DEVELOPMENT AND INSTALLATION OF SEMI-HOT CELL EQUIPMENT FOR IRRADIATED MINIATURIZED SPECIMENS PREPARATION, MANIPULATION AND TESTING

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ABSTRACT

During the period from 2012 to 2015, the Mechanical Testing Department of UJV Rez, a. s. was involved in two research projects focused on the implementation of new testing techniques into the standard process of evaluation of NPP irradiated structural materials degradation. These projects were conducted with the support of Technology Agency of the Czech Republic and their main aim was the implementation of innovative semi-destructive testing methods (SPT - Small Punch Testing, ABIT - Automated Ball Indentation Testing) in the portfolio of accredited testing procedures and their application on irradiated materials testing, especially with the focus on irradiated materials of hardly replaceable NPP components. For the purpose of NPP components irradiated materials mechanical testing, the Integrity and Technical Engineering Division of UJV Rez, a. s., operates 51 hot and semi-hot cells equipped with the state-of-art technology for specimen preparation, testing and PIE, creating a solid basis for the solving of research projects of this kind. However, for the purpose of the performed projects it was necessary to design a new hot cell, the equipment within the semi-hot cell, and the procedures to enable the testing and evaluation of the thin sub-sized specimens without affecting their fracture surface while using standard master/slave manipulator tongs. This paper describes the process of the development and the installation of the equipment for remotely controlled miniaturized specimen preparation, manipulation, testing and PIE in the hot cell and semi-hot cell facility of UJV Rez, a. s., Integrity and Technical Engineering Division.

1. INTRODUCTION

Since 1970, UJV Rez, a. s., the Integrity and Technical Engineering Division, operates 51 hot cells situated on the floors of the Radiochemistry building. In the first period of operation until 1978, considerable attention was paid to verifying the operational abilities of fuel elements. Since 1980, most of the activities are focused on the determination of degradation of NPP irradiated structural materials, especially of the WWER type. At present, the main purpose of the facility is to support the Czech (Dukovany NPP, Temelín NPP), Slovak and several Ukrainian NPPs within the framework of their reactor pressure vessel surveillance programs. Besides the portfolio of standard accredited mechanical tests (impact testing, fracture toughness testing, etc.), the laboratory is also focused on the development of innovative testing methods and their employment in the determination of irradiated material operational degradation (within Czech grant projects, EC framework programs and IAEA CRPs).

This paper presents the implementation of new testing techniques into the accredited laboratory of Mechanical Testing Department of UJV Rez, a. s. that are intended to be used for the evaluation of radiation degradation of NPP's irradiated structural material. These techniques are the “Small Punch” penetration testing (SPT), and the instrumented hardness “Automated Ball Indentation Testing” (ABIT).

1.1 Refurbishment project

The starting point for the refurbishment was the requirement to enlarge the testing capacity of the Mechanical Testing Department in the scope of testing for the surveillance programs of Czech and Slovak commercial nuclear reactors. In 2009, decided decision was made to refurbish five semi-hot cells from the former radiochemistry facility. The preparatory activities included a feasibility study of the reconstruction, a project work plan and the obligatory approval of State Office for Nuclear Safety of the Czech Republic. Considerable attention was taken within the project to planning and continuous photo documentation. For each stage of the work a detailed assignment procedure was prepared.

The former radiochemistry facility consisted of five glove boxes with several rod manipulators, connected with a belt conveyer transport system. Significant advantage that has been taken to account in the preparatory stage was the absence of α contamination in the former facility. This fact contributed to simplification of the work procedures prepared for the dismantling phase of the refurbishment. In 2010, reconstruction works started with the dismantling phase. The hot and the semi-hot cells are accessible from two sides – from the operator area and from the active maintenance corridor. From both sides a sealed area from modular plastic panels was constructed to prevent the possible contamination outside of the work place. After that, glove boxes and its support construction were dismantled. Also, according to the new design of the planned semi-hot cells, the shielding concrete wall of the transport system was dismantled. Construction phase of the project started in the beginning of 2011 with the assembly of the support system for modular steel shielding. Shielding consists of several layers of 50 mm thick steel plates connected with bolts. After the steel shielding assembly, the cells were equipped with the welded inner layer of stainless steel, which was sanded after the installation (Fig. 1, Fig. 2). Subsequently, construction works continued with the installation of inner lighting system, painting of the front wall in the operator area and the assembly of the shielding windows (Fig. 3, Fig. 4).

