Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 24-25, 2013

Estimation of Fission Gas Release in FCM Fuel and UO_2 Pellets

Young Min Kim* and M. S. Cho
Korea Atomic Energy Research Institute
1045 Daedeok-daero, Yuseong-gu, Daejeon, 305-353, Republic of Korea
**Corresponding author: nymkim@kaeri.re.kr*

1. Introduction

A coated fuel particle (CFP) with a uranium mononitride (UN) kernel has been recently considered as an advanced fuel option, such as in fully ceramic micro-encapsulated (FCM) replacement fuel for pressurized water reactors (PWRs). In an FCM pellet, a large number of tri-isotropic coated fuel particles (TRISOs) are embedded in a silicon carbide (SiC) matrix. A TRISO consists of a kernel at its central region and four coating layers surrounding the kernel such as the buffer, inner pyrocarbon (IPyC), silicon carbide (SiC), and outer pyrocarbon (OPyC).

The three coating layers of TRISOs and the matrix material of the FCM pellets are all barriers to releasing the fission gases. The TRISOs can mechanically or thermally break during reactor operation. Fission gases (FGs) released from a kernel are trapped within the FCM pellet matrix if the pellet is intact. However, some cracks occurring in a pellet make the fission gases be instantly released into the gap between the pellet and cladding. In a UO_2 pellet, FGs diffuse through UO_2 grains into their boundaries, and are then instantly released through open pores into the gap.

This study calculates fission gas releases (FGRs) from FCM and UO_2 pellets, and then compares the two FGR results.

2. FCM and UO_2 Pellets

Table I shows the layers of the TRISO used in an FCM fuel and their thicknesses and densities. The matrix material of an FCM pellet is nano-infiltration and transient eutectic-phase (NITE) SiC, whose density is greater than 99 % of its theoretical density (TD). The radius and height of a pellet are 6.08 and 10 mm, respectively. About 1013 TRISOs are embedded in an FCM pellet. The UO_2 density is usually 95 %TD. The powers are 175 mW per TRISO in an FCM pellet, and 17.7 kW/m in a UO_2 pellet.

3. Calculation Results

The COPA code [1] is used to calculate the temperature and FGR in FCM and UO_2 pellets. The related material properties were extracted from published reports [2-4]. Fig. 1 presents the temperature and thermal conductivity distributions within the two pellets. For a simple calculation, the temperature at the pellet surface was set to 350 ℃. The temperature distributions in the two pellets are nearly the same.

FGRs were calculated using an analytical solution for a transport in a spherical particle [5]. Fig. 2 shows a variation in the fractional releases of ^{85}Kr. In the FGR calculations, the considered FCM pellet was assumed to be cracked. The fractional release of krypton is about 0.3 % when all TRISOs break in an FCM pellet. The krypton release from a UO_2 pellet is greater than that from an FCM pellet throughout the entire irradiation period.

Table I: Thicknesses and Densities of Layers in a TRISO

Layers	Thickness, μm	Density, g/cm^3
OPyC	20	1.90
SiC	35	3.18
IPyC	35	1.90
Buffer	50	1.05
UN kernel	[a] 700	14.32

[a] This figure means kernel diameter.

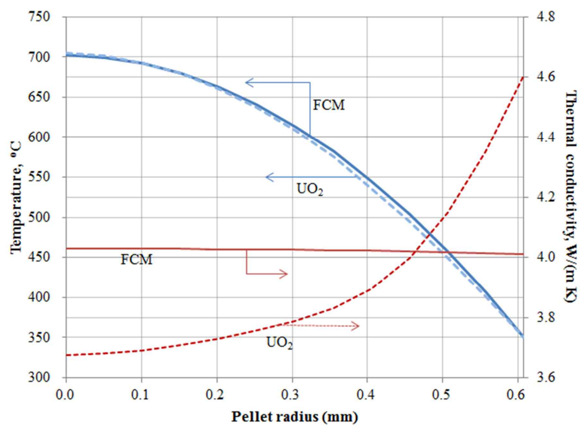

Fig. 1. Temperature and thermal conductivity in FCM and UO_2 pellets.

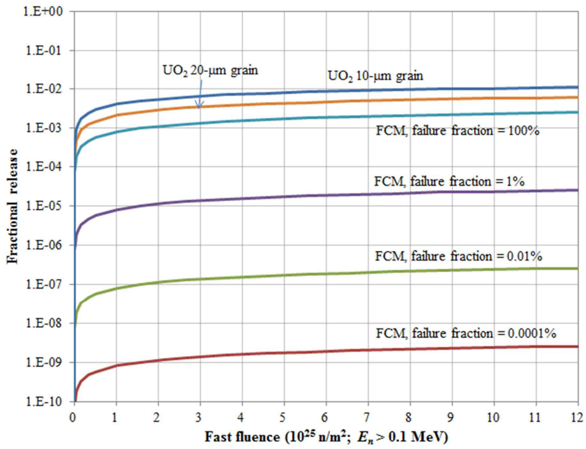

Fig. 2. Variation of ^{85}Kr fractional releases.

4. Summary

The fractional releases of krypton from FCM and UO_2 pellets have been estimated. Even when an FCM pellet is cracked and all TRISOs embedded in it breaks, the krypton release from an FCM pellet is lower than that from a UO_2 pellet. Actually, FCM pellets never breaks under FCM reactor conditions. Under normal reactor operation, no FGs are released from an FCM pellet into the gap between the pellet and cladding.

REFERENCES

[1] Kim, Y.M., Cho, M.S., Lee, Y.W. and Lee, W.J., 2008. Development of a Fuel Performance Analysis Code COPA. Paper 58040. In: Proceedings of 4th International Conference on High Temperature Reactor Technology HTR 2008, Washington, DC, USA, 28 September - 1 October.

[2] Boer, B., Sen, R.S., Pope, M.A., and Ougouag, A.M., 2011. Material Performance of Fully-Ceramic Micro-Encapsulated Fuel Under Selected LWR Design Basis Scenarios: Final Report. INL/EXT-11-23313.

[3] Hagrman, D.T. (Ed.), 1993. SCDAP/RELAP5/MOD3.1 Code Manual Volume IV: MATPRO -- A Library of Materials Properties for Light-Water-Reactor Accident Analysis. NUREG/CR-6150.

[4] IAEA, 1997. Fuel Performance and Fission Product Behaviour in Gas Cooled Reactors. IAEA-TECDOC-978.

[5] Beck, S.D., 1960. The Diffusion of Radioactive Fission Products from Porous Fuel Elements. BMI-1433.