Romanian Progress In The Advanced CANDU Fuel Manufacturing

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I. introduction

The initial concept in developing an advanced fuel compatible with CANDU 6 Reactor, using part of Nuclear Fuel Plant (FCN) Pitesti facilities [1] should be revised. New aspects were considered: working within FCN area, a technological transfer suspicion appears (inobservance of AECL-FCN confidentiality agreement), and the enriched Uranium use on FCN area is prohibited (IAEA requirement). Under these conditions, the Institute for Nuclear Research (ICN) decided to develop or modernize its own facilities for nuclear fuel (CANDU type) manufacturing. The intention was to cover the main technological steps in fuel manufacturing, beginning with powder manufacturing and ending up with fuel bundle assembling.

The development or modernization of own facilities for the nuclear fuel manufacturing open the possibilities for the collaboration with other entities interested in advanced fuel development. Having a Research Reactor for material testing and a Post Irradiation+ Facility, ICN can complete the irradiation and post-irradiation services with experimental fuel elements manufacturing, the services being completed. This can be a possibility to eliminate the interstates transport of nuclear materials. The new international requirements for the transport of the nuclear materials are drastic and need a lot of time and money for obtaining authorizations and for transport. It is financially advantageous to manufacture experimental fuel elements on the same site with the irradiation and post-irradiation facilities.

II. THE STATUS OF ADVANCED CANDU FUEL DEVELOPMENT IN ROMANIA

On the Cernavoda nuclear site, Romania has a CANDU 6 reactor in operation; another one is under construction and three others in different building stage. The Romanian government legalized in 2002 the short, medium and long-term development of nuclear industry by the law: The Nuclear Strategy Development in the Nuclear Field in Romania and the Action Agenda. The law is based on The National Nuclear Program that establishes the fundamental objective, the derivate objectives, the associated objectives for the modern society exactingness satisfaction and the strategies for the objectives achievement. The National Nuclear Program is revised every year. Referring to the advanced CANDU fuel, the law states: “On medium term, there is very probable the transition to the slightly enriched Uranium fuel cycle (SEU) and, eventually, to the Recovered Uranium (RU)”

Our institute (Institute for Nuclear Research - ICN) performs all the activities for the advanced CANDU fuel development inside the “Nuclear fuel” R&D Departmental Program of the Romanian Authority for Nuclear Activities (RAAN). The main technical and scientific goals of “Nuclear fuel” R&D Program are:

- Safety analyses related to the fuel behavior during accidents that determine the increase of fuel temperature and cladding defect:
- Monitoring of fuel performances during operation in Cernavoda NPP. Maintaining and improvement of the operational performance of the CANDU-type nuclear fuel, currently fabricated in Romania
- Development of new concepts of nuclear fuels that should bring about an increase in the efficiency of uranium utilization in NPP, a cutback of the fuel cycle cost and, consequently, the cost of the electric power produced by the NPP.
    - Completion of the physics manual on the SEU CANDU core.
    - Research focused on the decrease of the effects of limitative factors of fuel lifetime and on the burn up increase.
    - Technologies and facilities development for advanced fuel manufacturing
    - In-pile testing of experimental fuel elements.

- Development of computer codes system to analyze the behavior of SEU, MOX and DUPIC fuels.

- Development and support of expertise and response capability in the field of fuel behavior with the purpose to solve specific problems that occur during its utilization in NPP;

III. FACILITIES FOR ADVANCED CANDU FUEL MANUFACTURING

Between 2001-2005 an important direction in our institute was the development/modernization of facilities for different CANDU fuel types manufacturing. The concept in machines development was flexibility, the possibility to cover a large range of dimensions of manufactured pieces, and the automation to eliminate the human errors (if possible). The use of adequate tools, the change of the technological parameters and of the machines working program could lead to a complex experimental matrix.

Figure 1. Press for powders

For the UO_2 sinterable powder pressing, we modernized a 500 kN German Mayer pressing machine with bilateral action (Figure 1).