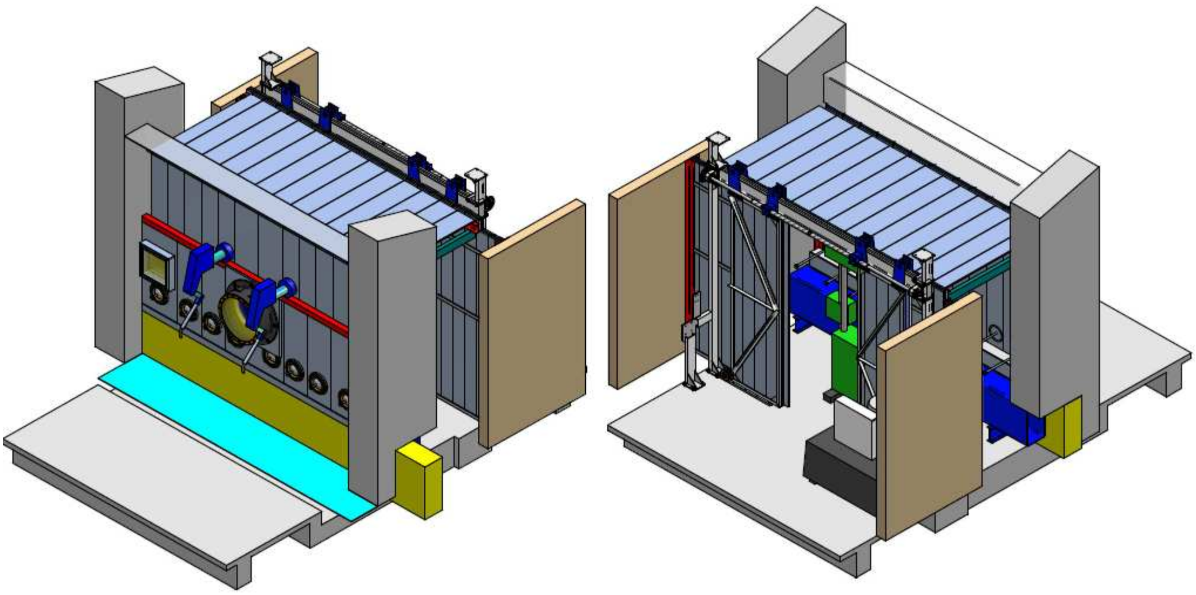

Fig. 1 Scheme of refurbishment of semi-hot cells at UJV Rez, a. s

Fig. 2 Semi – hot cells construction

Fig. 3 Construction – sanding of the interior, installation of the windows

Fig. 4 Present state of the semi – hot cells design at UJV Rez, a. s.

2. Development of innovative semi-destructive testing methods of high active material evaluation

During the period from 2012 to 2015, two projects have been realized with the support of Technology Agency of the Czech Republic. Both projects have been focused on the development of innovative semi-destructive testing method of high active material evaluation for nuclear reactor components lifetime assessment using the miniaturized specimen. The first project, **„**Development of procedure for evaluation of irradiated materials properties degradation of hardly replaceable components of nuclear power plants by the use of punch tests**“,** was realized from 2012 to 2014. The second project, **„**Development of innovative semi-destructive procedure of high active material evaluation for nuclear reactor components lifetime assessment**“,** will be completed at the end of 2015.

For the completion of the two projects, the implementation of both innovative testing techniques (SPT - Small Punch Testing, ABIT - Automated Ball Indentation Testing) was necessary**.** The test specimens for these tests are able to be manufactured from standard test material, e.g. bar or sheet, from broken test specimens from standard mechanical testing (from fracture toughness test, for instance), or directly from the components during their operation.

Successful solution of the projects required a new semi-hot cell equipment for the production, manipulation and testing of sub-sized specimens to be designed. All the equipment was developed with regard to the small dimensions of the test specimens. The requirement for not affecting the surface of specimens during the manipulation, during the production, and during the mechanical testing in hot cell while using standard master/slave manipulator tongs was taken into account.

2.1 Small punch test – test specimen production

The small punch test specimens have the dimensions of Ø8x0.5 mm, Ø6x0.5 mm, 10x10x0.5 mm, and 4x3x0.5 mm. In order to prepare test specimens from irradiated materials, the material was cut with a discharge machine (EDM) in a hot cell into discs with the required test specimen geometry, suitable for the grinding and polishing.

A diamond disc with an offcut of 300 µm was used initially. However the disc bent very often. This produced warped specimens. This problem was partially resolved by using a disc with an offcut of 150 µm. When the EDM was not suitable for the cutting, a diamond saw in another hot cell was used instead. To achieve the required 1% accuracy for the test specimen thickness h_0, additional equipment consisting of the automatic surface polisher was produced. The thickness of each SPT specimen was measured with a Mitutoyo gauge at the middle point on both ends. The thickness of the specimens produced varied significantly, from 250 to 790 µm. For this reason, it was decided to grind the specimens after cutting to produce specimens with the desired thickness of 250 ± 5 µm.

