Optimization of HTR fuel design to reduce fuel particle failures

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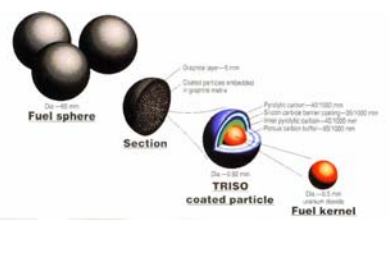
Abstract



In this paper, an attempt is made to formulate criteria that can be used in the redesign HTR fuel. A simplified fuel performance model is setup to calculate the fuel particle failure probability and impact as a function of the TRISO particle design and the particle packing fraction.

The model requires knowledge of the fast neutron dose, the fuel burnup level, and the fuel temperature. In this paper, neutronic, thermal-hydraulic and burnup calculations for the PBMR 400 MWth design are used to provide the fuel performance model with the required data.

Fuel performance

The failure probability of a TRISO particle during irradiation is related to the tangential stress on the SiC layer. This stress is calculated, by modeling the following phenomena explicitly:

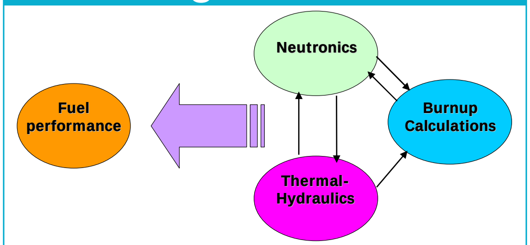
- Production of gaseous fission products inside the fuel kernel
- Diffusion of fission products from the kernel to the buffer layer
- Pressure build up in the buffer layer related to temperature, buffer volume and fission product concentration
- Production of CO gas in the TRISO, which causes additional pressure build up
- Temperature, burnup and neutron flux conditions during the lifetime of a particle

The failure impact Ψ is then defined, to evaluate the particle performance as:

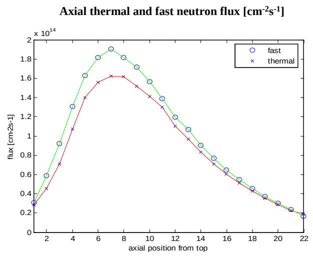
$$\Psi = \Phi V_k \, n_k \, B_{dis}$$

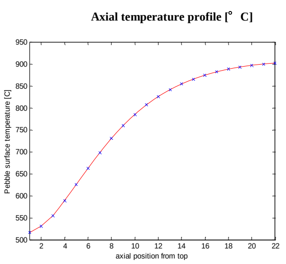
In which, Φ is the fuel failure fraction, V_k the kernel volume, n_k the number of TRISO particles per pebble and B_{dis} the discharge burnup of the pebbles (expressed in FIMA).

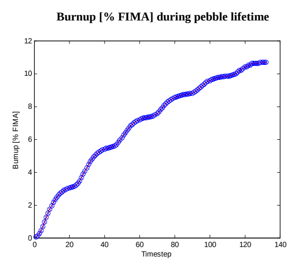
Modelling scheme



HTR operating conditions



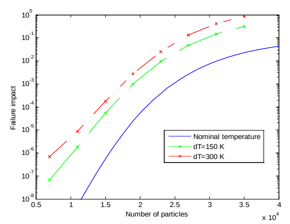


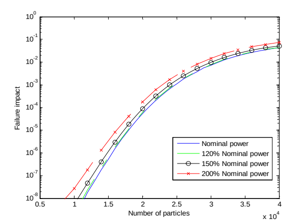


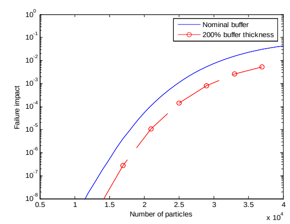
Data of the HTR operating conditions was taken from an extensive model of the PBMR-400, to serve as input for the fuel performance model:

- The diffusion code DALTON was used to generate the neutron fluxes and the power profile in the core
- The temperature profile was calculated with THERMIX (DIREKT)
- Burnup history was generated with SCALE-5 modules

Calculation results and conclusion







A particle fuel performance model was set up to evaluate HTR fuel design. It was found that the failure impact increases considerably with increasing number of particles (within a pebble) and reactor operating temperature, but decreases with a larger buffer layer.

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This is the title of the poster

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