The moulds and the dies were designed and executed in order to obtain an appropriate geometry of UO_2 sintered pellets. Having a very good experience, we can obtain sintered pellets with diameters between 8mm and 20mm and with controlled microstructure. Stress, displacement and pressing time can be pre-selected.

The sintering of the green pellets is performed in the Hydrogen atmosphere in a small capacity-sintering furnace (Figure 2). It was modernized by changing the old electrical and electronically components with new ones; the process is coordinated by

Figure 2. Sintering furnace

the computer. On the computer display the pre-selected time-temperature curve appears and, in parallel, it appears the real time-temperature curve, the temperature evolution in the furnace being known at every moment. All the data are recorded.

.The centerless grinding machine (Figure 3) was designed and executed especially for UO_2 sintered pellets manufacturing.

The centerless grinding machine operates observing the classical principle, but all the electric, electronic and hydraulic components are modern and reliable. The instrument board has two parts: programmable and working panels. On the former there are selected the technological parameters while the latter is the operating panel. The machine can grind cylindrical compacts with a diameter of 5-50mm, with less than one-micron roughness and mobile sled can be moved with a few microns.

Figure 3. Centerless grinding machine

The end-cap sheath welding machine (Figure 4) was designed and manufactured in collaboration with a Romanian manufacturer specialized in robotics. The welding is done by resistance heating. It is flexible, modern and computerized. All the technological parameters, machine working programs and the current source characteristics are pre-selected on the computer and introduced in the machine memory. On the instrument board there is selected the number of working program and the machine is ready to operate. The front panel is for machine operation. The machine can operate in manual or automatic cycles.

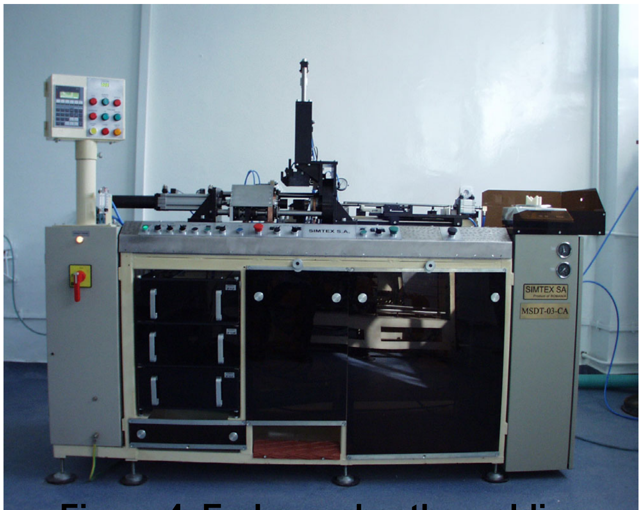

Figure 4. End cap-sheaths welding machine

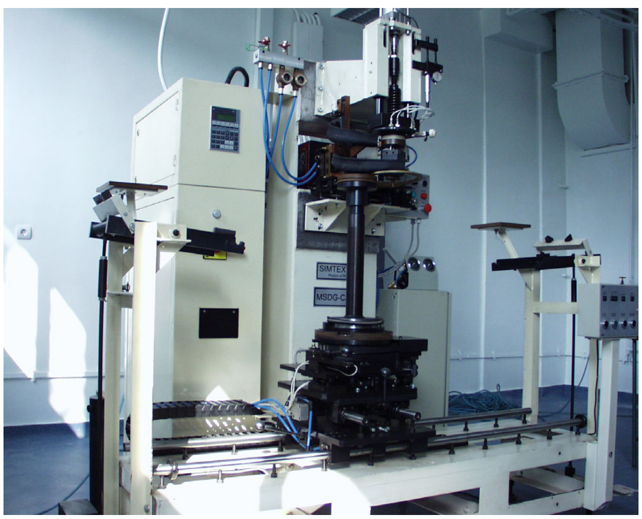

Figure 5. End cap-end plate welding machine

It has appropriate interchangeable tools to weld fuel elements for standard fuel and it can be easily modified for other diameters. The machine was tested using a special device designed for this purpose.

