NDT as a tool, for Post-Irradiation Examination.

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Abstract

Non-destructive testing scored important successes in nuclear field. All NDT techniques available nowadays provide comprehensible indications on the behaviour of the track. This paper reviews the NDT techniques used in the post-irradiated examination of fuel element taken from Es-salam nuclear reactor. Indeed, the fuel element emits alpha, beta and gamma rays, that why, measurement are done in hot laboratory in order to guarantee safe conditions for users. The first approach is to explore the influence of a wide range of variables on the fuel element during irradiation. The currently methods used, are visual inspection, dimensional measurement, eddy current testing, x radiography and gamma scanning. With these methods, it is possible to obtain large amounts of quantitative and qualitative information about the fuel element behaviour during irradiation.

Keywords : Visual inspection, gamma scanning, eddy currents testing, post-irradiation examination .

Introduction

Non destructive testing has a central part in the post irradiation examination programmes operated by our laboratory. The first approach is to explore the influence of a wide range of variables by the survey of the degradation of the fuel element after irradiation.

Principally, the fuel element behaviour depends on heat transfer, pressure, burn up, irradiation and other factors. The NDT techniques used seem to us particularly interesting to qualify the behaviour of the irradiated fuel.

In this report some of the NDT techniques currently in use at our hot laboratory are described briefly. As a consequence the obtained data, contribute in the attempt to investigate and establish the probable causes of the different changes. The NDT post irradiation of nuclear fuel is widely used to find out the performances in the reactor core. From these tests, significant information and data are collected, mainly, on the cladding degradation, which is defined as the first safety obstacle. The NDT in post-irradiation examination, allow evaluating the assessment of the fuel rod.

The fuel rod is examined in the hot cells as one body. It cannot be dissociated, because the majority of the phenomena are depending between pellets and cladding [1].

I- Gamma Spectrometry

The gamma spectrometry mechanism includes four main sections, the scanning bench system, the collimator, the detector, and the data acquisition system.
The principle of the gamma distribution measurement is the detection and the spectrometric analysis of the gammas radiations emitted by the fuel rod. The gamma counting combined with the longitudinal fuel rod scanning, allow plotting the relative distribution of the fuel rod activity.
Two methods of measurement are employed in our hot laboratory:

Distribution of the total activity: it consists in reporting the axial distribution of the total gamma activity emitted by the fuel rod.

Distribution of the specific activity: opposing to the total activity, this method consists in reporting the axial distribution of a specific nuclide such as Cs or Zr.

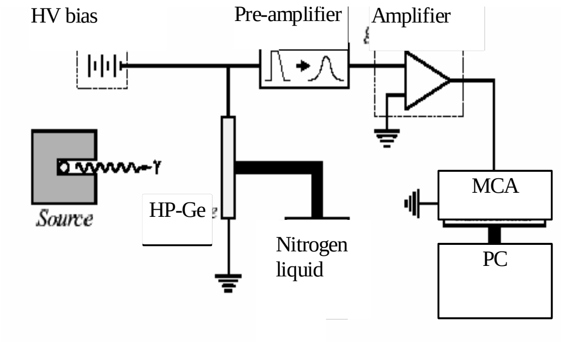

Fig.1 –Gamma-scanning System

I-1 The active length Measurement of the fuel pins (Analysis by MCS)

The obtained spectrum of the total activity of each fuel rod reveals small peaks, they are equivalent to the pellets interfaces, and the mean reason is the Caesium (Cs^{137}) migration towards the cold areas. Cs^{137} is detected around the contact pellet-pellet (fig.1)[3].

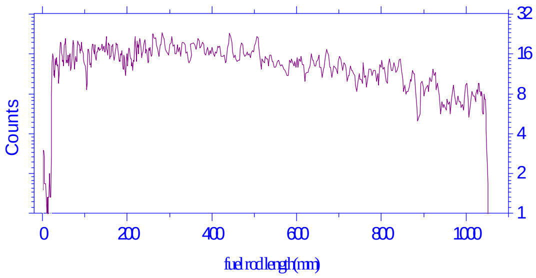

Fig.2 gamma scanning (global activity)

The maximum value of the burnup rate is around 2/3 of the fuel rod length, from the bottom.

I-2 Axial distribution of the gamma activity of Cs [137] along the rod.

The determination of fuel rod activity, is based primarily, on the choice of a good monitor, which attests the consumption of fuel, this monitor must have characteristics different from the other radioelement. In our case, where the assembly was cooled for rather long duration , it is necessary to choose the Caesium 137 which is characterized by a 30,2 years half-life, and a fission yield of 6,22% for U^{235} Its energy is 661,6 KeV (fig.3) [2].

