Design of Optimal Coating Layer Thicknesses for an 800-μm UCO TRISO of a Small Prismatic HTR

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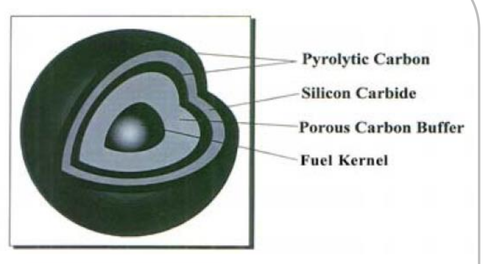
Objectives

- **TRISO with a large-sized UCO fuel kernel up to 800 μm is a candidate fuel for a small and long-life HTR for power supply in polar and remote areas since many fissile materials can be loaded in it.**
- This study **suggests the optimal coating layer thicknesses of an 800-μm UCO TRISO using a response surface method (RSM) that can ensure the fuel safety.**



A TRISO

Optimal Design for a TRISO

- The **optimal design is to minimize an objective function with its constraints, where the objective function describes the TRISO fuel performance and measures the merits of different TRISO designs.**
- **An RSM is applicable to an optimal design when its objective function is difficult to express mathematically and/or its evaluation is very time-consuming. A computer-generated optimal design of Design-Expert® is used to perform an optimal design with some constraints:**

Objective function $y = PF \cdot P_{f,SiC}$ with a constraint $0 \le t_B + t_I + t_S + t_O \le \left(\frac{3V_{compact} \cdot PF^{max}}{4\pi N_{TRISO} \cdot 10^{-12}}\right)^{1/3}$

where *PF* is the packing fraction of TRISOs in a compact $\in$ [0,1] and $P_{f,SiC}$ is the failure probability of the SiC layers $\in$ [0,1], $V_{compact}$ is the compact volume (cm^3), N_{TRISO} is the number of TRISOs in a compact, and t_B, t_I, t_S, t_O are the thicknesses of the buffer, IPyC, SiC, OPyC layers (μm).

Packing fraction $PF = \frac{4\pi N_{TRISO} \cdot 10^{-12}}{3V_{compact}}(t_B + t_I + t_S + t_O)^3$, Failure probability $P_{f,SiC} = 1 - e^{-ln2\left(\sigma_\theta / \sigma_{med}\right)^m}$

σ_θ is the tangential stress acting on the inner surface of the SiC layer (MPa), σ_{med} is the median strength of the SiC layer (MPa), *m* is the Weibull modulus (dimensionless).

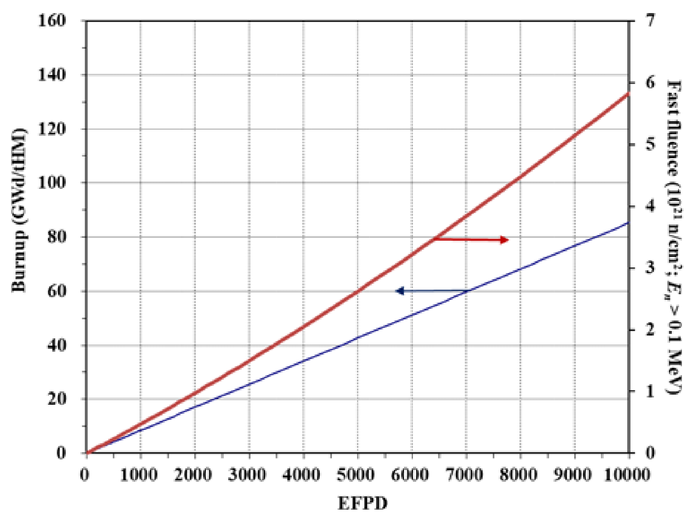
Calculation Results and Summary

- A reference reactor is a small prismatic HTR that has a fuel loading cycle of 10000 days. Its TRISO has an **800-μm UCO kernel with an enrichment of 15.5 w/o. The densities of the kernel, buffer, IPyC, SiC and OPyC are 10.5, 1.0, 1.9, 3.2 and 1.9 g/cm^3, respectively. The linear heat generation rate of the compact is 8.122 W/cm.**

- The thickness ranges for a optimal design are 100 to 150 μm for the buffer, 20 to 60 μm for the IPyC and OPyC layers, and 20 to 100 μm for the SiC layer. The compact considered is 1 cm in length and 1.162 cm in diameter. **The maximum packing fraction of TRISOs is 40 %**

- The optimum solutions are that the thicknesses of the buffer, IPyC, SiC and OPyC layers are 100, 35, 63, 34 μm, or 100, 40, 54, 40 μm.

Variation of fuel burnup and fast fluence



Optimum coating layer thicknesses

Thickness range, μm				Optimal thickness, μm				Packing fraction, %
Buffer	IPyC	SiC	OPyC	Buffer	IPyC	SiC	OPyC	
100~150	20~60 Targets at 35	20~100	20~60 Targets at 35	100	35	63	34	37.7
100~150	20~60 Targets at 40	20~100	20~60 Targets at 40	100	35	63	34	37.7
100~150	20~60 Equals 40	20~100	20~60 Equals 40	100	40	54	40	38.3

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