METHODOLOGY FOR GAP MEASUREMENT IN THE FUEL ELEMENT FABRICATED AT IPEN

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ABSTRACT

The use of radioisotopes in medicine is certainly one of the most important social uses of nuclear energy. The Nuclear and Energy Research Institute - IPEN occupies a special position in the history of nuclear medicine in Brazil as a producer of radioisotopes. Due to the serious international crisis in the supply of this material, Brazil has decided to build a new nuclear research reactor, the Reator Multipropósito Brasileiro – RMB (Brazilian Multipurpose Reactor), in order to assure the supply of radioisotopes to the Brazilian market. Since 1988, IPEN has fabricated the fuel for the research reactor IEA-R1. It was decided that the new reactor RMB will use the same type of fuel that is used in the IEA-R1 research reactor, with an increase in uranium concentration from 3.0 to 4.8 g/cm^3 using silicide technology. These new fuel elements will operate in conditions more severe than those currently found in the IEA-R1. Thus, it becomes necessary to develop a methodology to measure the gap between fuel plates inside the fuel element, in order to generate quantitative data to ensure that the cooling channels dimensions of the fuel element meet the specification. Currently, as the IEA-R1 fuel element is operating at low power, it requires just a gap checking with a gauge-type device. However, under the more severe operating conditions of the new higher power reactor RMB, a quantitative gap measurement is necessary to ensure the perfect performance of the fuel element. This paper describes a methodology and its device to perform the gap measurement.

1. Introduction

The use of radioisotopes in the medicine certainly is one of the most important social uses of the nuclear energy. Distributed for hospitals and clinics by the whole country, radiopharmaceutical products assist more than three million patients a year. The Nuclear and Energy Research Institute - IPEN occupies a special position in the history of the nuclear medicine in Brazil, developing and producing radiopharmaceuticals starting from radioisotopes produced in the nuclear research reactor IEA-R1, being responsible for 98% of the current total demand. The Brazilian demand for radiopharmaceuticals has been growing continually through the years, in a regime of approximately 10% a year.

The recent serious world crisis in the supply of radioisotopes caused serious impact in Brazil. To face that situation, Brazil decided to build a new nuclear research reactor, denominated Reator Multipropósito Brasileiro – RMB (Brazilian Multipurpose Reactor), with larger power than the current reactor of IPEN, in order to guarantee the supplying of radioisotopes to the Brazilian market [1].

Since 1988 IPEN has been manufacturing the fuel for the IEA-R1 reactor of IPEN, being the unique Brazilian manufacturer of this type of fuel [2,3,4]. It was decided that the new reactor RMB will use the same type of fuel than the reactor IEA-R1, increasing the uranium concentration to 4,8 g/cm^3 with the uranium silicide technology, in a first stage, and possibly to 7 g/cm^3 with the U-Mo alloy technology, in a second stage. The new fuel elements for the RMB reactor will operate in much more severe conditions than the ones found now in the IEA-R1 reactor of IPEN. The minimum channel gap is one of the parameters in the calculations for the hot channel and for this reason the tolerances are in most cases included in the thermodynamic calculation and the safety report. Then, a work was started seeking to develop and to implement in IPEN a methodology to measure the gap between fuel plates in the fuel element, generating quantitative data that will guarantee the dimensions of the cooling channels. Now, due to the low operational request of the fuel element operating in the IEA-R1 reactor, which has low power, just verification with pass-not-pass type calibers is enough to guarantee the dimensions of the cooling channels.

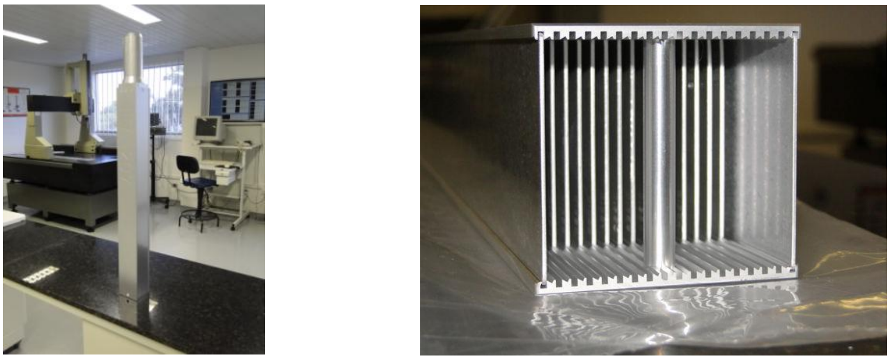
The quantitative data for cooling channels dimensions were obtained during the fuel element assembling process through a device fitted to the roll swaging machine that fix the fuel plates to the side plates. These measures will be part of dimensional analysis to qualify the fuel element. The determination of this parameter by means of this device will allow greater assurance in relation to the distance between the fuel plates and thus ensure the proper use of the fuel element within the core of the nuclear reactor. This paper presents a methodology for measuring the distance between the fuel plates, giving a metrological report with the dimensions for the cooling channels of the fuel element.

