Ageing Management and Long Term Operation in VVER440

ABSTRACT

Evaluation of the construction lifetime is necessary especially for operation of industrial buildings. For VVER440 in Slovakia we are using technologies of technical diagnostics, computer modelling and probabilistic approaches for their evaluation. The aim of the solution is to ensure such outcomes that will allow technically document that the operator has all tools allowing him to ensure required safety functions of industrial building. Based on the results of measurements, an overall quality rating of the building is carried out using the software Mathcad. The building lifetime is set on the basis of lifetime determination of all building parts of the structure. In conclusion there are defined the corrective measures for safe and economical operation. For data storage from inspection and to support the assessment, an ageing management database is developed in software Oracle. The aim of the database is to specify the information outputs for decision-making processes. Findings are compared with license conditions and requirements to obtain an evidence about the civil structure capability to fulfill the set safety functions. It includes a graphical module where we can search the found faults of building structures and where we can enter established facts interactively.

1 DEFINITIONS AND ABBREVIATIONS

Ageing Management Database
A supporting database application for the ageing management programme programmed in ORACLE to collect and evaluate ageing management data.

Degradation Mechanism
A specific process at which negative changes of material properties of systems, structures and components occur due to the environmental impact or operation.

Condition Indicator
A characteristic that can be monitored or measured or its trend can be monitored to estimate or directly indicate the existing or future capability of systems, structures and components to fulfil its function within specified acceptability criteria.

Failure
Partial or complete loss of capability of an element or a supporting system to fulfil required functions.

Ageing Management Programme
A system of organisational and technical measures for ageing management, including optimum organisational structure, determination of responsibilities, preparation of necessary methodologies, technological procedures, provision of materials and staffing.

Rehabilitation of Structure
Removal or replacement of partially worn or damaged parts of structure and formation of protection to extent its lifetime.

Technical Lifetime
Time after expiration of which properties degrade; the technical lifetime is always longer than the design one.

Technical Condition
Condition of structure specifying its capability to fulfil required functions under set conditions of its use. Besides other characteristics, the technical condition is described by values of diagnostic properties.

Design Lifetime
Lifetime under conditions defined by a designer.

ABBREVIATIONS

AOC - Abnormal Operation Conditions
UIS - Unit Information System
AMD - Ageing Management Database
PC - Primary Circuit
SC - Secondary Circuit
IQAP - Individual Quality Assurance Programme
NPP - Nuclear Power Plant
L&C - Limits and Conditions (Technical Specification)
IGC - Inter-Granular Corrosion
NDT - Non-destructive Testing of Materials
NOC - Normal Operation Conditions
AMP - Ageing Management Programme
AM - Ageing Management
SE-EBO - Slovenské elektrárne, a.s. – Atómové elektrárne Bohunice z. (Bohunice Nuclear **Pow**er Plant, branch)
SE-EMO - Slovenské elektrárne, a.s. – Atómové elektrárne Mochovce z. (Mochovce Nuclear **Pow**er Plant, branch)
SSC - Systems, Structures and Components
TI - Technical Inspection
NRA SR - Nuclear Regulatory Authority of the Slovak Republic

2 INTRODUCTION

The aim of the ageing management programme is to ensure serviceability of the Reactor Building during designed as well as scheduled long-term operations of SE nuclear units within the anticipated 60-years operation.

The Reactor Building civil structures ageing management programme is aimed at:

- Enhancement of the safety level by time forecast of condition of the NPP building civil structures;
- Evaluation of real condition of the technical lifetime utilisation and its trends;
- Conceptual influencing of conditions of use of the Power Block civil structures, i.e. operation, diagnostics, maintenance and modifications from the viewpoint of total utilisation of design lifetime to the set safety margin;

The building ageing management programme encompasses civil structures important from the viewpoint of the PC integrity, and thus of the nuclear safety. The following civil structures are concerned:

- Reinforced-concrete structure;
- Steel lining; and
- Components of technological equipment built into the civil structure.

The ageing management programme shall ensure reliability and safety of the monitored building civil structures by identification of:

- Initial condition;
- Materials and material properties;
- Ageing mechanisms;
- Places of degradation;
- Degradation level indicator; and
- Consequences of degradation by ageing and of follow-up failures at both the NOC and the AOC.

