

FEASIBILITY STUDY OF GAMMA-RAY MICRO-DENSITOMETRY FOR THE EXAMINATION OF NUCLEAR FUEL SWELLING

L. SENIS, V. RATHORE, P. JANSSON, P. ANDERSSON,

*Department of Physics and Astronomy, Uppsala University
Regementsvägen 1, SE-752 37 Uppsala, Sweden*

K. JOHNSON, D. JÄDERNÄS, C. LOSIN, D. MINGHETTI

*Studsvik Nuclear AB
SE-611 82 Nyköping, Sweden*

D. SCHRIRE

*Vattenfall Nuclear Fuel AB
SE-169 92 Stockholm, Sweden*

ABSTRACT

Nuclear fuel undergoes several thermo-mechanical changes during irradiation in a nuclear reactor, such as change of density, caused by solid and gaseous swelling. This affects the heat transport within the pellet and, when leading to the pellet-cladding gap closure, it also affects the gap conductance, causing stress in the cladding.

The density of irradiated fuel pellets can be measured in post-irradiation examination using several methods. In this work, a feasibility study was made using the gamma-ray transmission micro-densitometry technique. This is based on the comparison of two intensity measurements, with and without a sample with well-characterized thickness. Using a collimated source, a local examination of the density can be performed, scanning a pellet slice radially. The proposed technique aims to obtain a spatial resolution of cca. 100 microns.

In this work, the parameters of the setup, such as the source activity, detector counting time, slit dimensions, collimator length, and sample thickness, are used to predict detector efficiency and expected count rates. The obtainable precision of the density is assessed by first-order uncertainty propagation of counting errors in the gamma-ray detection to the density estimate.

A collimator design was presented that achieves a reasonable compromise between time requirements, precision, and spatial resolution. The sensitivity of the performance to set-up parameters was investigated. In addition, a realistic setup was modelled in MCNP6 for validation of the peak count-rate, and to ensure that the total spectrum count-rate is within typical throughput capabilities of HPGe detectors. The MCNP model was also used to confirm that the assumed attenuation law is valid in a relevant geometry, and to assess the spatial resolution, using the 10-90% edge spread of an Edge Spread Function.

It is concluded that fuel density can be determined with <1 % precision, using a 100-micron wide slit, and 1 hour of measurement.

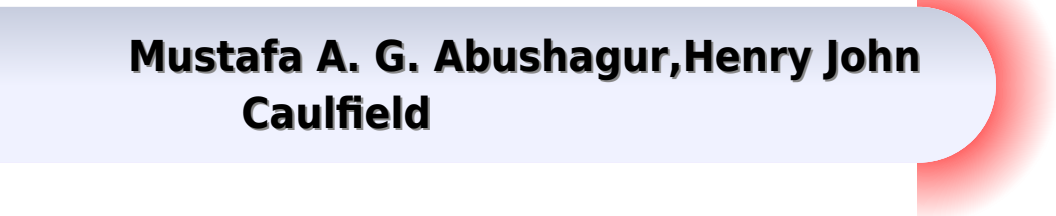
1. Introduction

The variation of fuel properties due to irradiation is important for the safe performance of the fuel during the operation in reactors [1]. In particular, swelling phenomena [2] influence the evolution of the mechanical stress to the cladding and the heat transport [3] from the fuel to the cladding.

For UOX and MOX fuels, the swelling has been observed to be correlated with burnup [4]. The phenomenon is mainly due to the fission products that change the microscopic structure of the fuel, in particular its stoichiometry and porosity [1] [5] [6]. The fission products are generated with a well-defined yield and include both solid and gaseous species. Both cause swelling [7].

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