PACKING MICROSTRUCTURE AND LOCAL DENSITY VARIATIONS OF EXPERIMENTAL AND COMPUTATIONAL PEBBLE BEDS

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ABSTRACT

In pebble bed type nuclear reactors the fuel is contained in graphite pebbles, which form a randomly stacked bed with a non-uniform packing density. These variations can influence local coolant flow and power density and are a possible cause of hotspots. To analyse local density variations computational methods are needed that can generate randomly stacked pebble beds with a realistic packing structure on a pebble-to-pebble level. We first compare various properties of the local packing structure of a computed bed with those of an image made using computer aided X-ray tomography, looking at properties in the bulk of the bed and near the wall separately. Especially for the bulk of the bed, properties of the computed bed show good comparison with the scanned bed and with literature, giving confidence our method generates beds with realistic packing microstructure. Results also show the packing structure is different near the wall than in the bulk of the bed, with pebbles near the wall forming ordered layers similar to hexagonal close packing. Next, variations in the local packing density are investigated by comparing probability density functions of the packing fraction of small clusters of pebbles throughout the bed. Especially near the wall large variations in local packing fractions exist, with a higher probability for both clusters of pebbles with low (<0.6) and high (>0.65) packing fraction, which could significantly affect flow rates and, together with higher power densities, could result in hotspots.

Key Words: Pebble Bed, HTR, Packing Structure, Packing Fraction, Hotspots

1. INTRODUCTION

The pebble bed type (very) high temperature reactor ((V)HTR) is one of the main candidates for next generation nuclear power plants. Its main benefits include online refuelling, high coolant outlet temperature resulting in more efficient electricity production and useable as process heat (e.g., hydrogen production), and passive safety, a particularly desirable property in light of the Fukushima accident. In a pebble bed reactor, the fuel is contained in TRISO particles which in turn are encapsulated in graphite pebbles. These pebbles form a randomly stacked bed inside a graphite reflector through which the helium coolant is pumped.

Often in pebble bed calculations the bed is fully homogenised using a uniform packing fraction. However, as was shown by Benenati and Brosilow [1] for the radial packing fraction profile, the packing density of randomly stacked beds is not uniform. Besides radial and axial density variations due to the wall, local density variations are expected due to the stochastic nature of the bed. In reactor analysis these variations can be of