The end cap-end plate welding machine (Figure 5) was designed and manufactured in collaboration with the same Romanian manufacturer specialized in robotics. The welding principle is resistance heating. Like end cap-sheaths welding machine, the technological parameters, machine working programs and the current source characteristics are pre-selected on the computer and introduced in the machine memory. The operator decides on the number of welding program and the machine is ready for operation.

The end cap - end plate welding machine can operate in manual and semiautomatic cycles.

The machine was tested using a simulated assembling special device. Working with this device, only end caps and end plates are used.

New equipment for control and materials characterizations was procured. The roughness meter for roughness measurements and the profilmeter for geometrical characterization of sintered pellets complete the equipments used for control.

The elemental control of the materials will be performed with a new and modern ICP-MS, with time-of-flight and orthogonal acceleration (Figure 6). The main technical characteristics of the equipment are: mass range of 3 to 260 amu, more than 30,000 full spectra per second ion extraction speed, sensibility up to parts per trillion, automatic detector protection and user-selectable matrix ions elimination with ion blanker, automatic sequencing and control. The software has a modular design, with method, samples, analysis, instrument control and results, external and isotope dilution calibration, automatic correction for interferences and measurements with internal standards.

Figure 6. ICP-ToF-MS

IV. MANUFACTURING OF A FUEL BUNDLE EXPERIMENTAL MODEL

Using our own equipment previously presented, the ICN manufactured an experimental fuel bundle model (Figure 7) to verify the validity of experimental data obtained in the previous tests conducted on "short" samples, the machine behavior and finally, entire manufacturing flux. Having a very good experience and very good results in UO_2 sintered pellets manufacturing this operation was excluded.

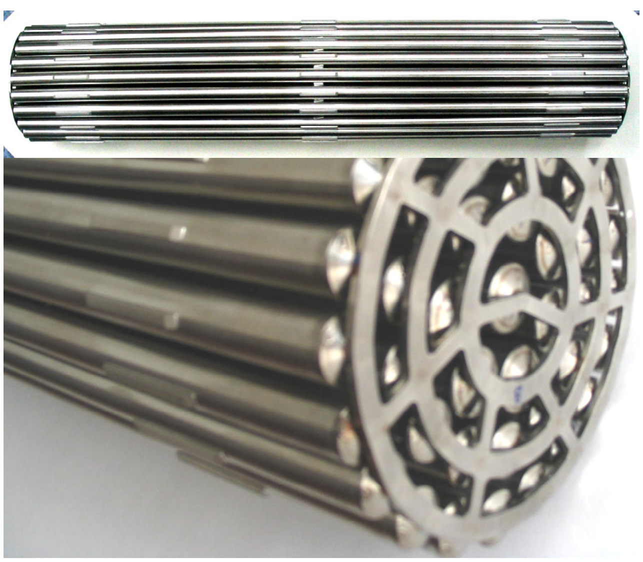

Figure 7. Experimental model of fuel bundle

The manufacturing of sheaths, end caps and end plates was performed with common equipment (lathe and milling machine).

V. CONCLUSIONS

Changing the concept regarding the fuel progress, the ICN developed/modernized its own facilities for nuclear fuel manufacturing covering the main steps from the manufacturing flowsheet.

The concept “flexible machines” permits the covering of a large range of fuel elements dimensions and large experiment matrices can be performed.

The new machines and equipments for nuclear fuel manufacturing and control complete the services range offered by ICN besides irradiation and post-irradiation examination.

The creation of an International Working Group for CANDU fuel development, including CANDU Owners and research-related organizations can focus efforts and material expenditures.

References

1. D. OHAI, G. Andrei, Romanian Program for SEU/RU Fuel Manufacturing at Nuclear Site Pitesti, *Proceedings of the 7th International Conference on CANDU Fuel,* vol.1, p.249, Kingston, Canada (2001)