The activity at the two ends of the scanning curve is slightly high (two last pellets). That is interpreted by the fact that the two ends are influenced by the reflectors effect, added to the **Cs** [137] migration effect

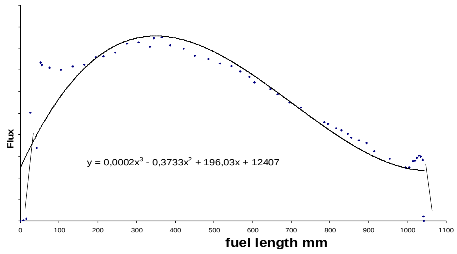

Fig. 3 Cs-137 Distribution along rod

II- Length Measurement

Fuel rod length measurement consists in mounting the fuel rod on a measuring bench located in the hot cell; measurement is done by using a LVDT. It is carried out by comparison with standard certified rod.
The length measurement is used to deduce permanent lengthening on the level from the cladding.
Length measurement of a total of 5 fuel rods were made to characterize fuel rod length, and to have a good statistics of measurement.fig-4

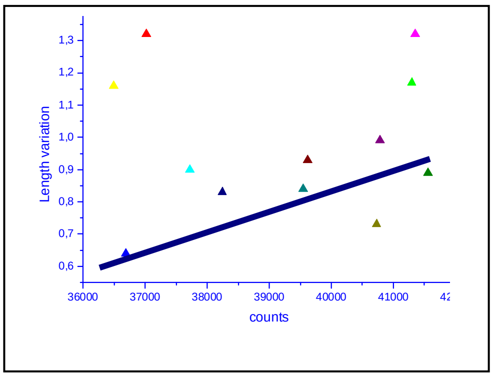

Fig. 4 Linear evolution length according to the burn up rate for the Zr-2 cladding

The cladding material, Zircaloy, is an anisotropic material, at low temperature it is structured in α phase with compact Hexagonal crystal, whose crystals are arranged in the thickness direction of the cladding. Under the effect of the irradiation, the crystal extends on the level from the base (length) and contracts in the direction the height (thickness of the cladding). This evolution of the crystal automatically induces an expansion of the cladding in the length direction.
Length Evolution (Δ L), with the relative values of the burnup rate, permit to note that there is a light proportionality between these two values, direct consequence of the irradiation [1].

III- Visual inspection and photography

The visual inspection is carried out from the observations of the fuel rod with a periscope, according to 4 lines with 90°, with an enlargement of 8 approximately. The film and the photographs resulting are entirely identified. The precision on the dimension is about ± 1mm.
In general, an additional recording, in wide plan and rotation on the level of each fuel rod, can contribute to give an entire the overall picture.

IV- Diameter and ovality measurement

The rod diameter and ovality measurements are obtained using profilometer installed on bench in hot cell. The profilometer includes two linear variable differential transducers (LVDT) placed at 180°. The measurement can be performed axially, spirally and around fuel rod. The LVDT react to changes in rod diameter, while crossing the fuel rod. The consequential signal is then converted to recorder on a strip chart. Rod rotation and linear displacement speed can be varied from outside panel. An accuracy of ±300 microns can be obtained using an analogical micrometer. The geometrical investigations of fuel rod surface, allow detecting and measuring the straightness, ovality, swelling ... etc. (fig. 5 and 6).

The test consists with the control of all the fuel rods, it includes the following operations:

- a profile control with combined rotation and translation,
- Rectilinear scanning of measurement of diameter on 04 shifted lines of 45°.
- Control of circularity in rotation, for particular points chosen after interpretation of the graphs of longitudinal scanning.

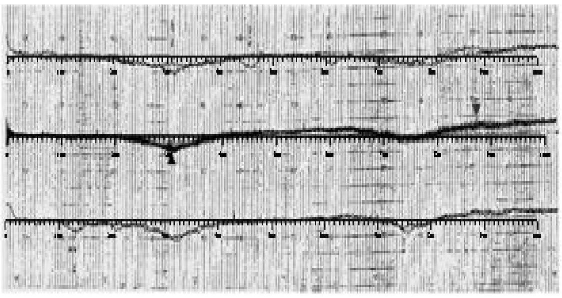

Fig. 5 Profiles along the fuel rod

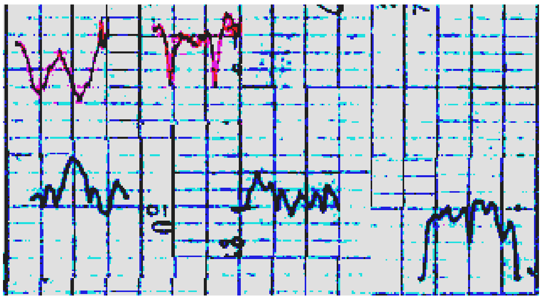

Fig. 6 profile of circumference

V- Eddy current testing

Fuel clad imperfections are detected with the eddy current test inspection equipment. The equipment consists of two differential coils through which the fuel rod is drawn. The signal output from the coil is displayed on the screen. A precisely standard tube of Zircaloy, is used to calibrate the eddy current system. This standard contains both internal and external defects [3].

VI- Conclusion

It is interesting to note that all those operations such as charging, discharging, handling and inspection before and during test, never damaged any fuel rods. The integrity of fuel rods was controlled visually and the results obtained confirm so well. Anyway, the NDT pos-irradiation results are an indispensable tool not only for normal operational surveillance but also for fuel design qualification.
All NDT operations were performed from the outside of the hot cells, in order to avoid the risk of gamma radiations. The calibration of the equipments need more time to achieve adequate results; also many interventions inside hot cell can be necessary before starting test. The telemanipulators are used, regarding the non accessibility to the equipments during test.

REFERENCES

[1] P. DEHAUDT. Le combustible nucléaire et son état physico-chimique à la sortie des réacteurs. Rapport CEA, (2000).

[2] D.REILLY, N.ENSSLIN, H. SMITH, JR., and S. KREINER, « Passive non destructive assay of nuclear materials » .Nuclear regulatory commission, chap 1.18 (1991).

[3] ALGHEM et al. Contrôle non destructif du combustible nucléaire. Rapport technique. CRNB/COMENA (2003).