Development and Installation of Semi-Hot Cell Equipment for Irradiated Miniaturized Specimens Preparation, Manipulation and Testing

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In the terms of nuclear power plant operational life management, current trend of components lifetime extension requires precise information of structural material degradation.

Present-day conventional methods of mechanical testing are usually based on the use of large specimens and higher consumption of testing material, whose availability and volume is often limited.

Sampling of the sufficient volume of the material is usually very hard to be realized without affecting the integrity of evaluated component.
At present time, considerable attention is paid at ÚJV Řež to the employment of innovative semi-destructive testing methods in the process of irradiated material degradation evaluation.

This is possible mainly due to successfully finished recent refurbishment projects at Hot Cell Facility enlarging the testing capacity of the laboratory.

On the other side, employment of techniques for the testing of miniaturized specimens brings consequences with necessity for more precise methods of specimen manufacturing and transportation as well as demands on the equipment for testing and analyses.
Hot Cell Facility - General Overview

- Operating fleet of 51 hot and semi-hot cells (from 1970)

- Focused mainly on mechanical testing in the frames of surveillance programs of WWER type reactors
  - Czech Republic (Temelín NPP, Dukovany NPP)
  - Slovak Republic (J. Bohunice NPP, Mochovce NPP)
  - Ukraine

- Involved in research projects
  - IAEA Coordinated Research Projects (CRPs)
  - EC Framework Programs
  - National grant research projects (Ministry of Industry and Trade, Technology Agency of the Czech Republic)
Hot Laboratory - General Overview

- Preparatory and auxiliary activities
  - Unloading of irradiation containers
  - Fluence monitors evaluation
  - Specimen machining
  - Specimen EBW reconstitution

- Shielded by 1,25 m of heavy concrete
- Assumed activity up to 370 TBq
- Department of High Activity Laboratories and Irradiation Experiments
„Semi-hot“ Laboratory - General Overview

- Mechanical testing – structural materials from surveillance programs
  - Tensile testing / SPT / ABIT
  - Impact testing
  - Static / Dynamic fracture toughness
  - Hardness testing
  - High temperature testing
  - SEM analysis
- Shielded by 150 mm of lead
- Assumed activity up to 37 GBq
- Mechanical Testing Department
Laboratory is accredited in accordance with ČSN EN ISO/IEC 17025
(Czech Institute for Accrediation)
During past years the refurbishment of former radio chemistry facility was carried out to enlarge the testing capabilities of Hot cell facility.

Several projects form 2011 to 2015 were focused on the refurbishment of seven semi-hot cells (glove boxes and monolithic type of cells called „Golem“).

More detailed information can be found in the proceedings from previous HOTLAB meetings:

- Refurbishment of semi-hot cells No. 11 – 15 (2011, Smolenice, Slovakia)
- Refurbishment of semi-hot cells No. 9 and 16 with implementation of new specimens transport system (2014, Baden, Switzerland)
Refurbishment projects

- Refurbishment of the monolithic semi-hot cell „Golem“
Refurbishment projects

- Present state of the refurbished semi-hot cell laboratory
Projects

- In several past years, two grant projects of Technology Agency of the Czech Republic focused on the implementation of innovative semi-destructive testing methods into evaluation of irradiated NPP structural materials degradation were approved for support:
    - Cooperation with Czech Technical University in Prague (FNSPE) and Material and Metallurgy Research, Ostrava
  - **Automated Ball Indentation Testing (2013 – 2015)**
    - Cooperation with Czech Technical University in Prague (FNSPE)
Small Punch Testing (SPT)

- Test method is based on the testing of thin clamped specimens using semi-spherical punch with the measurement of the specimen deflection.
- The purpose of SPT is to determine mechanical properties of materials (yield strength, ultimate tensile strength, fracture mechanics properties).
Automated Ball Indentation Testing (ABIT)

- Semi-destructive testing technique for determination of true-plastic strain curves of metallic materials and the structural components including welds and heat-affected zones

- Determination of mechanical properties – yield strength, ultimate tensile strength, strain hardening exponent

- It is based on the principle of strain controlled multiple indentations at a single penetration location on a polished surface by a small spherical indenter

- Instrumented hardness test method is fully automatic and does not require the diameter of the indentation to be measured after testing.
Automated Ball Indentation Testing (ABIT)

Instrumented Hardness Test method geometry during force application and after force removal (complete unloading)

Schematic of applied force versus indentation depth of the ball indenter

Real test data for IAEA correlation material A533B (JRQ)
Small Punch Test – Test Specimen Production

- The dimensions of the small punch test specimen – ø8x0.5 mm, ø6x0.5 mm, 10x10x0.5 mm and 4x3x0.5 mm,
- The test specimen production from irradiated materials:
  - In the first approach, the specimens were cut by standard metallographic saw, which resulted in the high volume of deformed specimens (produced disc bent often)
  - As a partial solution – use of the saw disc with the off cut of 150 μm was used (not preferable due to high volume of subsequent grinding)
  - In general, the material is cut using electric discharge machine (EDM) in a hot cell into discs with required test specimen geometry (with some improvements of the machine).
  - When the EDM is not suitable for cutting – diamond saw is used instead (e.g. for cutting of specimens from sub-sized Charpy type specimens with the cross section of 4 x 3 mm)
Preparation of the Small Punch Test Specimen

- New polishing equipment installed in semi-hot cell No. 11
Preparation of the Small Punch Test Specimen

- Additional components of the polishing facility - **sample holder JIG** (polishing capacity up to 6 specimen simultaneously) and **robotic arm** for transferring and adjusting of the JIG with the samples in the polishing machine (necessary due to 5 kg load limit on the M/S manipulator)
Small Punch Test Testing Equipment

- Equipment for assembly of the specimens testing fixtures – various types of fixtures depending on the type of specimen (Ø8 x 0,5 mm, 10 x 10 x 0,5 mm, 4 x 3 x 0,25 mm)
Manipulation with the SPT samples

- Every semi-hot cell involved in the SPT testing was equipped with the system of pneumatic sample holders.
- Motivation was to eliminate the possibility of damaging the surface of the thin specimen with the grip of M/S manipulator (with possible influence on the test results).
Modification of ASPEX SEM to enable fractographic analyses
Modification of INSTRON temperature chamber with the installation of automatic specimen positioning system
Conclusions (1/2)

- Equipment, essential for the preparation, testing and subsequent analyses, was designed by the ÚJV Řež and successfully implemented in the process of SPT and ABI testing of irradiated materials.

- Use of the new equipment in hot and semi-hot cells enables the possibility of sub-sized specimens testing without affecting its integrity by non-precise machining and manipulation.

- This brings opportunity for the use of small size specimens in the standard testing processes of irradiated NPP materials and to enlarge the volume of testing data base in the frame of RPV surveillance programs.
Conclusions (2/2)

- Based on the experimental data, both methods (SPT, ABIT) showed to be very promising for assessment of structural irradiated NPP materials degradation (esp. for hardly replacable components) and will be further developed at the institute.

- At the present time attention is paid to enlargement of test results database, especially for irradiated materials from the surveillance programs.

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Thank you for your attention

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