2. Methodology

2.1 Fuel Element Assembly

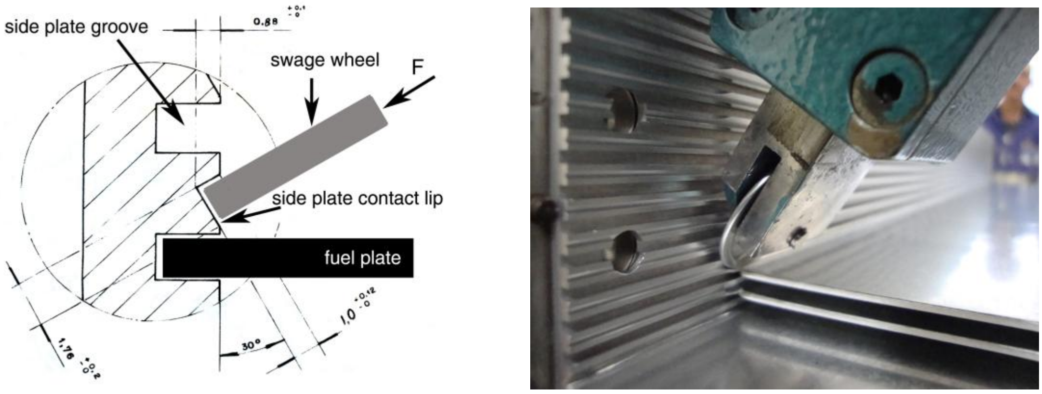
IPEN routinely manufactures fuel elements for its research reactor IEA-R1 and in this work the distances between fuel plates were determined in this fuel element. The current configuration of the IEA-R1 reactor core incorporates 25 fuel elements in a 5x5 matrix. The fuel elements are formed by assembling 18 fuel plates, which are spaced allowing the passage of water that serves as a coolant and moderator. The fuel plates consist of a meat containing fissile material, which is fully covered with an aluminum cladding. They are manufactured by adopting the traditional picture frame assembly technique and rolling to the proper thickness. Powder metallurgy techniques are used in manufacturing the fuel plate meat, which are composed of dispersions. Several types of dispersions can be used, where powders of uranium compounds, such as U_3O_8, U_3Si_2 or UMo alloys, are mixed with aluminum powder, which is the structural material used as the matrix of the fuel meat. Figure 1 shows views of the fuel element fabricated at IPEN, with the 18 fuel plates arranged parallel to each other. The distance between the fuel plates define the dimensions of cooling channels.

The fuel element is assembled by fixing the fuel plate to the side plates, which have grooves where the fuel plates are fitted. The fixation is made by roll swaging. A swage wheel is placed over the side plate contact lip and a force is applied, as shown in figure 2A. The swage wheel is dislocated along the side plate groove length and the fuel plate is mechanically fixed by deforming the side plate contact lip (figure 2B). One side of the fuel plate is fixed and the swaging head is rotated to starting fix the other side of the fuel plate. The swaged connections are tested to assure that a minimum pullout load capacity of 27 N per millimeter of the side plate length is maintained. After the fuel assembly is swaged, the end nozzle and handle pin are attached.



A B

Fig 1 – Fuel element fabricated at IPEN (A) and details of the cooling channels (B)



A B

Fig 2 – Fuel element swaged joint (A) and roll swaging operation (B)

2.2 Measuring Device

The quantitative determination of the distance between fuel plates is made during the fuel element assembly. In the case of the IEA-R1 research reactor, according to the request in the fuel design, the spacing between fuel plates is 2.89 ± 0.25 mm. Figure 3 shows photographs illustrating the roll swaging machine. A system to measure coordinates in XYZ axes was installed in this machine. In conjunction with this coordinate system it was assembled a probe attached to the Z axis of the machine. Figure 4 shows photographs illustrating the measurement system installed in the roll swaging machine. It is possible to control the position of the probe in the X and Y axis and to perform the measurement in the Z axis. The probe repeatability is ± 0.025 mm.

2.3 Measuring Methodology

The measurements are performed in 21 points over every swaged fuel plate. The measurement positions are the same used to determine the fuel plate thickness, as established in the production routine. The fuel plate thickness measurement locations are very well defined, with the coordinates of seven determinations in the X axis and three determinations in the Y axis, as shown in figure 5.

