requirements of NTD ASI Section III do not apply to fuel elements, internals, equipment and pipeline supports, metal structures, turbine casings, shipping containers, metal lining of concrete buildings.

Only after a detailed examination of the differences in the results of the assessment of the strength and durability of the components can one begin to evaluate the individual procedures of both standards with the words: it matches; does not match; the difference is not fundamental; the difference is acceptable for defined measures.

REFERENCES

[1] ASME Report STP-NU-051-1,“Code Comparison Report for Class 1 Nuclear Power Plant Components,” American Society of Mechanical Engineers Standards Technology, LLC, December 31, 2012, New York, USA.

[2] American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, 2007 Edition, Section III, Division 1, “Rules for Construction of Nuclear Facilities Components,” New York, USA.

[3] Association Française pour les régles de Conception, de construction et de surveillance en exploitation des matériels des Chaudières Electro Nucléaire, Règles de Conception et de Construction des Matériels Mécaniques des Ilots Nucléaires REP (RCC-M Code), 2007 Edition, France.

[4] Korea Electric Association, Korea Electric Power Industry Code, 2005 Edition up to and including the 2008 2nd Addendum, Korea.

[5] Multinational Design Evaluation Programme, “Technical Report: Fundamental Attributes for the Design and Construction of Pressure-boundary Components,” MDEP Technical Report TR-CSWG-03, OECD Nuclear Energy Agency, France.

[6] Strength Evaluation Equipment and piping VVER type nuclear power plants, Identification number: NTD ASI – III – 2023, Praha, Czech Republic.

[7] PNAE G-7-002-86, Rules of strength calculation for equipment and pipelines of nuclear power plants, State Committee of The USSR For Supervision Over Safe Implementation of Activities In Nuclear-Power Engineering, Russian Federation.

[8] PNAE G-7-008-89, Rules of arrangement and safe operation of equipment and pipelines for nuclear facilities, Russian Federation.

[9] PNAE G-7-009-89, Equipment and piping of nuclear power installations. Welding and overlaying, basic provisions, Russian Federation.

[10] PNAE G-7-010-89, Equipment and pipelines of nuclear power units. Rules of welding and alloying joints control, Russian Federation.