The purpose of the Ageing Management is to:

- define mechanisms of degradation of the civil structures;
- define critical places;
- define identification methods and methods of degradation mechanism monitoring;
- define acceptance criteria of allowable degradation;
- define the data range necessary for lifetime evaluation;
- define outputs of building lifetime evaluation;
- evaluation of withdrawal of lifetime due to degradation mechanism effects;
- preparation of assessment of the building condition (fulfillment of legislative requirements);
- preparation of corrective actions in case of unexpected lifetime withdrawal trend;
- collection and recording data for evaluation of the building condition;
- retention of data characterizing condition of equipment in the Ageing Management Database;
- create technical specifications for safety after plant closure.

3 MATERIAL AND OPERATION CHARACTERISTICS

Reinforced-concrete walls of the hermetic boundary consist of reinforced blocks with the thickness of 1,500 mm mutually connected by welding. Components constructed in this manner are fitted with lining plates on their obverse sides (somewhere on both sides). After geometric arrangement, internal space of the reinforced blocks was filled with concrete mixture providing for the containment shielding.

a) EBO Weather Conditions

The SE-EBO Reactor Building is situated in the cadastral area of Velke Kostolany and Pecenady in the Trnava region (Western Slovakia). It is situated on an elevated flat of the valley that is a continuation of East spurs of Male Karpaty mountains.
Assumed extreme values of the most monitored meteorological elements of air temperature and precipitations in this century in Jaslovske Bohunice region are as follows:

- absolute air temperature maximum 38.0 °C;
- absolute air temperature minimum -30.0 °C;
- the highest annual precipitation 830 mm;
- the highest snow cover height 60 cm.

b) EMO Weather Conditions

The SE-EMO Reactor Building is situated in Levice district in the altitude of 350 m with 50 summer days per year, in the warm, mildly dry area with mild winter. The summer is usually warm – with 15 % tropic days and 50 % days that can be characterised as summer days in average. In winter are less than 30 days with the all-day freezing.Assumed extreme values of the most monitored meteorological elements of air temperature and precipitations in this century in Mochovce region are as follows:

- absolute air temperature maximum 37.0 °C;
- absolute air temperature minimum -25.0 °C;
- the highest annual precipitation 750 mm;
- the highest snow cover height 50 cm.

c) Data on Internal Environment

The vent system at the inlet unit sucks fresh air from the inlet shaft and filtrates it using inserted dust filters. The heat exchangers have been designed for heating from -12 to +18 °C in winter, and for cooling from +29 to +25 °C in summer.
Concrete structures are exposed to long-term effects of temperature at increased humidity. The humidity values range from 20 to 100 %.

The concrete structures' temperature ranges in relation to the measured place position from 15 ^{o}C to 70 ^{o}C. Temperatures in various places of individual premises markedly differ. They depend on effectiveness of ventilation equipment in the place of monitoring, and from seasons, operation or outage of the particular Unit, and they differ also in the Units themselves. In many cases, requests for maintaining a certain temperature at operation are not prescribed, in particular if non-attended premises are concerned. Since operation temperatures in the containment reach 50 ^{o}C and more, their effect can be characterised by heat transfer towards colder non-hermetic premises and to the ambient environment, and thus it evokes tensile stresses in concrete it its colder side.

d) Data about Bedrock

The SE-EBO Reactor Building is situated in the central part of Blatnianska depression of the Danube Basin and it is situated on a geological substrate formed from a relatively gross loess blanket from the Pleistocene medium and top periods. In the loess bedrock, the Pleistocene and Pliocene gravels and sands are situated. The Miocene sediments in their bedrock are represented by clays, sandy clays and sands from Pont and Panon periods.

The SE-EMO Reactor Building is situated in rocks – on a volcano range with high bearing capacity. The foundation plate plan dimensions are 147.00 x 79.95 m, the thickness equals to 1.5 m and it is constructed from B250 concrete. Thanks to its character, thickness and dimensions, the foundation plate of the Reactor Building can be characterised as a massive reinforced-concrete structure.

e) Data about Neutron Flux in Reactor Vicinity

In the core level, composition of the construction material behind the reactor vessel is as follows. The reactor vessel surface is 1.92 m far from its centre. Then there is the air gap with the thickness of 0.315 m. It is followed by heat insulation with the total thickness of 0.100 m. The air gap with the thickness of 0.035 m is followed by a marmolite concrete layer with the thickness of 0.7 m. This layer making a neutron flux protection finishes in the distance of 3.07 m from the reactor vessel centre. This layer is followed by structural concrete of the reactor pit with the thickness of 2.60 m. This concrete must be assessed from the radiation damage effects viewpoint.

