

Destructive Examination of Experimental CANDU Type Nuclear Fuel Tested in TRIGA Reactor

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1. Abstract / Introduction

The facilities of RATEN - ICN Pitești allow the testing, manipulation, and examination of nuclear fuel and irradiated materials. The most important facilities are the TRIGA research and material test reactor consisting of two cores (Steady State Reactor – SSR and Annular Core Pulse Reactor - ACPR) and the Post-Irradiation Examination Laboratory (PIEL). The purpose of this work is to present by post-irradiation examination, the behavior of CANDU fuel, irradiated in the 14 MW TRIGA reactor.

The CANDU experimental fuel was tested using the TRIGA Reactor irradiation devices in order to increase the operating limits of the fuel, for the burn-up efficiency improvement and to help identify possible manufacturing irregularities.

In order to investigate the Romanian CANDU fuel behavior and to check and improve the quality of the Romanian CANDU fuel, the power ramping tests have been performed on experimental fuel elements in the TRIGA SSR reactor and their behavior has been analyzed by post-irradiation examination (PIE) in the hot cells.

2. PIE techniques at RATEN – ICN Pitești

2.1 Non-destructive examination techniques

The non-destructive examination provides satisfactory information about the tested material considering the fact that they are non-invasive examination methods. The applied non-destructive examination techniques at RATEN – ICN are:

visual inspection of the cladding;

- profilometry (diameter, ovalization, bending) and length measuring;
- determination of axial and radial distribution of the fission products activity and tomography by gamma scanning.

2.2 Destructive examination techniques

Another use of the non-examination techniques is providing essential information for performing the destructive examination which consists of:

- fission gasses analyses;
- macrostructural and microstructural characterization by metallographic and ceramographic analyses;
- fuel burn-up determination by plasma coupled mass spectrometry;
- mechanical properties determination;
- fracture surface analysis by scanning electron microscopy.

3. Metallographic and ceramographic examination of experimental CANDU fuel

For metallographic and ceramographic examination, a CANDU experimental fuel pin was sampled.

The metallographic samples were embedded in epoxy resin inside the examination cell then transferred to the metallography cell for further preparation. This preparation consists of successive polishing operations in order to achieve a plane surface of the probe, followed by chemical etching in order to highlight the microstructural characteristics of the fuel such as pellet fissures aspect, the grain growth and distribution, the porosity generated by the fission gases, oxide layer and cladding thickness, the hydride plaques characteristics and orientation. The results can be observed in the following pictures



Figure 1. Experimental fuel instrumented with thermocouple



Figure 2. Fuel grains aspect in the middle of the pellet



Figure 3. Cladding aspect of the fuel

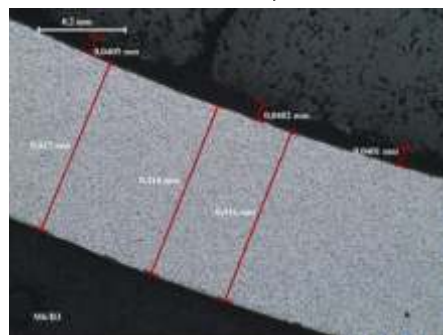


Figure 4. Cladding and gap thickness measurement



Figure 5. Macrograph of longitudinal cross-section

4. Conclusions

Microstructural and macrostructural characterization was performed on a LEICA TELATOM 4 optical microscope having a magnification up to x1000. A computer-assisted analysis system is used for the quantitative determination of structural features, such as grain and pore size distribution. The analyses by optical microscopy provide information concerning the aspect of pellet fissure, the structural modifications of fuel and the sizes of the grains and the thickness of the oxide layer and the cladding hydriding.

The sample longitudinal and cross-section macrographs (figure 1 and figure 5) show connected radial and circular fissures which are normal for CANDU UO_2 pellets and the cladding (figure 4) does not present nonconformities, having a uniform thickness.

The pellet microstructure was analyzed using a magnification of 200x. The examination showed that the fuel pellet consists of unaffected grains and equiaxed grains. (figure 2)

Hydride precipitates dimension and orientation were analyzed using 500x magnification and no major precipitates were observed (figure 3), which represent the expected result due to the short irradiation time.

References

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