After the testing, the equipment for polishing of the test specimen was installed in a hot cell at UJV Rez, a. s., combined with supporting instrumentation and master-slave remote control system (Fig. 5). The system design provided means of test specimen preparation in accordance with requirements for the small punch test specimens.

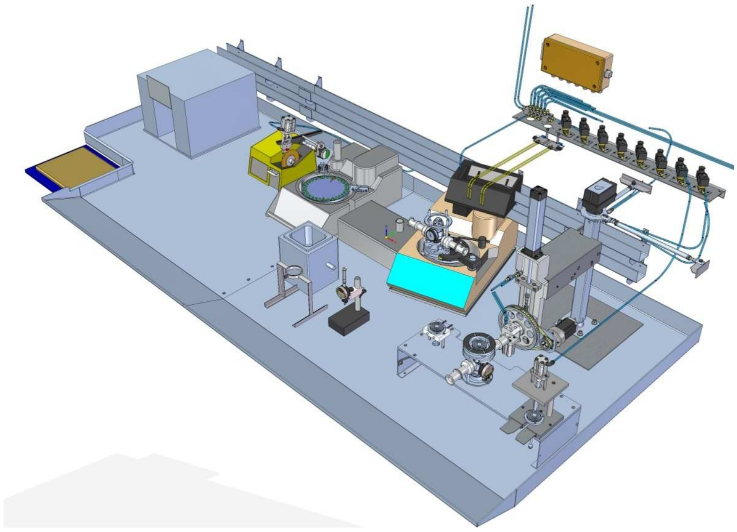

Fig. 5 Polishing equipment setup in a semi-hot cell

2.2 Grinding of the small punch test specimen

The grinding was done with a Logitech lapping machine. The principle of lapping is the removal of a material from the specimens using SiC emulsion floating between the specimen holder and a cast iron disc. The cast iron disc rotates the specimen holder which ensures continuous grinding of the specimen's surface. In order to use the lapping machine, the specimens had to be glued to a metal pad with a mass of around 5 kg. This was too heavy for the Master-Slave manipulators in the hot cell. To overcome this problem, an electronically controlled pneumatic robotic arm, capable of handling the load, was developed (Fig. 6). The main device is the sample carrier – JIG, which is used to hold specimens and subsequently to transport of specimens between the auxiliary settle and the lapping machine (Fig. 6). The polishing equipment setup in a semi-hot cell is shown in Fig. 7.

