Neutronics and Thermal Impacts of Graphite Foams in the Performance of Nuclear Energy Systems

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Abstract

Procedures to produce a light graphite foam (~ 0.5 g/cc) that exhibits heat conductivities similar to full density graphite have been developed at ORNL. The consequent substantial reduction in the thermal inertia may have a significant impact in standard designs of graphite system and make possible new concepts. We discuss two applications: a) a modular, zero burnup reactivity swing, reactor and b) the pebble bed accelerator-driven transmutator.

Extended Abstract

A graphite foam (density ρ ~ 0.5 g/cc, void fraction ~ 0.75) with heat conductivity similar to normal graphite (ρ ~ 1.6 g/cc) has been developed[1] at ORNL. The potential availability of ~ 75 % of the volume for loading fuel without reducing the heat conductivity makes this material a good candidate for radical new designs (in comparison the void fraction of normal graphite is ~ 20 %).

We[2] made extensive and systematic calculations with the Helios[3] and MCNPX[4] codes as function of the C/^{235}U ratio, the enrichment and the burnup for C densities corresponding to the foam. Depending on the purpose of the design, very different kinds of systems (from the point of view of the neutron spectra and the size) might be explored. We focused our attention on small, modular, and transportable designs with zero burnup reactivity swing, ideally a sort of "nuclear battery". For example a 1000 L solid core built with the foam and with parameters C/^{235}U=12, 12% enrichment and a 15 cm normal graphite reflector would produce, without refueling, 250 Gwd at a discharge burnup of 40 Gwd/ton. To illustrate the substantial reduction in thermal inertia, we made calculations of transients of neutronically equivalent, 1000 L spherical reactors built with the foam (ρ = 0.5 g/cc) and with porous normal graphite (to keep the same density). Figure 1 shows the case for a 20 cents in 1 second supercritical reactivity insertion

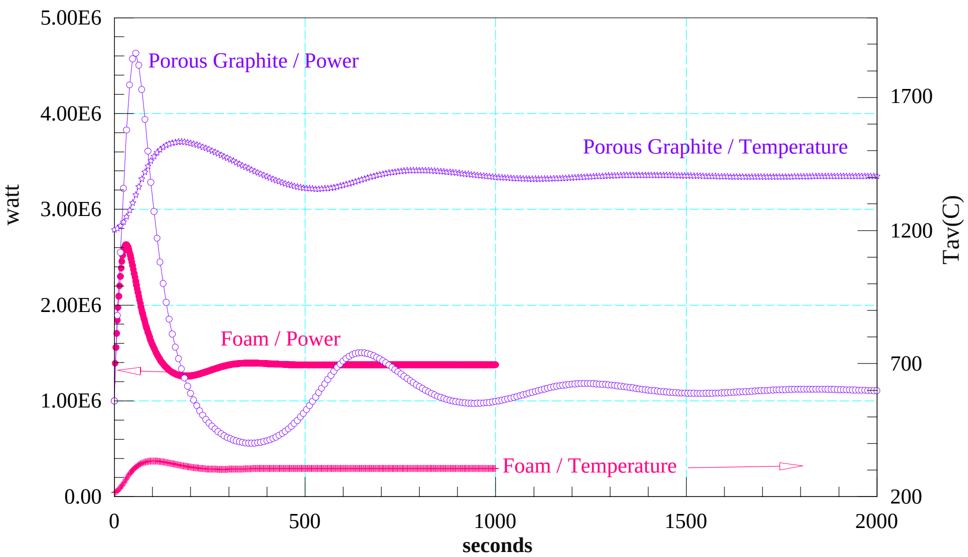

Figure 1:Power and temperature transients produced by a 20 cents supercritical excursion for the cases of spherical reactors built with graphite foam and normal graphite at equivalent densities. The initial power is 1 Mw and the temperature condition at the boundary is kept equal to 30 C.

Other designs could take advantage of the thermal characteristics of the foam. As an example we analyzed the case of the pebble-bed, gas-cooled, accelerator-driven, resonance-enhanced transmutator proposed by Rubbia[5] et al for the cases of pebbles built with normal graphite and the graphite foam. This was the only change in the comparison. Both sets of neutronics calculations (made for a 380 MeV proton beam) look qualitatively similar with minor quantitative differences that could be minimized with additional alterations of the design.

References

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