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Multi-scale nuclear fuel simulation with VER software

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PLEIADES is a scientific code platform dedicated to nuclear fuel behaviour simulation for several types of reactors: water cooled reactors, sodium cooled fast reactors, research and material testing reactors, etc. In this platform, the microstructures of these different types of fuel are studied using VER software (Representative Elementary Volume). These studies aim at the comprehension of the thermo-mechanical phenomena at the microscopic scale, and their homogenisation for implementation of their effective behaviour in fuel performance codes. Here are some applications:

- UO_2 fuel is a poly-crystalline ceramic (Figure 1). The mechanical behaviour of each crystal can be modelled with crystalline plasticity, based on dislocation mouvement. An overall behaviour is then deduced by homogenisation.
- MOX fuel contains heterogeneity due to the variation of Pu concentration on a microscopic scale. This can lead to stress and strain concentration near the Pu rich agglomerate. This heterogeneity can be simulated either with discontinuous geometry (Pu rich inclusions in Pu poor matrix, Figure 2), or with continuous Pu field (Figure 3). The macroscopic mechanical behaviour is established using homogenisation methods such as Mori-Tanaka or reduction techniques like Nonuniform Transformation Field Analysis.
- In some fuels, flat porosity is formed around the agglomerates. Simulations of these microstructures are carried out (Figure 4) in order to study the degradation of the fuel conductivity due to this porosity.
- For accident tolerant fuel, new concepts are studied, such as adding a highly conductive phase to the fuel. This is shown in Figure 5, where the metal phase around the agglomerates enhances the pellet conductivity.

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