Measurements have proven that the neutron flux at the marmolite concrete and the structural concrete interface of the reactor pit equals to Φ = 7.2 x 106 n.cm-2.s-1.

4 IDENTIFICATION OF DEGRADATION MECHANISMS

Long-term behaviour of the reinforced-concrete containment (as well as of other concrete structures) depends primarily on durability of these structures and their individual components and on their ability to withstand potential degradation impacts.

The containment civil structure components at which potential ageing mechanisms can be showed are in particular the followings:

- Concrete;
- Steel reinforcing bars in concrete;
- Steel lining;
- Penetrations;
- Seals and sealing inserts; and
- Protection coats.

Degradation factors affecting individual components of the containment civil structures are in particular the followings:

- Chemical actions;
- Physical actions; and
- Mechanical actions.

REINFORCED-CONCRETE STRUCTURE

Concrete properties change due to its ongoing micro-structural changes as well as due to environmental impacts with every passing day. Mechanisms of transport in pores and cracks and water presence are dominant factors affecting lifetime of concrete structure almost in all chemical and physical processes. Cracks occur almost in all concrete structures and due to a naturally low tensile strength of concrete, they cannot be absolutely prevented. Cracks are important also because they can predict serious structural problems, e.g. unequal setting-down, they can represent a route for penetration of adverse environment, and they can prevent fulfilment of operation conditions of a particular element that are set to it.

STEEL STRUCTURES, REINFORCING BARS, LINING

The support steel structure (columns, beams, roof girders, crane rails) is affected by the following degradation mechanisms:

- Impact of operation (mechanical stress);
- Temperature;
- Humidity; and
- Static and dynamic effects of loads.

Reinforcing bars from mild steel are inserted into concrete structures to withstand compressive and tensile stresses, to serve as structural reinforcements, and to limit the extent and width of cracks at operation conditions.

The reinforced-concrete structures use the lining to ensure leak-tightness of premises and to facilitate cleaning operations if decontamination is required.

The steel lining is exposed to the same general degradation mechanisms like the reinforcing bars from mild steel, out of which corrosion and fatigue are the most important. The lining is usually protected by coats preventing to withstand the environmental impacts and thus the corrosion. The most important is a local corrosion impact that can lead to loss of its leak-tightness. The local acting may occur as a result of collection of moisture in areas where the coat integrity has been violated or where sealing material at the floor lining joint has been damaged.

5 DEGRADATION MECHANISM IDENTIFICATION METHODOLOGY

Diagnostics of materials and reinforced-concrete structures is made by the so called building and technical survey. The term building and technical survey means several independently made market surveys.

- Basic building and technical survey – is based on visual inspection of the entire civil structure;
- Complex building and technical survey - is based on NDT measurements and supported by accompanying visual inspection of selected critical places;
- Special building and technical survey – is based on destructive methods.

A report with protocols is prepared from the every survey.

Building and technical survey methods

a) Sense methods; and
b) Instrumentation and laboratory methods.

Sense methods

They are used at detection of the following defects, e.g.:

- surface damages, quality of surface, humidity (magnifying glass, binoculars, mirror);
- cracks (magnifying glass, gauge, plastic foils for detection of depth);
- deformations and movements of larger extents (steel ball, spirit level, plumb line);
- defects of joints of structures;
- traces of biological factors in building materials;

- material quality – estimation of properties;
- hidden hollows.

Instrumentation methods
They are used for more detail detection of mechanical and physical properties. They encompass both the non-destructive and the destructive methods.

a. Non-destructive

They are used for testing materials without damages or with damages of the extent at which functional properties of the tested component remain preserved. Tests by these methods are applied in particular directly at the structure.

b. Destructive

It is necessary to sample the required material part for physical, mechanical and laboratory tests and analyses. These tests are made in a testing laboratory or in another laboratory. Surveys made by these methods should be minimised because of violation of the structure and reduction of finances and time required for the survey.

6 DATA COLLECTION AND REGISTRATION

Concrete containments in NPPs are exposed to many environmental impacts during operation; they may affect their capability to continue in fulfilment of functional and operational requirements. Due to significant safety as well as economic impacts that could occur if these structures were impaired to the level unacceptable for operation, it is important to inspect them in regular intervals.

