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Other Major Component Inspection I

Fuel Rod Inspection System, SICOM-ROD

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INTRODUCTION

Knowledge of the evolution of the nuclear fuel is necessary to guaranty the behaviour and safety in the operation, as well as to optimize the economic performance of the fuel cycle. For this reason, fuel manufacturers develop fuel behaviour models readily validated. On the other hand, when with the objective of improving the performance of fuel, some important modifications are made, it is necessary to prove the effect on the behaviour and evaluate the influence in each of the critical characteristics of the fuel assemblies. In these cases, before a complete refuelling with new designed fuel is inserted, it could be necessary, in accordance with the importance of the modification, to burn a reduced number of fuel assemblies of the new design. This kind of fuel assemblies is known as demonstration assemblies. During the demonstration process, some characterisation of the behaviour of the fuel is made, usually at the end of each cycle. The information obtained would be used to assess the criteria for commercial operation of the new designed fuel.

An important part of this characterisation is made using NDE methods, applied at the nuclear plant during the refuelling outages. The features to be checked in this circumstance use to be the following: general condition of the assembly and its main parts, dimensional variations, corrosion layer thickness and fuel rod tightness.

Tecnatom and ENUSA have developed a set of equipments for spent fuel assemblies like SICOM-ROD in order to satisfy this demand.

CAPABILITIES

SICOM-ROD has the capability to measure the corrosion layer and the dimensional profile on single fuel rods (PWR and BWR). Also, it can perform the eddy current inspection using bobbin and RPC coils.

- Pancake coil for measurement of the thickness of the oxide layer.
- Two LVDT sensors for profilometry of the fuel rod.
- Bobbin coil for the integrity inspection of the fuel rod.
- RPC for eddy current inspection. It can detect and measure wear.
- The crane gives the axial movement to the single fuel rod. SICOM-ROD remains on the spent fuel rack.

DESCRIPTION

The mechanical equipment consists of two clearly differentiated parts: an upper, static section located above the main support plate of the equipment, and a lower section that moves below this plate.

Upper section

The upper part (see Fig. 1) includes all the devices required for performance of the inspection, with the exception of the rotary coil, which is located in the lower section. Consequently, and apart from the support elements, this part includes the circular coil, the coil for oxide measurement and two LVDT's, for the measurement of the diameter of the fuel rod. Also in this upper part is placed the module used to control the insertion movement of the rod (resolver), the main connections box, a rod-centering device and the support for the rod insertion tool. Both, the resolver box and the main connections box are designed to be watertight and are also pressurized in order to prevent water coming into contact with the electrical and/or electronic parts.

Bobbin Coil

This coil is in charge of the control of defects in the rod to be inspected. The material used for the main body of this item is a polymer with high resistance to radiation.

Oxide Measuring Coil

This coil is used to measure the oxide layer. The coil must be perfectly aligned with the axis of the rod to be controlled and it is necessary to have a centering system, which also ensures that there is contact between the coil and the rod. Permanent contact between the rod and the coil is achieved by means of two springs that also act on the rod insertion control system.

LVDT

Linear Variable Displacement Transducers (LVDT) are high precision measuring elements that, in this case, are in charge of controlling the diameter of the rods. Two LVDT are used for this purpose.

Rod Insertion Control (Resolver)

In order to be able to measure the position of possible defects, it is essential that there be some element controlling the insertion of the rod. In this case this is achieved by means of a roller that runs along the rod and that is connected to a resolver. The entire system is designed for use in highly radioactive environments and under water, for which reason the resolver box is pressurized. As the roller and the rod must always be in contact, and in order to ensure that this contact exists also for the rod and the oxide control coil, there are two springs that link the two systems and produce the desired effect without decentring the rod.

Main Connections Box

This box is internally pressurized in order to prevent the water access. All the modules of the equipment are connected to this box and from it emerge the different connections to the interfaces.

Centering Device

This system is in charge of centering the rod to the greatest possible extent inside the system. In order to prevent the fretting and wear of the rod, the system incorporates a part made of a polymer providing high resistance to radiation. The system has two centering devices, which are fully independent from the system and may be installed or removed as required.

Figure 1 - Upper section

Lower section

This part includes all the elements required for use of a rotary coil (see Fig. 2). There is a watertight, pressurized box that houses a motor, a resolver and the rotary coil system itself. Also includes the slip-ring, in charge of the connection between the cables of the coil (rotating) and the associated box connectors (static).

Rotary Coil System

This probe is in charge of detection and characterization of wear defects.

Motor and Resolver

These two elements are necessary to provide movement and control it. The motor is connected by means of a system of gears to the rotary coil system and to the resolver.

Slip-Ring

This is a commercial grade element in charge of keeping the terminals of the rotary coil connected to the pins of the corresponding output connector, by means of rubbing brushes.

Reed Relay

The rotating system includes a permanent magnet and a Reed relay that allows the “point of origin” of each turn to be identified. This is necessary for the Data Acquisition System.

Absolute Coil

The watertight box contains a support for a calibrated tube for comparison with the rotary coil measurements.

Figure 2 - Lower section

INSPECTION TECHNIQUES

Oxide thickness layer

The “separation effect” between the surface of non-conducting oxide and the conducting base material will be used (known as the lift-off effect). The amplitude of the signal due to the lift-off is proportional to the separation of the probe from the base material, and also to the thickness of the oxide layer. A calibration rod with different layers of oxide (at least three) will be used in the calibration, and with this data the software sets a calibration curve which relates the amplitude of the eddy current signal with the thickness of the oxide.