Fig 3 – Views of the roll swaging machine

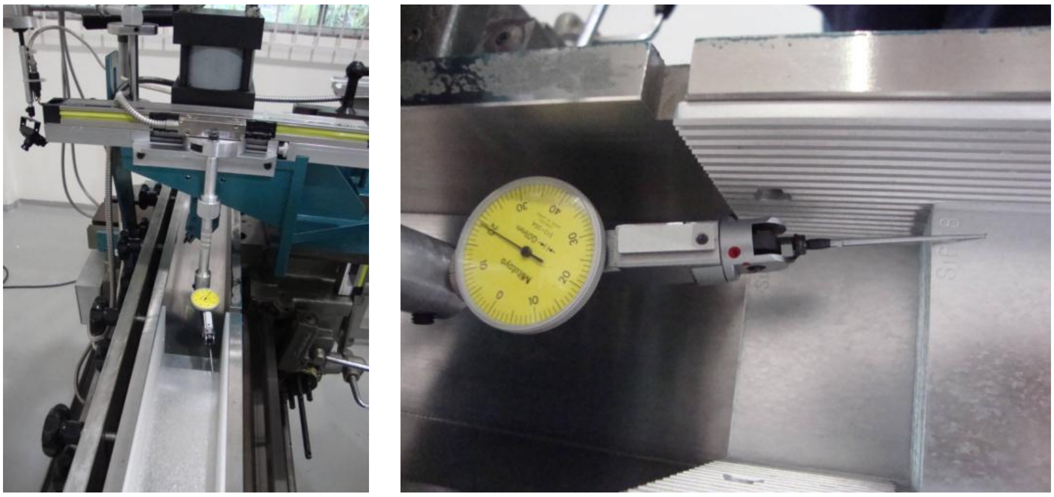


Fig 4 – Measurement system installed in the roll swaging machine

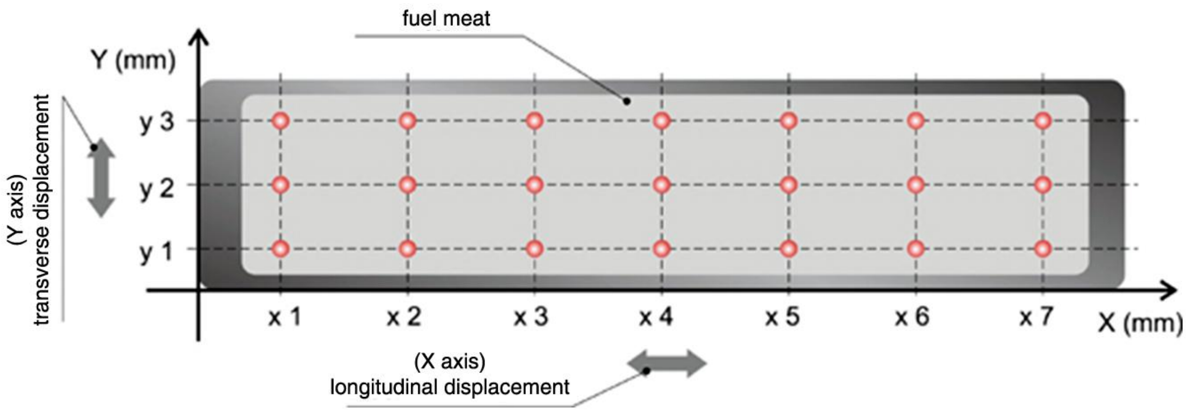


Fig 5 – Measurement positions, the same used to measure plate thickness

After swaging each fuel plate, the measurements are performed in the 21 specific points used in determining the thickness of the fuel plate mounted. All measurements are collected by a computer, which processes the data and calculate the distance between the plates in the 21 measuring positions, once knowing the thickness of the plate in the 21 measured points. After swaging one fuel plate, the reference zero is taken from the central point of the end of the fuel plate previously mounted (position x7y2 according to the figure 5).

3. Results

The methodology was applied for measuring the cooling gaps of a fuel element (IEA 224) during a routine fuel fabrication under realistic fabrication conditions. The results are presented in table 1.

Tab 1: Results for gap dimensions determined with the proposed measuring methodology

Gap Number	**Gap Dimension (mm)**		
	maximum	minimum	mean
1	3.00	2.76	2.88 ± 0.07
2	3.00	2.65	2.86 ± 0.09
3	3.03	2.68	2.86 ± 0.10
4	2.85	2.65	2.76 ± 0.05
5	3.01	2.65	2.81 ± 0.10
6	3.14	2.73	3.00 ± 0.11
7	2.76	2.64	2.65 ± 0.03
8	3.11	2.67	2.94 ± 0.12
9	2.76	2.64	2.68 ± 0.04
10	3.11	2.68	2.93 ± 0.10
11	2.91	2.64	2.78 ± 0.08
12	3.14	2.71	2.96 ± 0.09
13	3.03	2.73	2.84 ± 0.07
14	3.05	2.73	2.89 ± 0.09
15	2.96	2.69	2.80 ± 0.06
16	3.14	2.89	3.00 ± 0.06
17	2.92	2.64	2.74 ± 0.09

4. Conclusion

The development of a device and the related procedure to perform the gap measurement in the fuel element fabricated at IPEN for the IEA-R1 research reactor was completed successfully. The generated data seems to be consistent. The next step is to fabricate full sized dummy fuel element according to the new RMB reactor design and to apply this methodology to do the gap measurement.

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