Findings should be compared with licence conditions and AMP requirements to obtain an evidence about the civil structure's capability to fulfil the set safety functions. Documenting the course, conditions and results of the monitoring in compliance with requirements of the quality assurance programme is an important step how to prepare a reliable AMP database for the given structure. The quality of documentation is important in particular from the viewpoint of changes in time, based on which the best possible estimation of further development or course of ageing processes can be formed. Data retention enables to identify a degradation impact trend with regard to the CS age. Increase of costs many signalise deterioration of operation conditions or incorrect maintenance and repair practices as well.

Monitoring interval of the basic building and technical survey in case of reinforced-concrete and steel structures equals to every 2 years at least.

Ageing Management Database
Civil structure is divided to the following civil parts in the AMD, and these parts are divided to the following individual system components (inspected places):

- Bedrock with foundations (divided to individual components);
- Supporting reinforced-concrete walls of rooms adjacent to the containment;
- Hermetic boundary of the containment containing the following components: reinforced-concrete with reinforcing bars, hermetic lining (containing the following component types: welds without control volumes, control volumes of welds, pressurizing nozzles, plates, anchors, coat), hermetic penetrations (electric, pipe), hermetic doors, hermetic covers, reactor lid etc.;
- Containment internals (concrete reactor pit and refuelling pit, and their carbon and austenitic steel linings);
- Supporting steel structures.

This division has been designed on the basis of recommendation of the final report of SALTO programme (IAEA, EBP, Final working group 4 report, Structures and structural components, 12/2005).

“Building constructions” module

The “Building constructions” module deals with the issue of operational life of selected constructions as well as structures of nuclear power plants that are stressed by the impact of weather conditions, are exposed to the action of circulating chemically treated water, are stressed by high temperatures or pressure, and are deteriorated by radiation field. Some data are aggregated, e.g.: data about relevance of breakdowns, deteriorating mechanisms, maintenance interventions, tests, incl. laboratory tests.

“Qualification” and “Seismic Qualification” modules

The qualification process confirms that the device is capable (during the whole period of its operational life) of fulfilling safety function requirements during the whole time when environment conditions are acting. Qualified operational life means: a period of normal work during which the ageing process does not cause such deterioration of device that might lead to malfunctioning during the successive postulated event.

The “Qualification” module allows monitoring of the above mentioned requirements (i.e. it provides a clear view of the devices together with their qualified operational life, requalification intervals, replacement of devices with terminated qualified operational life, and mapping of changes relating to environment quality. The seismic module monitors a special part of environmental impact on the mechanical, electronic, and architectural devices. It sums up the influences of seismic factors for three basic modules of database (that is the reason why it is connected with them). It includes an extended database of relevant data that are necessary for assessing seismic situations. In this manner it is possible to follow and evaluate approximately 15000 pcs. of devices located in the nuclear power plant.

7 SCOPE OF CIVIL STRUCTURE MONITORING

The containment civil structure condition is monitored periodically at every Unit according to specified interval.

INSPECTION PLAN

The Inspection Plan organised according to individual survey types.

a. Basic building and technical survey

b. Complex building and technical survey

c. Special building and technical survey

Basic building and technical survey

Concerning its scope, it is based in particular on visual examination and observation. Inspection of visible areas with orientation on condition of surfaces, occurrence or corrosion of steel structures; to concentrate on wet places. Visual examination of details (anchorage of columns, crane rail vicinity). Inspection of envelopes and the roof cladding.

Complex building and technical survey

It is made by visual examination of selected critical places and by NDT. Time intervals as well as the examination type and scope depends on importance and complicatedness as well as on condition and intensity of use of structure as well as on condition of used building materials.

Special building and technical survey

These examinations are extraordinary and they sometimes require use of special instrumentation. Laboratory tests of samples are in particular used.

They are performed:

- on the basis of recommendations from other inspection;
- in case of substantial changes in condition, operating parameters of intensity of use of the structure;
- in relation to unusual events (e.g. fire, tornado, rapid overloading at change of technology, diversionary activities etc); and
- after a certain time interval.

8 MAINTENANCE ACTIONS

Type and quantity of maintenance actions performed at equipment are significant indicators for assessment of condition of the Reactor Building civil structures. From the equipment lifetime viewpoint, actions at which the equipment was repaired or its part was replaced due to unacceptable indications are important. Such actions are as follows:

a. Grinding;
b. Welding and Welding on;
c. Machining;
d. Replacement of civil structure parts or the structure as a whole.

Information about maintenance actions are registered in the AMD.

The following data of every action are registered:

a. Identification data about equipment, part and inspected place;
b. Date when the action was made;
c. Description and result of action; and
d. No. of SAP order.

9 REFERENCES

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