The axial position of the probe with regard to the origin of the coordinates of the rod being inspected is known from the information given by the axial encoder (longitudinal position).

Profilometry of the fuel rod

A module with two LVDT’s at 180º is mounted on the inspection tool, the fuel rod passes between the two and in this way, with each pass, the measurement corresponding to the diameter along the entire length of the rod is obtained. The measurement of the other diameter is obtained by simply rotating the rod to the wanted position and making it pass through the measurement module.

The TEFRIS-LVDT´s software allows the acquisition, recording and analysis of the data using a personal computer. Among other things, a record will be made of the data regarding the measurement of diameters and the position of the LVDT’s, and a later analysis will allow the determination of the diameter of each point on the rod.

The data acquisition will be carried out continuously by displacing the rod through the LVDT module. The displacement speed of the rod will be 50 mm/second, so that the data acquisition of each generatrix and its opposite in one rod, will take approximately two minutes.

Integrity with bobbin coil

The depth of the defects will be determined in accordance with the phase angle of the eddy currents signal, given that the phase angle depends on the depth of the defects and, in this case, for defects which are produced from the outer surface of the rod, the greater the depth, the greater the phase angle. Therefore, a curve will be made to relate the phase angle of the signals of the defects of the calibration tube and their depths. This curve will be used to obtain the depth of any defect detected in the inspection of the fuel rods.

The axial position of the probe with regard to the origin of the coordinates of the rod being inspected is known from the information given by the axial encoder (longitudinal position).

Integrity with rotating coil

The rotating probe will consist of a coil, in absolute mode, the axis of which will be perpendicular to the axis of the rod and, therefore, sensitive to any defect orientation. The amplitude of the eddy currents is proportional to the volume of the material lost in the cladding of the fuel rod and, in this case, the amplitude of the signal at each point of the surface is also proportional to the depth of the defect. With the defects mechanised on the calibration rod, the calibration curve will be established and this will relate the amplitude of the eddy currents signal with the depth of the fretting.

The inspection of the entire surface of the rod with the rotating probe will be carried out by means of a helicoidally trajectory. This trajectory is achieved by the axial movement of the fuel rod and the rotating movement of the probe. The step of the helical line should be no greater than 1.2 mm, which ensures there is an overlap between two steps.

Both, the axial and circumferential position of the probe with regard to the rod being inspected are known from the information given by the two encoders: axial (longitudinal position) and circumferential (angular position).

QUALIFICATION

The qualification of this equipment was carried out for BWR and PWR fuel rods. This process included "the procedure acceptance test" (PAT) "with blind rods" in order to verify the precision of each measurement, "the factory acceptance test" (FAT) in ENUSA-Juzbado and "the blank test" in Olkiluoto NPP.

Precisions obtained were:

- External diameter: ±10 microns (see Fig. 3)
- Oxide thickness layer: ±5 microns
- Section loss: ±3 %
- Thickness loss: ±10 %
- Length of crack: ±1 mm
- Axial speed: 10 to 50 mm/s RPC speed: 10 r.p.s.

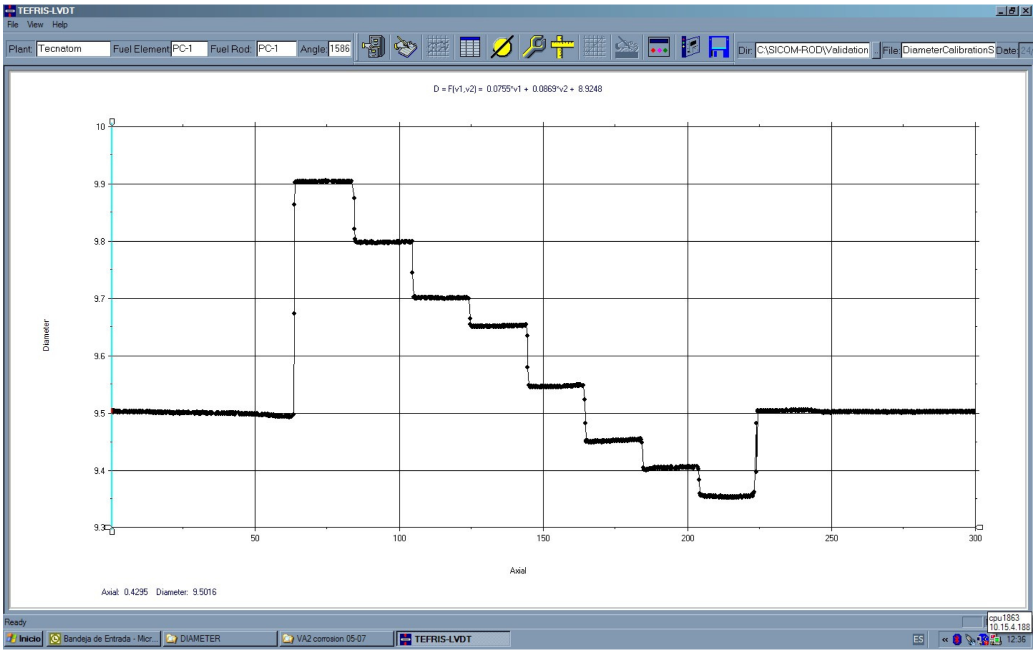

Figure 3 - Profilometry qualification

EXPERIENCE

The SICOM-ROD has been used in the following nuclear power plants:

- Yeonguang (Korea)
- Olkiluoto (Finland)
- Fosmark (Sweden)
- Garoña (Spain)
- Almaraz (Spain)