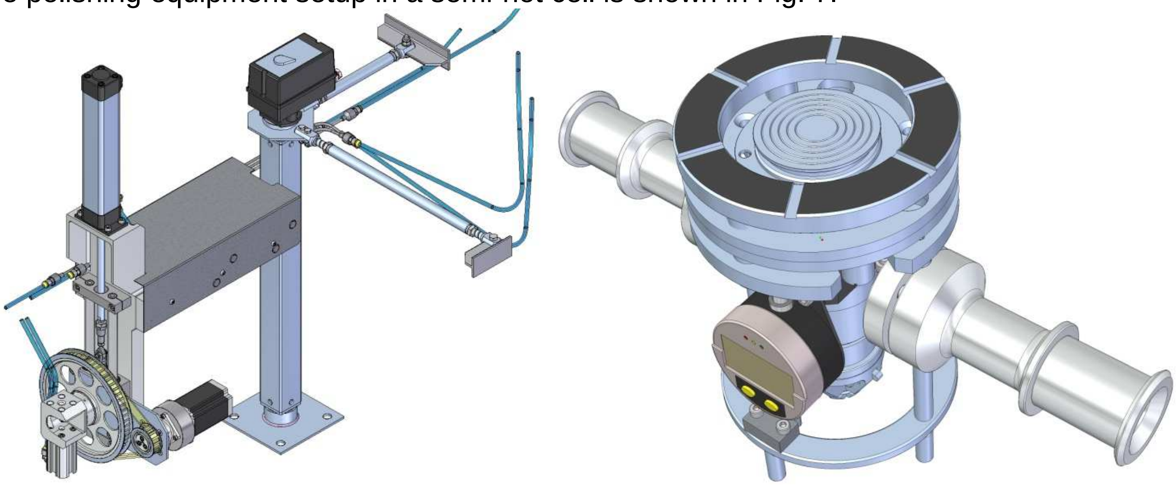

Fig. 6 Scheme of the robotic arm and JIG

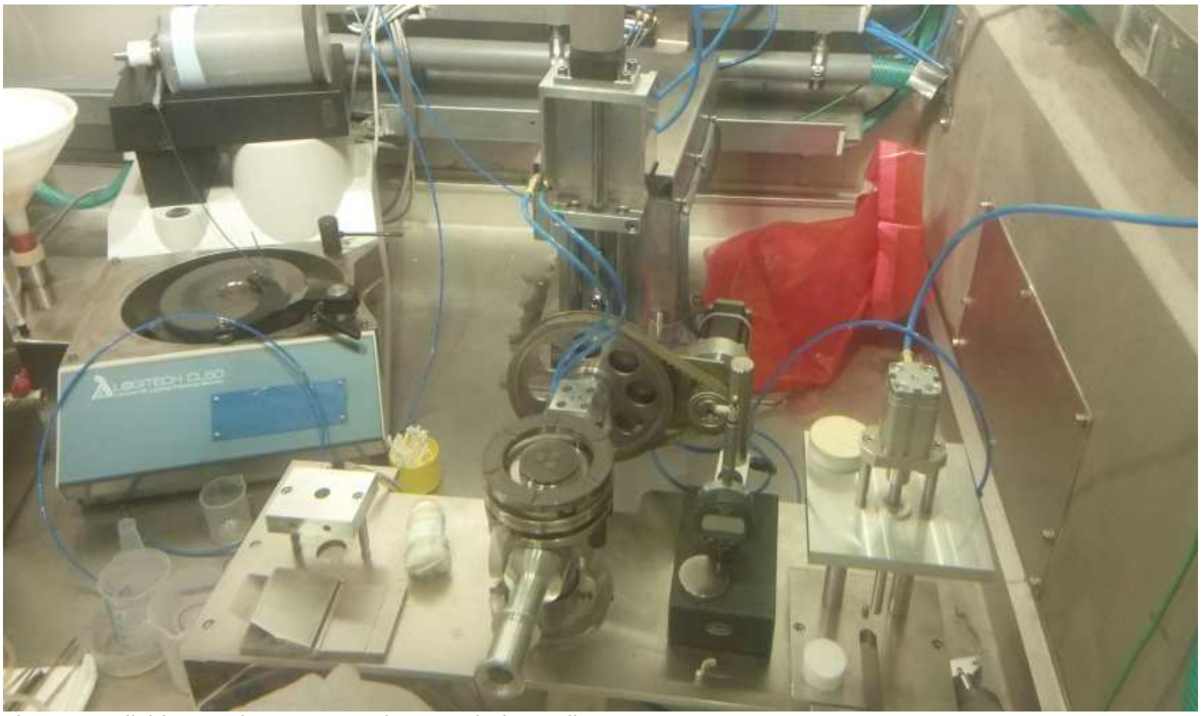

Fig. 7 Polishing equipment setup in a semi - hot cell

2.3 Small punch test testing equipment

With respect to the small dimensions of the miniaturized test specimens, the equipment for their manipulation during the test was developed. In the case of the standard test specimens, the standard master slave manipulators are used. However, for the purpose of the undertaken projects it was necessary to design a new semi-hot cell equipment for remotely controlled miniaturized specimen manipulation, testing and PIE.

The small punch test equipment setup at UJV Rez, a. s. is shown in Fig. 8. The testing is performed on an electro-mechanical testing machine INSTRON (installed into semi-hot cell).

Fig. 8 The equipment for assembly of the specimens testing fixtures and manipulation of the single SPT specimens in semi-hot cell

2.4 Instrumented hardness test equipment

The devices for instrumented hardness test method contain of the indenter with various diameter (2.5, 1.575, 0,762, 0.508 mm). Spherical indenter is made from tungsten carbide. For the purpose of the project, a device to load the samples in the thermal chamber was developed – Fig. 9. The spherical indenter displacement is measured with a high sensitivity linear variable differential transformer (LVDT) extensometer RDPE lin 56. This transducer is used for the displacement/position measurement. It is capable of an accurate position measurement of the movement of the armature relative to the body of the displacement transducer. The LIN differential-inductance LVDT is inductive (similar to a LVDT sensor) and because there is no contact across the sensor element, it is very robust. This sensor has been selected for high temperature, high pressure and high nuclear radiation position measurement applications. Automation of the test, where a PC and test controller were used in innovative ways to control the test including real-time graphics and digital display of load depth test data as well as to analyse test data.

Fig. 9 Device for positioning of the tesing the samples in thermal chamber

3. Conclusion

During last several years, at hot cell facility of UJV Rez, a. s., considerable attention was paid to employment of the innovative testing methods in the process of irradiated structural NPP materials degradation evaluation. For the success of projects it was necessary to modify standard equipment used in testing semi-hot cells and to design and manufacture new devices for machining, manipulation, testing and other PIE. Implementation of the new equipment into hot and semi-hot cells enables the possibility of subsized 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.

4. Acknowledgement

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