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#06-62 Design and characterization of a gamma imaging system for fuel rod deformations

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The study of accidental situations is one of the major asset for nuclear industry in guaranteeing the so-called regulated safety of its electricity production facilities. The Loss Of Coolant Accident (LOCA) is tested in experimental reactor and hot cell to verify the mechanical properties of the fuel rod, the safety criteria and the associated calculation codes. The VINON-LOCA experimental set-up, currently under development in CEA Cadarache, aims at observing, online, the Fuel Fragmentation, Relocation and Dispersal (FFRD) during a LOCA sequence. The tests will consist in placing a fuel rod in a shielded cell, which will be heated by magnetic induction in order to reproduce the temperature conditions of the first phase of a LOCA transient. Instrumentation positioned in the cell will be placed close to the fuel rod in order to monitor its behaviour during heating. A proposed technique to quantify the fuel rod deformation is the use of gamma imaging. In this context, we have designed and developed, in partnership with CEA Cadarache, EDF and Framatome, a gamma imager to monitor the deformation of the fuel rod. Preliminary experimental tests carried out at LAMIR Laboratory of CEA Cadarache have estimated that the variation in the diameter of the fuel rod during heating is 2 to 3 mm. The gamma emitters, which will enable the swelling to be monitored, are derived from the fission products of the pre-irradiated rod. Only the most energetic gamma rays passing through the cladding of the rod, and then through the experiment's containment, will be imaged.

The work presented therefore concerns, firstly, the design of a collimator offering the best compromise between mechanical feasibility, cost, signal-to-noise ratio and angular resolution, thus making it possible to visualise the deformations of the fuel rod, and secondly, a preliminary evaluation of the experimental performance of the proposed gamma imager.

The chosen detector is the Widepix pixel detector developed by ADVACAM s.r.o. The Widepix detector is based on the Timepix technology resulting from the Medipix international collaboration founded at CERN. It consists in 512 × 1280 square pixels of 55 µm-pitch, hybridised to a 1 mm-thick semiconductor, i.e. a pixelated detection surface of 20 cm^2. In addition to positions of interactions, the detector also provides their energies, which can be used to reduce the intrinsic resolution of the pinholes in the collimator.

The collimator was dimensioned using Monte-Carlo simulations with MCNP6.2. During the design of the collimator, the material (tungsten), the pattern (with parallel holes) and the geometry (thickness, septa and pinhole diameter) were studied. Among the strong hypotheses, we chose to design the collimator with the most energetic gamma rays emitted by the radioisotope with the highest photon flux, namely Cs-137 emitting gamma rays of 661.7 keV. We finally ended up with a collimator of 6.2 cm thickness, pierced with an arrangement of pinholes of 1 mm diameter and 1 mm septa. This design results in an angular resolution of 0.48° for a field of view of 2.8 × 7 cm^2 at 25 cm.

Preliminary experimental measurements were then carried out on a Cs-137 irradiator located at the LNHB of CEA Saclay, and validated the possibility of identifying a variation in the incoming gamma rays flux diameter of the order of 2 mm using the proposed imager.

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